Ad-Avoidance Technology
- Who Should Welcome It?

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THE ECONOMICS OF MEDIA AND TELECOMMUNICATIONS

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Abstract

The business model of many commercial TV-networks is to interrupt TV programs with advertising breaks. In this paper we investigate consequences of the fact that that today ad-averse viewers can adopt a technology which enables them to skip advertising breaks. Perhaps somewhat surprisingly, we find that the ad-avoidance technology can make TV networks and advertisers better off. The viewers as a group however, are always worse off when we take into account their costs associated with adopting the technology.

Keywords: media economics, pricing ads, technology adoption.

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1   Introduction:

Many commercial broadcasters have two sources of revenue. They charge consumers for watching TV and sell advertising time. The consumers dislike advertisements however and try to avoid them, while the value of an ad to an advertiser increases in the number of viewers to which the ad is exposed to. To internalize for this averse relationship, TV networks have charged relatively low prices for watching TV and tried to make it difficult to avoid the ads by interrupting the programs by advertising breaks. Today, however, there exists a technology which makes this interruption strategy less effective. By adopting a Digital Video Recorder (DVR) viewers can now enjoy TV programs with only a small time delay, which enables them to skip the ads when they come on. Some, for instance Garfield (2005), argue that this may undermine the two-sided business model of TV networks. The aim of this paper is therefore to investigate which consequences this technology may have for TV networks, viewers and advertises.

Our point of departure is that the viewers are heterogeneous with respect to advertising aversion; while some are very ad-averse others only slightly so. This implies that a TV network must sacrifice revenue from at least some [types of] viewers. If it tries to capitalize on the least ad-averse by selling a lot of advertising, the willingness to pay will be excessively low for the viewers who are relatively averse to advertising. On the other hand, if the TV network represses the advertising level in order to serve the highly averse viewers more efficiently, the least averse viewers will be very inefficiently exploited. Our main point is that when the viewers can adopt ad-avoidance technology by incurring a sunk cost, they will self-select into the technology in such a way that the TV network's trade-off becomes less pronounced. An interesting implication from this is that a TV network may benefit from the consumers being able to adopt the DVR technology, and this may be so despite the fact that fewer consumers as a consequence will be exposed to the ads that it sells. Furthermore, and perhaps more surprisingly, we show that due to the TV network's response, it is also perfectly possible that the DVR technology may make advertisers

better off, while the viewers as a group will always be worse off.[1]

In order to see the intuition for these perhaps seemingly counterintuitive results, note that a viewer can only avoid the ads if he is willing to incur the sunk cost which is associated with adopting the technology. The consequence is therefore that viewers who are highly averse to advertising will find it worthwhile to adopt the technology, whereas the least ad-averse viewers will not. This implies that when the DVR technology is available, a TV network can increase the advertising level and thereby exploit the least ad-averse viewers more efficiently without fear of losing the direct revenue with which the viewers who dislike advertising the most contribute. In fact, we show that since the willingness to pay for watching TV increases for the group that adopts the DVR technology, the TV network may find it profitable to increase the price for watching and the advertising level simultaneously. If the DVR penetration in equilibrium is sufficiently low, the positive effects of a more efficient [higher] watching price and a more efficient advertising level will dominate the negative effect of the advertising revenue foregone, due to the fact that DVR adopters are shielded from advertising.

Since both the watching price and the intensity of ads will be dependent on the DVR penetration, it follows that a marginal increase in the DVR penetration to some degree will affect all viewers. Thus, even though an adopter himself becomes better off, it is not given that the consumers as group benefit. In fact, we find that only when quite ad-averse viewers adopt the ad-avoidance technology, the adopter's gross private benefit is sufficiently high to dominate the total negative externalities the adopter imposes on the other viewers.[2] Hence, as well as the TV network's profit, the total consumer surplus is hump-shaped in the DVR penetration. Interestingly,

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[1]This is an equilibrium result we obtain when allow the TV network to invest in program quality. In this version of the paper however, the quality investments are removed for analytical convenience. Thus, here we find that when the viewers are worse off, the advertisers are worse off as well. Nonetheless, we still find that the advertisers and the viewers as a group can be better off, if the DVR penetration is sufficiently low. The version with endogenous quality investments is available from the author on request.

[2]The gross private benefit is defined as the extra utility that the adopter obtains from watching TV, hence the adopter's private cost from adopting is not accounted for.

the aggregate consumer surplus is maximized for a lower DVR penetration than that which maximizes the TV network's profit.

When all viewers are exposed to advertising, the TV network sets a high advertising price. This is partly done to internalize the advertisers' willingness to pay and partly to repress the advertising level. Thus, since it is less necessary for the TV network to repress the level of advertising when the most ad-averse viewers adopt the DVR technology, the price of advertisements decreases more than to compensate the advertisers for reaching fewer viewers. However, when the DVR penetration is high, the TV network will find it optimal to charge a high price for watching TV. This increases the alternative cost of selling advertising such that once again the TV network will charge a relatively high ad price in order to repress the ad level. Eventually, the advertising price will therefore not decrease sufficiently to compensate the advertisers for reaching fewer viewers. Thus, compared to when no viewer has access to the DVR technology, also the advertisers are better off if the DVR penetration is low, and vice versa.

Whether or not a viewer buys a DVR is probably, apart from its price, determined by the prices and levels of advertising of the full bundle of TV networks that he consumes. Thus, since we are interested in the actions of just one TV network, it seems reasonable to treat the DVR penetration as an exogenous variable, which is what we do in the main section of the paper. However, in order to close the model, we make an extension where the DVR penetration is endogenized. This is done by opening up for forward-looking consumers to buy DVRs from a monopolist, prior to watching TV. When we take into account the sunk cost that is incurred when adopting the technology, the aggregate consumer surplus is always lower than when the technology is not available.

The fact that consumers dislike ads on TV is incorporated in most models that analyze the broadcasting industry, see for instance Choi (2006), Armstrong & Weeds (2007) and Kind. et al. (2009). However, even though viewers have always tried to avoid the advertisements, for instance by going to the bathroom, this behavior has received surprisingly little attention. To our knowledge, such behavior is in general terms only discussed by Stühmeier & Wenzel (2011). However, their model does not

capture the very specifics of the DVR technology, i.e. that a viewer by incurring a sunk cost can avoid all advertisements at zero marginal cost. Two papers that do capture these specifics are Wilbur (2008a) and Anderson & Gans (2011).

Whereas Wilbur only discusses in general terms how the DVR technology may help TV networks to measure ad-avoidance behavior, Anderson & Gans (henceforth A&G) set up a formal model inspired by the seminal work of Anderson & Coate (2005). With this model, they elegantly analyze several questions related to the DVR technology. For instance they show, as we do, that the level of advertising increases in the DVR penetration., a finding which is in accordance with the empirical results of Wilbur (2008b). Our paper differs however by the fact that their model does not capture the following relationship; the less averse to advertising a viewer is, the more TV programs he watches and therefore the more advertising revenue he generates. [3] This minor difference seems to translate into quite different qualitative findings. For instance, we find that the profit of a TV network is maximized for an intermediate degree of DVR penetration, while they find that the profit always decreases in the DVR penetration.[4] Furthermore, we find that all groups of agents are better of when the most ad-averse viewers adopt the DVR technology, while A&G find that the total social surplus decreases, even when the penetration increases from zero.[5]

It is also worth noting that some findings of Tåg (2009) are related to our findings. He shows that an online media firm will choose to increase the ad intensity of a free service if it launches a clone which is free of advertising but which the consumers must pay to consume. On the surface his result is therefore somewhat similar to ours which states that when the viewers adopt ad-avoidance technology, the price for watching and the advertising level may increase simultaneously. The

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[3]In A&G's model, it is less likely that a viewer will subscribe to the TV network the more averse towards advertising he is, but all viewers who choose to subscribe and are exposed to advertising, generate equally much advertising revenue.

[4]A&G focus mainly on free-to-air TV, but also discuss subscription based fees. Some of their findings about the fees coincide with our findings. However, their conclusion that the profit of the TV-network decreases in the PVR adoption applies also when they consider subscription payments, which contradicts our finding.

[5]They emphasize that this is a local result and not necessarily a global one.

driving mechanisms of our results are nevertheless quite different from those of Tåg. The intuition for his results is that when having a premium service in addition to the free service, the media firm has an incentive to increase the advertising level in order to increase advertising averse consumers' willingness to pay for the premium service. However, in contrast to the [online] media firm, the TV network in our model provides only one service. It is not possible for the TV network to discriminate between the viewers that are and the viewers that are not exposed to advertising. Furthermore, we assume that a TV network alone cannot affect the DVR penetration.

