Effects of TV airtime regulation on advertising quality and welfare*

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Abstract

This paper investigates how regulations that limit advertising airtime may affect advertising quality and social welfare. I show, first, conditions under which an advertising cap may reduce or improve the average quality of advertising broadcast on a free-to-air TV platform. Second, an advertising cap may reduce TV platform's and firms' profits, while the net effect on viewers' welfare is ambiguous because the ad quality may decrease as a result of a regulatory cap offsetting the direct gain from watching fewer ads. The results suggest that a regulator that is trying to increase social welfare via regulation of the volume of advertising on TV should take the effect of advertising quality into consideration. Implementing an advertising cap without regard to ad quality may result in lower social welfare than leaving advertising airtime unregulated.

Keywords: Advertising; Ad quality; Regulation; TV; Two-sided markets.

JEL Classification: D62; M37; M38.

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1 Introduction

Motivation. The quality of TV ads matters not only for commercial purposes, but also because it influences the quality of the TV viewing experience. TV viewers may consider some ads as entertaining, while other ads may cause a nuisance. Advertising represents a remarkable proportion of airtime of various TV channels, and regulators limit advertising airtime on TV in various countries. But what if these caps drive to a change in the quality of the TV ads? This paper sheds light on potential mechanisms through which ad caps may affect ad quality positively or negatively, and it discusses the welfare impacts of such caps.

Individuals in developed countries spend a significant share of their time watching TV. For example, in the first quarter of 2019, the average US American adult spent almost four hours per day watching live TV (The Nielsen Company, 2019), while in the UK, the average viewer aged 4+ watched slightly more than three hours and twelve minutes per day in 2018 (Ofcom 2019). In Japan, the average time was three hours and twenty-one minutes per day in 2017 (eMarketer, 2018). TV broadcasting offers an opportunity for firms to advertise to a large pool of consumers. In 2018, TV ad spending increased to more than USD 140 billion across twelve countries including Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, UK and US. TV ads account for c. 42% of all worldwide advertising spending (Digital TV Europe, 2018).

In the US, the frequency and length of commercial breaks are generally unregulated with some programs on major TV channels recording advertising levels in excess of twenty minutes per hour. In many other countries, regulators limit advertising airtime on TV. These time restrictions are usually intended to ensure that viewers are not exposed to excessive amounts of ads, and that the overall viewing experience meets a certain quality standard. For example, in Australia, regulations limit ads airtime to ten minutes in any single hour, while in Europe, the revised EU Audiovisual Media Services Directive published in 2018 sets a daily cap on advertisements of 20% of broadcasting time. Some countries, such as France, Germany and the UK, have implemented even stricter national regulations, particularly on public service broadcasters with ad caps below 10 minutes per hour.

Description of the paper. I utilize a basic free-to-air TV model supported by advertising revenues that yields predictions on how advertising quality is determined by firms and influenced by advertising caps. In this paper, advertising quality expands the demand for an advertised product (via persuasion), while it also reduces the viewers' nuisance of watching a TV ad. In the extreme, if the advertising quality of a TV ad is sufficiently high, the viewer may even enjoy watching that ad. Within this context, higher ad quality could result from adding valuable entertainment such as humor or upbeat music to the ad, or a celebrity endorsement of the product to be advertised (Ford, 2018; Carrillat and Ilicic, 2019). This may not necessarily be synonymous with a higher art form, but I take the standard assumption that advertising costs increase with ad quality.

The reasoning for a free-to-air model is two-fold. First, free-to-air TV platforms are more likely to be affected by advertising caps than paid services such as cable TV and subscription video on demand. Note that a pay-TV platform by setting lower advertising levels may be able to generate higher subscription revenues, which do not exist in a free-to-air model. In other words, subscription revenues may act as an incentive for platforms to moderate their volume of ads. Li and Zhang (2016) show that pay-TV platforms can broadcast too few ads, while free-to-air TV might act in the opposite manner. Second, historically, free-to-air has represented a significant share of TV viewing across a number of countries. Pay-TV and on demand services such as Netflix and Amazon Prime Video services are taken into account in the model as an alternative option to free-to-air TV (see "Partial participation of viewers" in section 4).