In order to model viewers' consumption decisions in a convenient fashion, we assume that TV-programs are sold at pay-per-view. This approach is also applied in Kind et al. (2009) and Bergh et al. (2012). The assumption should however not restrict our results from being valid also when TV networks charge a subscription fee, inasmuch as the driving mechanism is that the DVR technology separates more ad-averse viewers from those that are less ad-averse. Hence, also when the business model is subscription based, the DVR technology opens for the possibility that both groups of viewers can be served more efficiently. The results may in fact be stronger since highly ad-averse viewers may choose to subscribe to the TV network only if they do have a DVR, i.e. there might be a market expansion effect when subscription fees are charged.

The remainder of the text is organized as follows. In the next section we derive the TV-network's response to an exogenous DVR penetration and consider how the different agents are affected by the availability of the technology. We then endogenize the DVR penetration in the third section, while in the forth section we make some concluding remarks and discuss further research. All proofs and non-crucial algebra are relegated to the appendix.

2   The basic model:

Consider a TV-network which serves advertisers and viewers. Assume that the TV network provides a mass of heterogenous TV programs, normalized to unity.

Further, assume that there is a mass of viewers, also normalized to unity, who are heterogeneous with respect to advertising aversion. A viewer watches the $c \in [0, 1]$ programs he prefers the most. In order to capture that the viewers' marginal utility of TV consumption is decreasing, we assume that the gross utility a viewer obtains from the c'th program he watches is $1 - c$.[6] If we treat the number of programs as a continuous variable, a viewer's gross utility (u) from watching TV c programs is:

$$u = \int_0^c (1 - c) \, dc \equiv c \, (1 - c/2) \, .$$

Whenever a viewer watches a program, he is charged a price p. If he is exposed to advertisements, he incurs a non-pecuniary cost of θA in addition, where A is the number of advertisements that the program contains and θ is his disutility of having to watch an advertisement.[7] We assume that θ is uniformly distributed, i.e. $\theta \sim U[\tau, 1 + \tau]$ where $0 < \tau < 1/2$ is the disutility for the viewer that dislikes advertising the least.[8] Thus, if a viewer of type θ is exposed to advertising, the generalized price he faces for watching a TV program is $p + \theta A$. In order to simplify the analysis we assume that the viewers' taste in programs is uniformly distributed and independent of θ. Since there by definition is no correlation between a viewer's aversion to advertising and which programs he prefers, the ex-ante demand for all programs is equal. Thus, there is no incentive for Ramsey type strategies. It is in other words optimal for the TV network to set the same price and the same advertising level for all programs. If the TV network sells A advertisements, each program will contain A advertisements. The net utility (U_θ) of a representative type θ viewer that is exposed to advertisements is then:

$$U_\theta = u - (p + \theta A) \, c.$$

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[6]Decreasing marginal utility can stem from the consumers watching the programs they like the best first, or simply because the viewers have an alternative cost of time.

[7]By assuming that the cost of watching advertisements for a viewer is linear in the number of advertisements to which he is exposed, we simplify the algebra. If we open for this cost to be convex, the result will be less advertising in equilibrium, but it will not affect the qualitative results.

[8]If no viewer owns a DVR and $\tau > 1/2$, the TV network chooses not to sell advertising. For further details, see the advertisers' profit expression below.

By solving the viewer's F.O.C. ($\partial U_\theta / \partial c = 0$) we obtain the individual program demand:

$$c_\theta = 1 - p - A\theta.$$

However, if the viewer has a DVR, he will not be exposed to any advertisements. Thus, he will behave as if $\theta = 0$. The utility of a DVR owner is then $U_{\theta=0}$ and his demand for TV-programs is consequently:[9]

$$c = 1 - p.$$

Assumption 1: The $\gamma \in [0, 1]$ most ad-averse viewers have DVRs.

In the next section we derive that if any viewer buys a DVR, it is the viewers that are most averse to advertising who do so. In this section, we therefore assume this to hold.[10] By assumption 2, the total program demand from the viewers that are exposed to advertising is:

$$D_1 = \int_\tau^{\tau + (1-\gamma)} c_\theta d\theta.$$

Since all viewers that own a DVR will watch the same number of programs, the total program demand from the DVR owners is:

$$D_2 = \gamma c.$$

The aggregate demand for programs is then:

$$D \equiv D_1 + D_2 = (1-p) - (1-\gamma)(1 + 2\tau - \gamma)A/2. \tag{1}$$

We assume that there are N advertisers, who all have an expected benefit equal to 1 from exposing a viewer to a message. For simplicity we assume this benefit to be

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[9]For convenience, we drop subscript $\theta = 0$

[10]The assumption can easily be justified inasmuch as that the ones who dislike advertising the most, are also the ones who are willing to pay the most to get rid of it, all else equal.

independent of whether a viewer has previously been exposed to the same message.[11] Thus, an advertiser's gross benefit of posting an advertisement in a TV program is solely determined by the number of non-adopters watching the program. Since there is a unit mass of programs and each viewer that is exposed to advertising watches c_θ programs, the probability for a given viewer to be exposed to an ad posted in a given program is simply $f(c_\theta) = c_\theta$. The total number of viewers to which an advertisement is exposed is then $F = \int_\tau^{\tau+(1-\gamma)} f(c_\theta)d\theta = D_1$. An advertiser's net benefit from buying an ad is therefore $D_1 - r$. Thus, if advertiser n buys A_n ads, its net benefit equals:

$$B_n = (D_1 - r) A_n. \tag{2}$$

In order to derive the demand for advertisements, write $A = \sum_{i \neq n} A_i + A_n$, and solve advertiser n's F.O.C. $(\partial B_n / A_n = 0)$, in order to obtain:

$$A_n = \frac{1}{(1-\gamma)(1-\gamma+2\tau)} \left((1-\gamma)(1-p) - r - \sum_{i \neq n} A_i \left(\frac{1}{2}(1+\gamma^2) + (1-\gamma)\tau - \gamma \right) \right).$$

If we now impose symmetry, $(N-1)A_n$ can be substituted for $\sum_{i \neq n} A_i$. By solving for A_n and then aggregating up for $N = 1$, aggregate demand for ads becomes:

$$A = \frac{(1-p) - r/(1-\gamma)}{(1-\gamma+2\tau)}. \tag{3}$$

When p increases, each viewer watches fewer programs. Thus, the number of viewers that watch a given program decreases in p, which implies that an ad is exposed to fewer viewers. The advertisers' benefit from buying ads therefore decreases in

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[11]This assumption can be justified by the fact that every time a viewer is exposed to an advertisement, there is a positive probability that he will respond like the advertiser aims him to respond. Whether this probability is increasing or decreasing in the number of times he is exposed to the message is an empirical question. Thus, we assume that the probability is constant. Our assumption is different from that of Anderson and Gans (2011), who assume that one single ad is sufficient to reach all viewers and that there is no effect of the second advertisement.

p, which in turn translates into lower demand for ads. Since the advertisers' net benefit from buying ads also decreases in the ad price, the demand for ads decreases in r as well. The demand for advertisements also decreases in τ. This is because an increase in τ shifts the distribution of advertising aversion upwards, such that each viewer who is exposed to advertising watches fewer TV programs, all else equal.

An increase in γ has two opposing effects on the advertising demand. Since the expected number of viewers reached by an advertisement decreases, the effective price for reaching a consumer with an ad increases $(r/(1-\gamma))$. However, since it is the viewers who are at the margin most averse towards advertising that become shielded from advertising, each ad will displace disproportionately less consumption of TV programs when γ increases. This translates into a positive indirect effect on the advertising demand, inasmuch as the marginal ad an advertiser buys decreases the value of its inframarginal ad to a lower degree.

In the discussion below we distinguish between the revenue that the TV-network extracts from the viewer side (Dr) and the advertiser side of the market (Ar). For simplicity we assume that costumers at both sides are served at zero marginal cost. Hence the TV-network's profit (Π) can be expressed as:

$$\Pi = Dp + Ar. \tag{4}$$

where $D(p, \gamma, A)$ is given by Eq. (1) and $A = A(p, r, \gamma)$ is given by Eq. (3).

The TV-network's optimal price structure for a given DVR penetration is derived by solving F.O.C.s with respect to prices $(\partial\Pi/\partial p = \partial\Pi/\partial r = 0)$. Before we solve for the equilibrium prices, it is instructive to consider the two F.O.C.s separately. The F.O.C. with respect to the program price $(\partial\Pi/\partial p = 0)$ can be expressed as:

$$\frac{\partial\Pi}{\partial p} = \frac{\partial D}{\partial p}p + D + \frac{\partial D_1}{\partial A}\frac{\partial A}{\partial p}p + \frac{\partial A}{\partial p}r = 0. \tag{5}$$

Eq. (5) shows how the profit for the TV network changes if it increases the program price marginally, while the ad price is kept constant. The two first terms are standard; higher margin on the sales but less sales. The third term captures that the viewers who are exposed to advertising are less sensitive to a price increase than the viewers who are not. The explanation is that the advertising demand decreases in p,

which implies that the generalized price for the viewers who are exposed to advertising increases less than the monetary price. Finally, the last term captures the fact that since the advertising demand decreases in p, the revenue from the advertiser side of the market decreases as well. Thus, the higher the advertising price and the more advertising sales that are foregone when the price of programs is increased, the higher is the alternative cost of increasing the program price.

The F.O.C. with respect to the advertising price $(\partial \Pi / \partial r = 0)$ can be expressed as:

$$\frac{\partial \Pi}{\partial r} = \frac{\partial A}{\partial r} r + A + \frac{\partial D_1}{\partial A} \frac{\partial A}{\partial r} p = 0. \tag{6}$$

Eq. (6) shows how the profit for the TV network changes if it increases the ad price marginally, while the program price is kept constant. Once again, the two first terms capture that a higher price means a higher margin, but also less sales. The last term captures how a higher advertising price affects the revenue from the viewer side of the market. Since a higher ad price translates fewer ads sold, the demand for programs and thereby the revenues from the viewer side increases in the ad price. Thus, the more the sales of programs increase and the higher the program price, the higher the alternative cost of *increasing* the ad sales, i.e. *reducing* the advertising price.

Lemma 1: *Since the TV network serves both viewers and advertisers, there is an alternative cost of;*

a) *increasing the mark-up on the programs, in terms of lower advertising revenue, and;*

b) *decreasing the mark-up on the ads, in terms of lower revenue from the viewer side.*

In the appendix we solve the system of equations defined by Eqs (5) and (6). This gives:

		$\partial p^*/\partial \gamma < 0$ in $\gamma \in [0, \gamma(\tau)]$
$p^* = p(\gamma, \tau)$	$\partial p^*/\partial \tau > 0$	$\partial p^*/\partial \gamma > 0$ in $\gamma \in [\gamma(\tau), 1]$
		where $\gamma(\tau) > 0$ if $\tau > 1/6$
$r^* = r(\gamma, \tau)$	$\partial r^*/\partial \tau > 0$	$\partial r^*/\partial \gamma < 0$
$A^* = A(\gamma, \tau)$	$A^*/\partial \tau < 0$	$\partial A^*/\partial \gamma > 0$

Table 1; Equilibrium Values / Comparative Statics

Proposition 1: *The optimal prices depend on the distribution of aversion towards advertising (τ) and the DVR penetration (γ) where;*

a) *both the advertising price (r) and the program price (p) increase in τ, and;*

b) *the advertising price decreases in γ, while;*

c) *the program price increases in γ if $\tau < 1/6$ and is otherwise u-shaped in γ, with a maximum at $\gamma = 1$.*

When we discuss the intuition for Proposition 1, it is useful to bear in mind that the TV-network serves $(1 - \gamma)$ viewers who are heterogenous with respect to advertising aversion and γ viewers who are not exposed to advertising at all. This means that with only one set of prices, it is impossible to extract the full potential value of each viewer.[12] When maximizing the profit, the TV network will therefore assign weight to the different viewers based on how profitable they are. The least advertising averse viewers are the most profitable, and relatively more so the smaller τ is. This implies that the lower τ, the closer the price and advertising level will be to the levels that maximize the value of the type τ viewer. On the other hand however, the further away the price and advertising level will be from the levels that maximize the value of the most ad-averse viewers who are exposed to advertising and those viewers who are not exposed to advertising.

An increase in τ shifts the distribution of advertising aversion upwards such that more program demand is displaced per ad sold. The consequence is that the advertisers' demand for advertising decreases, while the TV network's alternative

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[12] There exist a price $p(\theta)$ and an advertising price $r(\theta)$, with a corresponding advertising level $A(\theta)$, that maximize the value of a type θ viewer, where $\partial p(\theta)/\partial \theta > 0$, $\partial r(\theta)/\partial \theta < 0$ and $\partial A(\theta)/\partial \theta < 0$. Furthermore, when $\theta \geq \beta$, it is optimal to set $A = 0$.

cost of selling ads increases, in τ. The latter effect is the most pronounced, so the TV network responds by increasing a higher price of advertisements. When it becomes less profitable to sell ads, we know from Lemma 1 that the alternative cost of setting a high program price decreases. Thus, the price of watching TV programs will increase in τ. An alternative intuition is that since the TV-network sells fewer ads, the demand for programs will be higher, which in turn calls for a higher program price.

An increase in γ implies that the most ad-averse viewers among the viewers who are exposed to advertising, become shielded from advertising. This has two effects; each ad is exposed to fewer viewers and each ad decreases the demand for programs disproportionately less. The former effect implies that the advertisers' willingness to pay for each ad decreases. The latter effect, however, increases the TV network's incentive to sell ads, since it decreases the alternative cost of selling ads. From Table 1 we see that it is the latter effect which dominates, inasmuch as a higher γ translates into a lower advertising price and a higher advertising level.

Since each viewer watches more TV when he has a DVR, the demand for TV programs increases in γ. Furthermore, since a higher γ means that the loss of program demand, which is relevant for the advertising demand, is lower, the alternative cost of setting a high program price decreases in γ. Both effects contribute to a higher program price, all else equal. However, inasmuch as the TV network's alternative cost of selling ads also decreases in γ, there is one effect which works in the opposite direction. This is the fact that each viewer who is still exposed to advertising becomes more valuable, so these viewers will be assigned more weight. Since, in isolation, the revenue from serving these viewers is maximized for a rather low program price, this effect contributes to a lower program price, all else equal. Whether the program price increases or decreases in γ will consequently be determined by the interaction between the three effects.[13]

In order to see how these effects interact, suppose that all viewers are exposed to advertising, i.e. $\gamma = 0$. When τ is high, there are now two effects that contribute to the level of advertising being lower than when τ is low; overall the viewers are

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[13]This result is related to Proposition 9 in Anderson and Gans (2011).

more averse to advertising and the most ad-averse subset is assigned more weight. The implication of the latter effect is the following; the higher τ, the more revenue is sacrificed from the viewers in the least ad-averse subset [in order to sustain the revenue from the viewers in the most ad-averse subset]. From this it follows that the value of the viewers in the least ad-averse subset increases more in γ the higher τ, since there is no need to repress the advertising level in order to cater for the most ad-averse viewers when these have DVRs. In other words, the effect which contributes to a lower program price is stronger the higher τ.

Another consequence of the most ad-averse subset being assigned more weight is that their consumption prior to the adoption of the DVR technology will be closer to their consumption after adoption, i.e. the consumption effect will be smaller. Hence, the two effects that force the program price upwards are weaker and the effect that pushes the price downwards is stronger the higher τ. If τ is sufficiently high, the program price therefore decreases in γ around $\gamma = 0$. Nevertheless, when γ increases, the alternative cost of setting a high price becomes very low. The explanation is since few viewers are exposed to the ads, the total loss of program consumption relevant for the advertising demand is low when γ is high. Thus, the program price will therefore eventually increase in γ always be maximized for $\gamma = 1$.