In the model, viewers are concerned about their total exposure to TV ads. The impact of such exposure on the utility of a viewer depends on the aggregate ad quality, net of nuisance cost, across all ads watched or, equivalently, the net average ad quality multiplied by the volume of TV ads. I show how the average ad quality in a TV platform may be increasing or decreasing with the volume of ads broadcast. The former will be the case if information and persuasion are substitute inputs for firms. In other words, the marginal product of investing in ad quality is lower for firms with a stronger informative effect. Under mild assumptions, the marginal firm can exhibit higher ad quality compared to inframarginal firms with a higher informative effect. Consequently, if the TV platform sells more advertising slots, such sales will increase the average ad quality. If so, an advertising cap confines advertisement slots to firms with a higher informative effect, which are also the firms with higher willingness to pay for an ad slot, to the detriment of firms that would invest in ads of higher quality but are now excluded from the advertising market due to the cap. On the contrary, if information and persuasion are complementary inputs for firms, then a cap will increase the average ad quality because the excluded firms from TV ads are those willing to invest less in ad quality. Also, if ad quality and the number of ad slots purchased by a firm are complementary (substitute) inputs, firms may choose to invest less (more) in ad quality as the advertising fees increase with a tighter cap.

An advertising cap may entail the following welfare effects. A tighter cap incentivizes the TV platform to set higher advertising fees, as a lower fee cannot increase the volume of advertising sales in view of the cap. A tighter cap will, thus, make firms pay more per ad slot. However, if a cap expands the mass of viewers, some firms may boost their sales in the product market and increase profits as a result. The net effect on viewers' welfare is ambiguous. Although there are fewer ads when an advertising cap is imposed, the average advertising quality may also be reduced. Such possibility suggests that a regulator that is trying to increase social welfare via regulation of the volume of advertising on TV should take the effect of advertising quality into consideration. This paper contributes to the literature on entertainment in advertising by showing that implementing a cap without regard to a potential change in ad quality may result in lower social welfare than leaving advertising airtime unregulated.

Related literature. To the author's knowledge there has been no previous research on the link between regulation limiting the advertising airtime and advertising quality on TV. This paper brings together three topics that have been approached separately in the literature: normative work on the optimal choice of advertising levels; the role of quality (entertainment) in TV advertisements; and how ad quality on TV can empirically be measured.

In the first stream of related literature, seminal normative work on advertising, such as Steiner (1952) and Spence and Owen (1977), tended to focus on the benefits that ads generate to the audience but ignored the surplus obtained by the firms. The assumptions of fixed levels of advertising airtime and prices prevent the analysis of whether the market under- or over-provisions advertisements. Anderson and Coate (2005) explored market failures in the broadcasting industry by modeling how media platforms fulfill their role of providing content to viewers and simultaneously supplying eye-balls to firms. Their work connects the product market to the advertising market and analyzes the trade-off between the nuisance stemming from commercial breaks during the broadcasts and the informational gains generated by the content of these commercials. They show that the market equilibrium may under- or over-provide advertising airtime, depending on the nuisance cost to viewers, the substitutability of programs, and the expected benefits to firms from contacting viewers. My model builds on Anderson and Coate (2005) by allowing firms to invest in ad quality (persuasion). Anderson and Jullien (2015) provide an excellent survey on advertising-financed business models, including normative aspects. A common assumption within this stream of literature is that ads are a nuisance to viewers. In my model, because firms can choose their ad quality, they can reduce ad nuisance (or even turn ads into a net benefit) to viewers.

Over the last two decades, several other articles have studied the welfare effects of advertising caps. On the theoretical literature, Dukes (2004) showed that less product differentiation or more media differentiation leads to higher market levels of advertising. In particular, if media is sufficiently differentiated, the advertising levels will surpass the social optimal level. Rothbauer and Sieg (2015) studied the welfare effects of caps in free-to-air TV channels, one of them being less content differentiation. They identified circumstances in which leaving the market unregulated is optimal. Kerkhof and Münster (2015) showed that ad caps can increase the per-viewer price of ads. Consequently, media content can improve for viewers. If so, welfare can potentially increase, even if viewers are not ad averse. Greiner and Sahm (2018) considered a duopoly of TV channels, which are vertically differentiated in content, and compete in prices for both viewers and firms. They analyzed the case where the high-quality content broadcaster is subject to an advertising ban. They showed that preventing the high-quality broadcaster from selling ad slots leads to fewer viewers watching it. This is because after the ad ban the broadcaster is unable to sell its viewership to firms, relying on subscription revenues only. The two co-authors found that the ad ban can result in a welfare decrease. On the empirical literature, Filistrucchi et al. (2012) analyzed some of the impacts of an advertising ban that happened on the French public TV in 2009. They provided empirical evidence that such ban had no significant impact on the public TV's share of viewers or on the private TVs' level of advertising. They suggested that such result can be explained by viewers' heterogeneity across different TV channels. Zhang (2018), using a dataset from twelve TV broadcasters in France, found that ad deregulation in France would increase profit of TV broadcasters, but could reduce the surplus of both viewers and firms.