By substituting the equilibrium prices into the profit expression given by Eq. (4) we obtain:

$\Pi^*(\gamma, \tau) = 2\,(\gamma + 1)\,(2\tau - \gamma + 1)\,Z$	
where $Z = Z(\gamma, \tau)$ $\partial \Pi^* / \partial \tau < 0$	$\partial \Pi^* / \partial \gamma \mid_{\gamma=0} > 0$ $\partial \Pi^* / \partial \gamma \mid_{\gamma=1} < 0$ [14]

Table 2; Equilibrium Profit /Comparative Statics

If we plot $\Pi^*(\gamma, \tau, q)$ for $\tau = 0.05$ (solid line) and $\tau = 0.3$ (dashed line), we obtain:

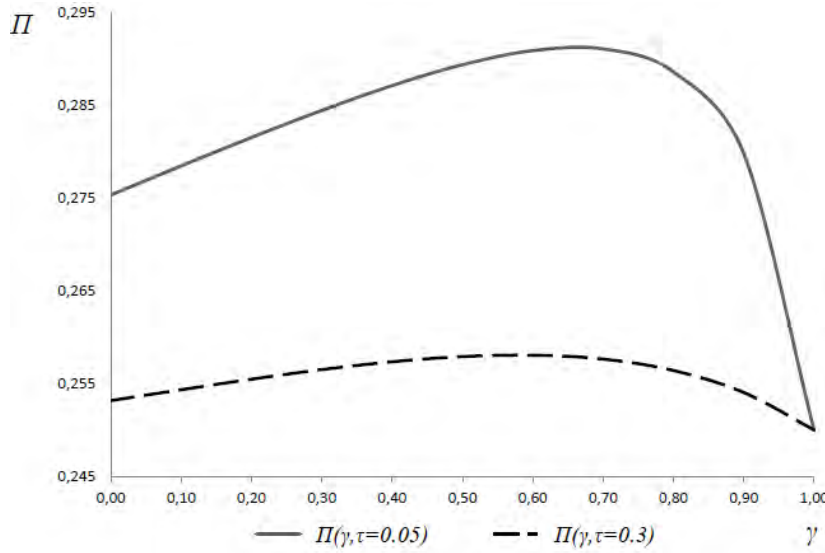[14] $Z(\gamma, \tau, q)$ is defined in the appendix

Figure 1: Profit / DVR Penetration

Proposition 2: *There exists a $\gamma^{TV}(\tau)$ which maximizes the profit of the TV network, such that;*

    a) *the profit is hump-shaped in γ with a minimum at $\gamma = 1$, and;*

    b) *both the maximum profit level and the DVR penetration which maximizes the profit, decrease in τ ($\partial\Pi(\gamma^{TV})/\partial\tau < 0$ and $\partial\gamma^{TV}/\partial\tau < 0$).*

The first part of proposition 2 gives the main message of the paper; if the TV network responds optimally, its profit will be maximized for an intermediate DVR penetration. The intuition for this result follows from three effects that impact the TV-network's profit when the marginal viewer who *is* exposed to advertising adopts the DVR technology. The first effect is that the adopter's TV consumption will no longer generate advertising revenue, an effect which impacts the TV network's profit in a negative direction. However, the second effect is that the adopter will watch more TV and hence he will contribute to more revenue at the viewer side.[15] The third and final effect is that the profitability of the viewers who remain exposed to advertising will increase. The explanation is that the alternative cost of selling

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[15] If the TV-network is financed by a subscription-based fee, this is equivalent to an increase in the adopter's willingness to pay for the TV network. Hence, the TV network can increase the subscription fee without losing the viewer, i.e. set the subscription fee such that the new marginal viewer [that is exposed to advertising] is indifferent between subscribing and not subscribing.

advertising decreases since it is the viewer that is at the margin most averse to advertising who now becomes shielded from advertising.[16] Since the two latter effects impact the TV network's profit in a positive direction, its profit increases in γ when the two latter effects dominate the advertising revenue with which the adopter would have contributed.

A low γ implies that the marginal viewer is quite averse to advertising. Hence, prior to adoption of the DVR technology, the viewer watches less TV, and his presence among the viewers that are exposed to advertising restricts the optimal advertising level more, the lower γ. All else equal, the positive effects from a viewer's adoption of the technology are therefore stronger, while the loss of advertising revenue is smaller, the more ad-averse the viewer is. This explains why the TV network's profit increases most when γ is low. Furthermore, since one viewer's adoption increases the profitability of the non-adopters, the loss of advertising revenue increases convexly in γ. Together with the fact that the positive effects decrease in γ, and that the profit will be lower when all viewers have adopted the DVR technology than when no viewer has done so, we know that the TV network's profit must decrease steeply in γ when it approaches 1.

The more averse to advertising a viewer is, the less profitable it is for the TV network to serve him. Since the viewers overall are more ad-averse the higher τ, it is straight forward that the profit level of the TV network decreases in τ. However, a higher τ also means that the viewers are a more homogenous with respect to advertising aversion. This implies that for the TV network, the [absolute] gain from the most ad-averse viewers being shielded from advertising is lower. Hence, when τ is high, a TV network prefers a lower DVR penetration than when τ is low.

We have now considered how a TV network should optimally respond to an exogenous DVR penetration and how it's profit is affected when it does so. Let us now consider how the TV-network's costumers are affected by the technology and the TV network's response. The advertisers' profit is simply obtained by substituting into Eq. (2) for the equilibrium values from Table 1. The aggregate consumer

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[16]The TV network has no longer a marginal incentive to repress the advertising level in order to maintain the program demand of the adopter.

surplus *from TV consumption* is obtained by substituting into Eq. (7) below for the values from Table 1:[17]

$$CS = \gamma U_{\theta=0} + \int_{\tau}^{\tau+(1-\gamma)} U_\theta d\theta \tag{7}$$

Proposition 3: *There exists a $\gamma^{CS}(\tau)$ which maximizes the aggregate consumer surplus and a $\gamma^B(\tau)$ which maximizes the advertisers' profit, such that;*

a) *both aggregate consumer surplus and the advertisers' profit are hump-shaped in γ, with a minimum at $\gamma = 1$, and;*

b) *the advertisers' profit is maximized for a lower DVR penetration than the aggregate consumer surplus, which in turn is maximized for a lower DVR penetration than the TV network's profit i.e. $0 < \gamma^B < \gamma^{CS} < \gamma^{TV} < 1$, and;*

c) *all levels decrease in τ.*

In order to see the intuition for the consumer surplus part of Proposition 3, consider the situation where all viewers are exposed to advertising. Since the TV network now faces a demand for advertisements, its profit margin of selling TV programs is higher than when all viewers own DVRs. In order to boost the demand for TV programs, the TV network therefore sets a relatively low price on TV programs. The low price more than compensates the viewers as a whole for the aggregate disutility associated with the advertisements. However, for viewers that are relatively ad-averse, the disutility from the advertisements outweighs the benefit of the lower program price.

Suppose now that the most ad-averse viewer adopts the DVR technology. Since the program price will be lower than when the TV network does not sell advertising at all, the adopter will now be better off as well. Nonetheless, price and advertising level always change to such a degree that the total effect on the other viewers is negative. Due to this negative externality, it is not given that the consumer surplus increases in γ. We find the private benefit to dominate the negative externality when highly ad-averse viewers adopt ad-avoidance technology, but not when modestly ad-adverse viewers adopt. Perhaps somewhat surprisingly, we find that the

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[17]Note that we do not take into account the costs of adopting the DVRs.

total consumer surplus is maximized for a lower DVR penetration than the DVR penetration that which maximizes TV network's profit.

The lower τ, the more profitable it is for the TV network to boost TV consumption by setting a low program price. This price effect is sufficiently strong to dominate the fact that the advertising level decreases in τ as well, so hence the aggregate consumer surplus decreases in τ.

It is perhaps somewhat surprising that the advertisers' profit is maximized for a positive DVR penetration, inasmuch as a positive DVR penetration implies that some viewers are not reached by the advertisements. The intuition is that when all consumers are exposed to advertising, the TV network sets a high price for two reasons; to internalize the advertisers' willingness to pay and to internalize that some viewers are very averse towards advertising. However, when the most ad-averse viewers adopt the DVR technology, the latter incentive for charging a high ad price vanishes. The consequence is therefore that when the DVR penetration increases from a low level, the advertising price decreases more than to compensate the advertisers for reaching fewer viewers. Nevertheless, when the DVR penetration is high, the price of TV programs is high as well. This increases the alternative cost of selling advertisements, and gives the TV network a renewed incentive to marginally repress the advertising level by setting a high ad price. Thus, when the DVR penetration increases from a relatively high level, the lower advertising price will no longer fully compensate the advertisers for reaching fewer viewers. Hence, when the DVR penetration becomes sufficiently high, the advertisers' profit starts to decrease in the DVR penetration.

From our results so far, it follows that:

Proposition 4: *The social surplus is maximized for a positive DVR penetration.*

Proposition 4 summarizes Propositions 1-3. The result is straight forward, since the TV network, the advertisers, and the viewers as a group, are all better off for a low DVR penetration. The reason why everyone can be better off at the same time is that the DVR technology serves as an discriminatory device which

the viewers self-select into. Thus, the DVR technology separates less from more ad-averse viewers and therefore enables the TV network to serve both the least and the most ad-averse subset more efficiently. This benefits the TV network, but also the advertisers, since the TV network represses the level of advertising by setting a ad high price. Furthermore, the viewers as a group are better off since the private benefit of the adopters in sum exceeds the negative externalities that are imposed on the non-adopters. However, if sufficiently many viewers adopt the technology, also viewers who would have been served more efficiently in the group which is exposed to advertising will be shielded from it. The social surplus decreases in the DVR penetration from the point where "too many" viewers are shielded from advertising. The explanation is that the fewer viewers that are exposed to advertising, the higher the prices of both programs and ads, such that when the DVR penetration is high, both the aggregate consumption of TV programs and the sales of ads are excessively low.

3   Extension: Endogenous DVR Penetration

In the previous section we derived a TV network's optimal price structure for an exogenous DVR penetration. We argued that this seemed reasonable, inasmuch as whether or not a viewer adopts the DVR technology is probably influenced by the price and advertising level of a number of TV networks. However, it is interesting to study how the joint actions of TV networks affect the DVR penetration, since the DVR penetration in turn determines the TV networks' profit. To do this, we open up for viewers being able to buy DVRs prior to watching TV. There are two reasons why this seems like a reasonable approach. First, even though the DVR penetration may change over time, it is probably quite stable from day to day. Hence, both the TV networks and the advertisers should be well informed about the current DVR penetration when they make their decisions. Second, after adoption of the technology a viewer will be shielded from advertising regardless what the TV network does, while the TV network in principle can change its prices from day to

day.

For simplicity we assume that the monopoly TV network is in fact a mass of small TV networks, which set prices like the monopolist TV network described above. We can do this without loss of generality if we split the mass of TV programs between different TV networks and assume that the TV programs are sufficiently differentiated such that the viewers perceive them as being independent products.[18,19]. Thus, we continue with U_θ being the utility of the bundle of TV networks for a viewer of type θ .[20] If a viewer chooses to adopt the DVR technology, however, he will obtain utility $U_{\theta=0}$ from consuming TV programs, but then in addition he must pay the price of the DVR technology (P).[21] A viewer of type θ therefore adopts the DVR technology if:

$$U(\gamma, \tau)_{\theta=0} - P \geq U_\theta(\gamma, \tau)$$

or:

$$P \leq (U_{\theta=0}(\gamma, \tau) - U_\theta(\gamma, \tau)) \tag{8}$$

When inequality (8) holds with equality, it gives the maximum a type θ viewer is willing to to pay in order to adopt the DVR technology. Since $\partial U_\theta/\partial \theta < 0$ it follows immediately from inequality (8) that the more averse a viewer is, the more likely it is that he adopts the DVR technology. Hence, Assumption 2 holds.

A viewer's utility of adopting the DVR technology is dependent of γ. At this stage, however the value of γ is not yet determined. A viewer must therefore have an expectation about γ in order to calculate whether it is worthwhile for him to pay

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[18]Assume that $U_\theta = \sum_{i=0}^1 (c_i(1 - c_i/2) - (p_i + A_i\theta)) - b\prod_{i=0}^1 c_i$ where i is TV network i.

[19]All qualitative results in the main section hold when differentiated TVnetworks compete. However, the program price level and the advertising level of each TV network are lower, and more so the closer substitutes the TV networks being.

[20]It is not clear how the number of TV networks affects a consumer's surplus. More TV networks mean lower prices and less advertising on each network, which benefits the viewres. However, when the TV networks are substitutes, the utility of a TV-network is lower than the utility of the monopoly TV network, all else equal. Thus, we assume here that the two effects perfectly counter each other such that a viewer's utility can be expressed as U_θ.

[21]A viewer that has adopted the PVR technology will not be exposed to advertising, hence his utility is as if he were type $\theta = 0$.

P in order to adopt a DVR. We therefore assume that the viewers are rational and able to form [correct] expectations about γ, by observing the DVR price and having information about the distribution of advertising aversion (τ) and the TV-networks' pricing strategies. For the marginal adopter inequality (8) must hold with equality. Thus, when γ viewers adopt the DVR technology, the marginal adopter is identified by $\hat{\theta} = \tau + 1 - \gamma$. By substituting $\hat{\theta}$ into inequality (8), we obtain the highest price for which γ viewers will buy the DVR as a function of the viewers' expectations and the aversion parameter τ. If we now plot Eq. (8) for $\tau = 0.05$ (solid line) and $\tau = 0.35$ (dashed line), we obtain:[22]
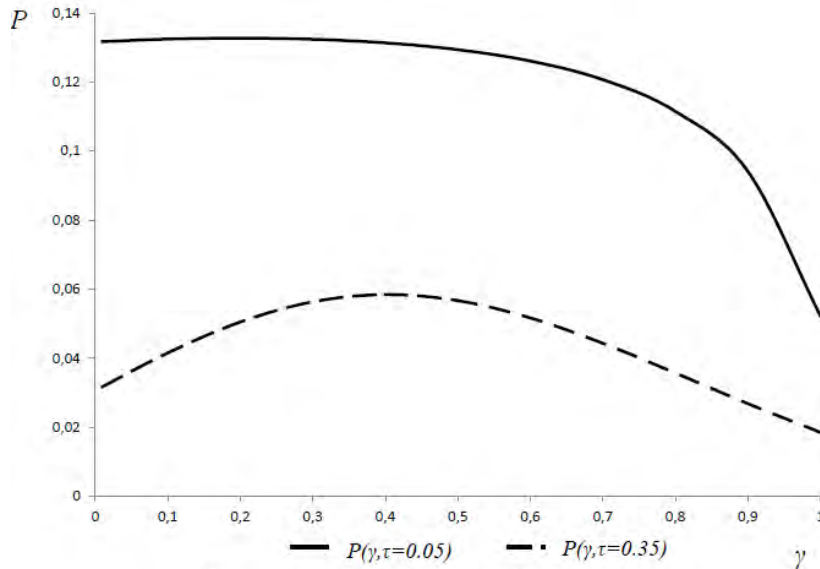
Figure 2: DVR Price / DVR Penetration

Figure 2 needs some explanation. The graphs show the maximum the γ most ad-averse viewer is willing to pay for adopting the DVR technology, given that he is the most ad-averse non-adopter. The point where the graphs meet the price-axis is therefore the maximum the most ad-averse viewer is willing to pay, given that he expects no other viewer to adopt. The next point to the right then becomes the maximum the second most ad-averse viewer is willing to pay, given that he expects the most ad-averse viewer to adopt, and so on. For this reason, it may seem counter intuitive that the price is hump-shaped. However, this is due to the TV networks'

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[22]We refer to Eq (8) when inequality (8) holds with equality.

responses. As the DVR penetration increases, the program price changes and the advertising level increases. These changes affect the utility of adopting the DVR technology. Hence, the marginal adopter's willingness to pay is determined by his aversion towards advertising and how the TV networks set prices, given the current DVR penetration. Initially the response increases the value of adoption sufficiently to dominate the fact that the [next] marginal viewer is more adaverse. However, since the program price increases in the DVR penetration, the utility of adopting the DVR technology decreases in γ, all else equal. Thus, when γ becomes sufficiently high, the price effect in combination with the marginal non-adopter being less averse to advertising when γ is high, dominate the fact that the advertising level increases in γ. Hence, when the DVR penetration is high, the DVR price have to be reduced quite significantly in order to convince the [next] marginal viewer to adopt. This explains the steep fall in P when γ is close to 1.

From Figure 2 we can conclude that the willingness to pay for the DVR technology is high when the level of advertising aversion is low, and vice versa. This may seem counterintuitive, but the intuition follows from the TV networks pricing strategy. When advertising aversion is low, the TV networks set low program prices and sell lots of advertising compared to when τ is high. This makes it very beneficial for the viewers to be able to avoid the ads, which in turn makes their willingness to pay for the DVR technology decreasing in τ.

Lemma 4: *For a given DVR price, the DVR penetration decreases in the level of advertising aversion (τ).*

If the DVR technology is supplied by a competitive industry, it will be available at marginal cost. Hence, the DVR penetration will be pinned down by the marginal cost. In this section we assume however that the DVR technology is supplied by a monopoly seller. This is done in order to capture what is also discussed in Anderson and Gans (2011), namely that a strategic DVR seller will exploit the fact that the viewers anticipate the TV networks' behavior. For simplicity, we normalize the marginal cost to zero, such that the profit of the DVR supplier is:

$$\Gamma = \gamma P. \tag{9}$$

In order to solve the DVR supplier's maximization problem analytically, we need to fix a value for τ. We therefore derive the optimal DVR price for a low (0.05), an intermediate (0.2) and a high (0.35) value of τ. The maximization strategy we apply is to find γ^*, i.e. the γ that maximizes Eq. (9) given that the price is set in accordance with Eq. (8) and the viewers' expectations are correct in equilibrium. The optimal price of the DVR is then obtained by substituting γ^* back into Eq. (8).