The second body of related literature suggests that the quality (entertainment) in TV ads affects the quality of the viewing experience. Aaker and Bruzzone (1985), based on a nationwide sample of viewers that responded to a questionnaire on TV ads in the US, found that viewers experienced lower levels of irritation when ads featured a credible spokesperson, or included humor. Elpers et al. (2003) found that viewers choose to stop watching ads with low levels of entertainment or high information content, while Wilbur (2016) showed that viewers tend to avoid some ads more than others. Teixeira et al. (2014) found that entertainment in ads impacts purchase intentions via persuasion, and increases the ad's attractiveness. They construe entertainment consistently with other literature on the role of entertainment in ads. In particular, entertainment means that the TV "ad itself is attractive and induces pleasure throughout its viewing".

The third stream of related literature examines how advertising quality on TV can be measured. Advertising quality is hard to verify and measure. Institutions such as the Australian Broadcasting Tribunal (ABT) have used costs as a proxy for quality. However, the ABT acknowledged that cost should not necessarily be equated with quality (Wright, 1994). Early attempts to generate quality scores for TV ads have relied on surveys to infer the best-liked ads and the most-recalled ads. Since 2007, Google has been exploring ways to measure the quality of TV ads. Google aggregates data describing the precise second-by-second tuning behavior for millions of TV set-top boxes, covering millions of US households, doing so for several thousand TV ads every day. From this data, Interian et al. (2009) and Zigmond et al. (2009) developed measures that can be used to gauge how appealing and relevant commercials appear to be to TV viewers. One such measure is the percentage of initial audience retained: how much of the audience tuned in to an ad when it began airing and remained tuned to the same channel until the ad finishes. More recently, Teixeira et al. (2014) attempted to measure the level of entertainment of TV ads by: (i) filming the viewers' facial reactions, (ii) checking whether viewers watched the ad until the end, and (iii) asking, after the full or partial view of each ad, whether viewers intend to purchase the brand.

The rest of the paper is organized as follows. Section 2 sets up an advertising-supported TV model that allows to study the impact of ad caps on ad quality and welfare. Section 3 describes the model equilibria and key results. Section 4 discusses in further detail some of the assumptions in the model, and addresses the robustness of the key results. Section 5 concludes the paper. Proofs and further technical details are in the Appendix.

2 The model

In this section I set out a basic advertising-supported broadcasting model, characterize each participating agent (free-to-air TV platform, viewers, firms and a sectoral regulator) and describe how they interact in a four-stage game.

Free-to-air TV platform. There is one profit maximizing TV platform representing the free-to-air TV market in a country. A monopoly provides a first-order approximation to markets where platforms have market power. The TV platform has the capacity to cover all viewers and firms. It sets a fee, $f \geq 0$, to sell ad-airtime (e.g. per 30-second slot) to firms, and broadcasts free content to viewers.

Each advertisement takes a fixed amount of time which will be deducted from the programming time. The TV platform faces a fixed cost, $K > 0$, regardless of the broadcast mix of advertising and regular programming. The amount K must be sufficiently small such that the TV platform's profit is non-negative to ensure participation in equilibrium. For simplicity, the TV platform has constant marginal costs normalized to zero in providing both content to viewers and advertising slots to firms. The qualitative results are unaffected if for the TV platform airing programming costs more than advertisements. If so, ads would have a negative marginal cost representing the cost saving from not having to purchase or produce further content, while K may be interpreted as the cost of content for an ad-free TV platform. More advertisements and, thus, less programming would reduce total cost for the TV platform. Also, I assume that each firm will not buy more than one advertising slot. The case where a firm can buy multiple advertising slots is addressed in section 4. The TV platform's profit is defined as

$$\Pi_{TV}(f) \equiv f\hat{x} - K, \tag{1}$$

where $0 \leq \hat{x} \leq 1$ is the mass of firms advertising on the TV platform.