From the hump shapes of the graphs depicted in Figure 2 it is clear that some prices belong to three equilibria. In order to see this, pick any price which is higher than the most ad-averse viewer's willingness to pay and lower than the highest price that gives positive sales when the expectations of the viewers are correct. Any such price intersects the graph in two points. Hence, both points are equilibrium candidates for the given price. Furthermore, since the price is higher than what the most ad-averse viewer is willing to pay if he expects no other viewer to adopt, zero DVR sale is also an equilibrium candidate. In such cases, the viewers' expectations determine which equilibrium that is realized. In order to refine the set of equilibria, we impose the following assumption:

Assumption 2: If a viewer regrets having bought the DVR when the advertising level and the program price are realized, he can return the DVR to the seller and get a full price refund.[23]

For a given price, the DVR seller always prefers the equilibrium which gives the highest DVR penetration. Under Assumption 4, this equilibrium will always be played. The reason is that since the viewers can return the DVRs, buying is a weakly dominating strategy for all viewers that are more ad-averse than $\theta = 1 + \tau - \gamma^*$.[24]

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[23]This strategy is easy to implement and it is frequently applied by sellers of durable goods.

[24]Pick a viewer type on the interval $\theta \in [1 + \tau - \gamma^*, 1 + \tau]$. If he buys the DVR and he is the marginal viewer, he is indifferent between keeping and returning the DVR. If he is among the inframarginal adopters, i.e. to the left of the marginal viewer, he is better off by keeping the DVR. Finally, no viewer who is located to the right of the marginal viewer when the equilibrium preferred by the DVR seller is played, has incentives to buy the DVR technology.

However, for a viewer that is less ad-averse, not buying is a weakly dominating strategy. This implies that at the stage where the TV networks set prices and advertising levels, γ^* viewers are shielded from advertising. Since the DVR price is set in order to make viewer type $\theta = 1 + \tau - \gamma^*$ indifferent between buying and not buying, the marginal DVR adopter is consequently indifferent between keeping and returning the DVR. Furthermore, all viewers who are more ad-averse than the marginal adopter, are better off by keeping the DVR, while no non-adopter regrets being a non-adopter. Hence, the intended equilibrium is realized and in equilibrium no viewer ever returns the DVR.[25]

Lemma 5: *The DVR price decreases, while the DVR penetration increases in the aversion level, i.e. $\partial P/\partial \tau < 0$ and $\partial \gamma^*/\partial \tau > 0$.*

The intuition for the first part of Lemma 5 is straight forward. When the aversion level is low, the DVR supplier exploits that the viewers' willingness to pay is high. Hence, it sets a high price. However, the lower τ, the more heterogenous the viewers, i.e. the greater the difference in willingness to pay for the DVR . This implies that in the interval where the optimal DVR price decreases, the DVR price must be reduced more in order to convince the next marginal viewer to adopt, all else equal. In other words, the [relative] marginal revenue of the DVR seller decreases in τ, which makes the optimal DVR penetration decreasing in τ as well.

We can now consider how the agents of the model are affected by the fact that the DVR technology is made available by a strategic monopolist. The consumer surplus that takes into account the cost of adopting the DVR technology is given by Eq. (10) below, while there is no change in the profit expressions for the firms:

$$CS = \gamma \left(U_{\theta=0} - P(\gamma^*, \tau) \right) + \int_{\tau}^{\tau + (1-\gamma)} U_{\theta} d\theta \tag{10}$$

If we substitute for γ^* into Eq. (10), the TV networks' profit given by the expression

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[25]In effect, the option of returning the DVR removes any uncertainty about which equilibrium is played. We could also simply have assumed that when a price which belongs to several equilibria is played, the equilibrium preferred by the DVR seller is realized. The explanation is that if it was not realized, the DVR seller would have been better off by setting a higher price.

in Table 2, and the advertisers' profit given by Eq. (2), and then compere the expressions to when we do the same for $\gamma = 0$, we find that;

Proposition 5: *Compared to when the DVR technology is not available, when it is supplied by a monopoly firm;*
- **a)** *the TV networks are better off;*
- **b)** *the viewers as a group are worse off, and;*
- **c)** *the advertisers are worse off.*[26]

The DVR supplier always supplies more DVRs than that which maximizes the TV networks' profit, i.e. $\gamma^{TV} < \gamma^*$. However, the number of DVRs sold in equilibrium will not be sufficiently high to make the TV networks worse off compared to when the DVR technology is not available.[27] The viewers as a group, however, are always worse off compared to when the technology is not available. The reason is that the adopters' cost of buying the DVR technology reduces the adopters' net private benefit to such an extent that the aggregate private benefit never exceeds the negative externalities which are imposed on the non-adopters. Furthermore, the DVR penetration is always so high that the advertisement price in equilibrium does not decrease sufficiently to compensate the advertisers for the loss of viewers exposed to their ads.

4 Concluding Remarks:

The aim of this paper is to theoretically investigate the consequences of that the viewers today can adopt technology which enables them to avoid the advertisements that interrupt TV programs. We do this in a model where a monopoly TV network

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[26]In a previous version of the paper, we allowed for the TV network by investing in program quality being able to boost the demand for TV programs. Apart from the fact that the quality level turned out to follow the shape of the TV network's profit level, all but one result survived when we removed the quality investments. This result that did not hold was that for low values of τ the advertisers were better off when a monopoly supplied the ad-avoidance technology than when the technology was not available.

[27]This result holds when $\tau < 0.47$.

serves viewers that are heterogenous in their aversion towards advertising. The findings are perhaps somewhat surprising, inasmuch as we find that both the TV network and the advertisers may benefit from the DVR technology enabling the viewers to avoid the advertisements by incurring a fixed cost. Even more surprisingly may be the result that when we take into account the viewers' costs of adopting the DVR technology, the viewers as a group are always worse off when the technology is available. Furthermore, we find that the social surplus is always higher when a monopoly firm supplies the DVR technology than when the technology is unavailable. The first and the latter of our results are in stark contrast to what Anderson & Gans (2011), henceforth A&G, find when they consider a TV network which is free-to-air. They show that the profit of the TV network, as well as the social surplus, decreases even when the most ad-averse viewers adopt the DVR technology. [28]

All through the paper we make two simplifying assumptions which are worth commenting on. The TV network is a monopoly and it sells programs in a pay-per-view fashion. However, all qualitative results carry over to a model where differentiated TV networks compete. The pay-per-view approach is chosen such that we can tractable derive each viewer's demand for TV programs and aggregate this up to a total demand. This enables us to capture a relationship which is not captured in A&G; the more averse towards advertising a viewer is, the less programs he consumes when he is exposed to advertising and hence the less advertising revenue is foregone if he adopts the DVR technology. We believe that the different findings of our paper, relative to those of A&G, are driven by the fact that we, in contrast to A&G, capture this relationship, and not the fact that A&G has a different modelling approach, i.e. in A&G the TV network charges a subscription fee. The reason is that the driving mechanism of our results, i.e. that the DVR technology opens for possibility that the most and the least advertising averse viewers can be served more efficiently, applies also to a subscription based business model. The difference is simply that the TV network will then increase the subscription fee instead of increasing the program price, in order to internalize that the viewers obtain higher utility/consumes more TV programs when they are shielded from advertising.

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[28] A&G also find this when they consider subscription based TV.

TV signal providers play no role in our simple model, thus the TV network is assumed to set the end-user price and the DVR supplier is assumed to have no relationship with the TV network. However, as discussed in Kind et. al (2010) and Bergh et al. (2012), the end-user price is usually set by a TV signal provider. Furthermore, most viewers do not buy a DVR box from an independent firm as in our extension, but rent or buy it from TV signal providers. This complicates the picture as it means that the same firm sets both the DVR price and the price for watching TV. Moreover, when the TV signal providers can supply their customers with DVR technology, the bargaining power of the parties may be affected. In turn this may impact the contracts between the TV networks and the TV signal providers. We therefore conclude that our paper, together with A&G, sheds some light on the role of the DVR technology, but more research is needed to complete the picture. Further research should therefore attempt to incorporate the role of TV-signal providers.

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5 Appendix

A1: Proof of Lemma 1.

Part a)

$$\frac{\partial A}{\partial p} r = -\frac{r}{2\tau - \gamma + 1} < 0$$

Part b)

$$-\frac{\partial D_1}{\partial A}p = \frac{1}{2}\left(1-\gamma\right)\left(1-\gamma+2\tau\right)p$$

The revenue from the advertiser side of the market decreases in the program price and the revenue from the viewer side of the market decrases in the advertising sales. Q.E.D.

A2: Derivation of Equilibrium Values, Table 1.

The TV-networks F.O.C's with respect to the prices are:

$$\frac{\partial\Pi}{\partial p} = \frac{1}{2}\frac{\left(1-\gamma^2\right)\left(1-2p\right)-2\left((1+\gamma)(r-\tau(1-2p))\right)+4\tau r}{1+2\tau-\gamma} = 0$$

$$\frac{\partial\Pi}{\partial r} = \frac{2((1+p\tau)\left(1-\gamma\right))-p(1-\gamma^2)-8r}{\left(1-\gamma\right)\left(2\tau-\gamma+1\right)} = 0$$

By solving the system of equations we obtain:

$$p^* = 2\frac{1-\gamma^2+2\tau(3+\gamma)}{Z^{-1}} \tag{11}$$

$$r^* = \frac{\left(1+\gamma\right)\left(1-\gamma+2\tau\right)\left(3-\gamma+2\tau\right)}{\left((1-\gamma)Z\right)^{-1}} \tag{12}$$

where:

$$Z = \left(\left(7-\gamma\right)\left(1-\gamma^2\right)+4\tau(5-\tau+\gamma(4-(\gamma-\tau)))\right)^{-1}$$

The optimal advertising level is found by substituting into Eq. (??) for Eqs (11) and(12), we obtain:

$$A^* = \frac{2\left(1+\gamma-2\tau\right)}{Z^{-1}}$$

A3: Proof of Proposition 1.

$$\frac{\partial r}{\partial \gamma} = -\frac{16\tau^3(\tau(1 + \gamma(\gamma - 2)) - \gamma(2\gamma^2 - 9\gamma - 4))}{2Z^{-2}}$$

$$- 8\tau^2 \frac{(10\tau + \gamma(3\gamma^3 - 22\gamma^2 - 4\gamma + 30) + 25)}{2Z^{-2}}$$

$$- \gamma \frac{56\tau - \gamma\tau(232 + \gamma 2(24 - \gamma(42 - 4\gamma)))}{2Z^{-2}}$$

$$- \frac{\gamma(\gamma(\gamma^4 - 14\gamma^3 + 23\gamma^2 + 28\gamma - 49) - 14) + 25 + 148\tau}{2Z^{-2}} < 0$$

$$\frac{\partial r}{\partial \tau} = 2\frac{(1 - \gamma^2) 4\tau(5 + \tau(\gamma + 7) - \gamma(\gamma + 4)) + \gamma(\gamma^2 + \gamma - 1) - 1}{Z^{-2}} > 0$$

$$\frac{\partial A}{\partial \gamma} = 8\frac{2(\gamma^2 + 2(1 + \tau^2(\tau + 3 - 2\gamma))) + 5\tau\gamma(\gamma - 2) + \tau + \gamma(7 - \gamma^2)}{Z^{-2}} > 0$$

$$\frac{\partial A}{\partial \tau} = -8\frac{17(1 + \gamma) - 4\tau(1 - \tau(1 - \gamma) - \gamma^2) - \gamma^2(1 + \gamma)}{Z^{-2}} < 0$$

$$\frac{\partial p}{\partial \tau} = 4(1 - \gamma)\frac{11 + 4\tau(1 + \tau(\gamma + 3) - \gamma^2) + \gamma(7 + \gamma(\gamma - 3))}{Z^{-2}} > 0$$

$$\frac{\partial p}{\partial \gamma} = 2\frac{1 + \gamma^2(\gamma^2 - 2) + 4\tau(1 - 15\tau - 8\tau^2 + \gamma(13 - \gamma(5 + \gamma) + \tau(14 + \gamma)))}{Z^2} \gtrless 0$$

All numerators, except from the the numerater of $\partial p/\partial \gamma$, are positive for all defined combinations of γ and τ.

If we evaluate the numerator of $\partial p/\partial \gamma$ for $\gamma = 0$, we obtain $-32\tau^3 - 60\tau^2 + 4\tau + 1 \gtrless 0$, and if we evaluate it for $\gamma = 1$ we obtain $32\tau - 32\tau^3 > 0$. The former expression is negative if $\tau \approx 1/6$. Q.E.D.

A4: roof of Proposition 2.

By substituting into Eq. (4) for p^*, r^* and A^*, we obtain:

$$\Pi^* = 2(\gamma + 1)\frac{2\tau - \gamma + 1}{Z^{-1}}$$

By taking derivatives of Π^*, we obtain:

$$\frac{\partial \Pi}{\partial \tau} = -4(1 - \gamma)(\gamma + 1)(3 + 2\tau - \gamma)\frac{1 + \gamma - 2\tau}{Z^{-2}} < 0 \tag{13}$$

$$\frac{\partial \Pi}{\partial \gamma} = 2\frac{1 - \gamma(1 + \gamma(1 - \gamma)) + \tau(8(\tau - \gamma) + 2(1 - \gamma^2))}{(1 + \gamma - 2\tau)^{-1} Z^{-2}} \lessgtr 0 \tag{14}$$

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$$\frac{\partial^2 \Pi}{\partial \gamma \partial \tau} = -8 \frac{10 - \tau \left(18 + \gamma \left(98 + 36\gamma - 28\gamma^2 + 10\gamma^3 - 6\gamma^4\right)\right)}{Z^{-3}}$$
$$- 8\tau^2 \frac{\left(84 - 72\gamma^2 - 12\gamma^4\right) + \tau^3 \left(72 + 16\tau + \gamma \left(24 + 24\gamma + 8\gamma^2 - 16\tau\right)\right)}{Z^{-3}}$$
$$- 8\gamma \frac{\left(15 - 9\gamma - 18\gamma^2 + 3\gamma^4 - \gamma^5\right)}{Z^{-3}} < 0$$

Eq. (13) is negative for all defined combinations of γ and τ. If we evaluate the last term of Eq. (14) for $\gamma = 0$ we obtain:

$$1 + 2\tau \left(1 + 4\tau\right) > 0$$

Since the last term is positive for $\gamma = 0$, the full expression is positive around zero. If we evaluate the last term for $\gamma = 1$ we obtain:

$$8\tau \left(\tau - 1\right) < 0$$

Since the last term is negative for $\gamma = 1$, the full expression is negative around $\gamma = 1$. Hence, if the function is well behaved in γ, there exists a value γ^{TV} for which the profit of the TV network is maximized. Finally since $\partial \Pi^2 / \partial \gamma \partial \tau < 0$, it follws that the optimal $\partial \gamma^{TV} / \partial \tau < 0$

A5: Proof of Proposition 3.

a) The equilibrium consumer surplus is given by:

$$CS = \gamma U + \int_\tau^{\tau + (1 - \gamma)} U_\theta d\theta C =$$
$$= \frac{49 + \gamma \left(2 - 101\gamma - 4\gamma^2 + 55\gamma^3 + 2\gamma^4 - 3\gamma^5\right)}{6Z^{-2}}$$
$$+ \tau \frac{188 + 196\tau + \gamma \left(200 + 348\tau + 48\tau^3 +\right)}{6Z^{-2}}$$
$$- \gamma^2 \tau \frac{168 + 224\gamma + 20\gamma^2 - 24\gamma^3}{6Z^{-2}}$$
$$+ \gamma^2 \tau^2 \frac{228 + 68\gamma - 72\gamma^2 - 96\tau + 96\tau\gamma - 48\tau^2}{6Z^{-2}}$$

We can now do comparative statics by taking derviatives of CS with repsect to γ and τ. Starting with γ, we obtain:

$$\frac{\partial CS}{\partial \gamma} = \frac{2}{3} \frac{28 + \tau \left(118 + 339\tau + 274\tau^2 - 108\tau^3 + 24\tau^4\right)}{\left(Z^3 \left(1 + \gamma - 2\tau\right)\right)^{-1}}$$
$$- \frac{2}{3} \frac{\gamma \left(38 + 46\gamma - 76\gamma^2 - 8\gamma^3 + 38\gamma^4 - 10\gamma^5\right)}{\left(Z^3 \left(1 + \gamma - 2\tau\right)\right)^{-1}}$$
$$- \frac{2}{3} \frac{\tau\gamma \left(238 + 316\gamma - 428\gamma^2 - 70\gamma^3 + 62\gamma^4\right)}{\left(Z^3 \left(1 + \gamma - 2\tau\right)\right)^{-1}}$$
$$- \frac{2}{3} \frac{\tau^2\gamma \left(86 + \gamma \left(1404 - 246\gamma - 137\gamma^2\right)\right)}{\left(Z^3 \left(1 + \gamma - 2\tau\right)\right)^{-1}}$$
$$+ \frac{2}{3} \frac{\tau^3\gamma \left(1026 - 594\gamma - 130\gamma^2 + \tau \left(60\gamma + 240 - 24\tau\right)\right)}{\left(Z^3 \left(1 + \gamma - 2\tau\right)\right)^{-1}}$$

If we evaluate $\partial CS/\partial \gamma$ for $\gamma = 0$ and $\gamma = 1$ we can show that:

$$\frac{\partial CS}{\partial \gamma} \Big|_{\gamma=0} = \frac{2}{3\left(7 - 4\tau\left(\tau - 5\right)\right)} \left(1 - 2\tau\right)\left(28 + \tau \left(118 + 339\tau + 274\tau^2 - 108\tau^3 + 24\tau^4\right)\right) > 0$$

$$\frac{\partial CS}{\partial \gamma} \Big|_{\gamma=1} = -8\left(1 - \tau\right)^2 \tau \left(4 + \tau\right) < 0$$

Hence, CS is hump-shaped for all defined values of τ. Now, the derivative of CS with respect to τ is:

$$\frac{\partial C}{\partial \tau} = \frac{2}{3} \left(1 - \gamma\right) \frac{161 + +\gamma \left(109 - 258\gamma - 90\gamma^2 + 97\gamma^3 - 19\gamma^4\right)}{\left(\left(2\tau - \gamma - 1\right)Z^3\right)^{-1}} +$$
$$\frac{2}{3} \left(1 - \gamma\right) \frac{\tau \left(380 + 716\gamma - 108\gamma^2 - 332\gamma^3 + 112\gamma^4\right)}{\left(\left(2\tau - \gamma - 1\right)Z^3\right)^{-1}} +$$
$$\frac{2}{3} \left(1 - \gamma\right) \frac{\tau^2 \left(196 + 636\gamma + 156\gamma^2 - 220\gamma^3 + \tau\gamma \left(240 + 144\gamma\right)\right)}{\left(\left(2\tau - \gamma - 1\right)Z^3\right)^{-1}} < 0$$

The expression is negative for all defined combinations of γ and τ.

The equilibrium profit for the advertisers is:

$$B = \frac{2\left(1 - \gamma\right)\left(1 - \gamma + 2\tau\right)}{\left(\left(1 + \gamma - 2\tau\right)Z\right)^{-2}}$$

By taking deriatives of B with respect to γ, we obtain:

$$\frac{\partial B}{\partial \gamma} = \frac{1 + \tau \left(5 - \gamma \left(50 - 52\gamma + 14\gamma^2 - 7\gamma^3\right)\right)}{\left(4 \left(1 + \gamma - 2\tau\right)\right)^{-1} Z^{-3}}$$
$$+ \frac{\tau^2 \left(66 - \gamma \left(158 - 46\gamma + 18\gamma^2\right)\right)}{\left(4 \left(1 + \gamma - 2\tau\right)\right)^{-1} Z^{-3}} - \frac{\gamma \left(1 + 2\gamma - 2\gamma^2 - \gamma^3 + \gamma^4\right)}{\left(4 \left(1 + \gamma - 2\tau\right)\right)^{-1} Z^{-3}}$$
$$+ \frac{\tau^3 \left(92 - 48\gamma + 20\gamma^2 - \tau \left(8\gamma - 8\right)\right)}{\left(4 \left(1 + \gamma - 2\tau\right)\right)^{-1} Z^{-3}}$$

If we evaluate $\partial B / \partial \gamma$ for $\gamma = 0$ and $\gamma = 1$, we can show that:

$$\left.\frac{\partial B}{\partial \gamma}\right|_{\gamma=0} = 4 \frac{1 - 2\tau}{\left(7 + 20\tau - 4\tau^2\right)^3} \left(1 + \tau \left(5 + 66\tau + 92\tau^2 + 8\tau^3\right)\right) > 0$$

$$\left.\frac{\partial B}{\partial \gamma}\right|_{\gamma=1} = -\frac{1}{64\tau} \left(1 - \tau\right)^2 < 0$$

Hence, B is hump shaped in γ.

If we take take the derivative of B with respect to τ we obtain:

$$\frac{\partial B}{\partial \tau} = -4 \left(1 - \gamma\right) \left(3 - \gamma + 2\tau\right) \frac{9 + \gamma - 9\gamma^2 - \gamma^3 + 12\tau + 4\tau^2 + 16\tau\gamma + 4\tau\gamma^2 - 4\tau^2\gamma}{\left(\left(1 + \gamma - 2\tau\right) Z^3\right)^{-1}} < 0$$

The last fraction is positive for all defined combinations of γ and τ.Q.E.D.

b)

In order to show that $\gamma^B < \gamma^{CS} < \gamma^{TV}$ we choose any arbitrary τ and solve for the optimal DVR penetration for the different agents. By doing so for $\tau = 0.05$ and $\tau = 0.35$ we obtain;

	$\tau = 0.05$	$\tau = 0.35$
$\partial \Pi / \partial \gamma = 0$	$\gamma^{TV} = 0.662\,81$	$\gamma^{TV} = 0.600\,84$
$\partial CS / \partial \gamma = 0$	$\gamma^{CS} = 0.638\,62$	$\gamma^{CS} = 0.598\,31$
$\partial B / \partial \gamma = 0$	$\gamma^B = 0.435\,62$	$\gamma^B = 0.505\,21$

Q.E.D.

A6: Proof of Lemma 5.

The F.O.C. is:

$$\frac{\partial \Gamma}{\partial \gamma} = \frac{28 + \tau\left(115 - 49\tau - 512\tau^2 - 216\tau^3 + 144\tau^4 - 16\tau^5\right)}{2^{-1}Z^{-3}}$$
$$- \gamma\frac{10 + 84\gamma - 30\gamma^2 - 84\gamma^3 + 30\gamma^4 + 28\gamma^5 - 10\gamma^6}{2^{-1}Z^{-3}}$$
$$+ \tau^2\gamma\frac{1109 - 102\gamma - 1954\gamma^2 + 111\gamma^3 + 285\gamma^4 - 8\gamma^5}{2^{-1}Z^{-3}}$$
$$+ \tau^3\gamma\frac{660 + 2460\gamma - 620\gamma^2 - 476\gamma^3 + 24\gamma^4}{2^{-1}Z^{-3}}$$
$$- \tau^4\gamma\frac{1088 - 600\gamma - 416\gamma^2 + 32\gamma^3 + \tau\gamma\left(192 - 16\gamma\right)}{2^{-1}Z^{-3}}$$
$$+ \tau\gamma\frac{209 - 579\gamma - 297\gamma^2 + 549\gamma^3 + 87\gamma^4 - 85\gamma^5 + \gamma^6 - \tau^4\left(96 - 48\tau\right)}{2^{-1}Z^{-3}} = 0$$

By substituting parameter values for τ into $\partial\Gamma/\partial\gamma = 0$ we obtain:

	$\tau = 0.5$	$\tau = 0.2$	$\tau = 0.35$
$\gamma^* =$	0.816 09	0.833 55	0.926 78
$P^* =$	0.109 46	$6.231\,1 \times 10^{-2}$	$4.103\,0 \times 10^{-2}$

Hence, the higher the disutility of advertising the higher DVR penetration and the lower price. Q.E.D.

A7: Proof of Proposition 5.

Define $\Delta\Upsilon = \Upsilon(\gamma^*) - \Upsilon(0)$, where $\Upsilon = \Pi, B, CS$. A positive Δ indicates therefore that the agents are better off when the technology is available, while a negative Δ indicates that they are worse off.

	$\tau = 0.05$	$\tau = 0.2$	$\tau = 0.35$
$\Delta\Pi$	$1.244\,8 \times 10^{-2}$	0.002 43	0.000 66
ΔCS	$-2.505\,5 \times 10^{-2}$	$-2.373\,6 \times 10^{-2}$	$-0.026\,44$
ΔB	$-3.961\,5 \times 10^{-3}$	$-2.472\,7 \times 10^{-3}$	-4.544×10^{-4}
Γ	$8.933\,0 \times 10^{-2}$	$5.193\,9 \times 10^{-2}$	$3.802\,5 \times 10^{-2}$

The proof follows from the table. Q.E.D.

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Journal of Public Economics 92(2008) 1531-1539

The business model of many commercial TV-networks is to interrupt TV programs with advertising breaks. In this paper we investigate consequences of the fact that ad-averse viewers today can adopt technology which enables them to skip the advertising breaks. Perhaps somewhat surprisingly, we find that the ad-avoidance technology can make TV networks and the advertisers better off. The viewers as a group however, are always worse off when we take into account their costs associated with adopting the technology.