Viewers. There is a mass of viewers normalized to one. All viewers already have the necessary hardware to allow them to receive a TV service (The Nielsen Company, July 2009). This assumption is realistic for a number of developed countries, e.g. in 2018 the proportion of UK households with digital TV was 95% (Ofcom, 2018). Wilbur (2008) estimated a two-sided model of the TV industry in the US and found that viewers tend to be averse to commercials. In the UK, a majority of viewers sometimes or often see TV ads as "interfering" with their enjoyment of content, but they also see adverts as "informative" and "clever" (Ofcom, 2011). In this paper, viewers are averse to advertising airtime, while also appreciating the quality of ads. The nuisance perceived by viewers is related to the duration or number of ads. In particular, this negative effect of ads may be understood as the boredom and wasted time that the viewers bear each time there is a commercial break on TV. For the sake of exposition, in the model, all viewers do watch TV ads. This assumption is supported by recent research studies (The Nielsen Company, 2010; YouGov, 2019) that have found that many viewers do watch TV ads. However, there is also evidence that some TV viewers attempt to avoid the advertising time. Speck and Elliott (1997) explain that there are at least three possible ways to avoid ads: a cognitive strategy (ignoring it), a behavioral strategy (e.g. leaving the room, multi-tasking), and a mechanical strategy (e.g. switching channels, DVRs). Research indicates that 70% of adults use another device at the same time as watching TV (Ofcom, 2018). See also Liaukonyte et al. (2015) on the rapid growth of media multi-tasking. The main results of this paper hold qualitatively with ad avoidance, insofar a fraction of viewers still watches the ads.

Viewers' gross benefit of watching free-to-air TV is denoted by $v > 0$, where v is sufficiently high to ensure full participation. This is equivalent to assume that a representative viewer will always watch free-to-air TV regardless of the advertising volume. Such assumption is consistent with the findings by Filistrucchi et al. (2012) in that an advertising ban on the French public TV in 2009 had no significant impact on the public TV's share of viewers. For completeness, I discuss partial participation in free-to-air TV in section 4. Viewers' tastes for watching free-to-air TV are indexed by y uniformly distributed on $[0, 1]$, so that viewers with y closer to 0 have a stronger preference for watching free-to-air TV. Parameter $t > 0$ measures the differentiation among viewers with respect to the value of watching free-to-air TV. The nuisance cost of ads is measured by $\gamma > 0$ and is equal for all viewers. The term δq is the discount on the nuisance cost of ads airtime due to the average quality of advertising, where $\delta > 0$ is an ad quality evaluation factor and $q \geq 0$ measures the average quality of ads. This means that an increase in q will attenuate the nuisance costs of advertising airtime. Note that q can be construed as a positive externality associated to the ads production. In the limit case $\delta = 0$, viewers would not care about q. For δ sufficiently high, depending on q, viewers may enjoy advertising. For simplicity, not watching free-to-air TV yields a zero net utility. Formally, the utility derived by a viewer at y is defined by

$$U(\hat{x}, q, y) \equiv \begin{cases} v - \gamma \hat{x}(1 - \delta q) - ty & \text{if free-to-air TV} \\ 0 & \text{if otherwise} \end{cases}. \tag{2}$$

Like in Anderson and Coate (2005), firms extract the full surplus in the product market. This simplification allows to focus on the TV platform without concerns about an endogenous distribution of surplus between viewers and firms in the product market. Therefore, the viewer's choice with respect to watching free-to-air TV does not depend on the surplus in the product market, but solely on the programming contents instead. A summary of the notation for viewers follows in Table 1 below.

TABLE 1: Notation for viewers

Exogenous variables	
δ	Ad quality evaluation parameter.
v	Viewers's gross benefit of accessing an ad-free TV platform.
t	Viewers' taste parameter for watching free-to-air TV programmes.
y	Index for viewers.
Endogenous variables	
$\hat{x}$	Advertising volume (time) on free-to-air TV.
q	Average ad quality on free-to-air TV.
U	Utility of a viewer.
f	Advertising fee (per slot) charged by the free-to-air TV platform.

Firms. There is a mass of firms normalized to one. They may use the TV platform as an advertising outlet to reach viewers and ultimately increase profits. Those firms are local monopolists of new products. A monopoly allows to abstract from complex strategic interactions between firms at the product market level and it is a first-order approximation to markets where firms have a degree of market power. Ads are designed to inform consumers about the existence, characteristics, and prices of the new products as well as persuade them to buy. The informative view holds that many markets suffer from imperfect consumer information because of searching costs. Advertising comes out as one of the market answers to imperfect information, supplying consumers with further information at low cost. See Anderson and Renault (2006) for the incentives for a firm to provide information on price and the product attributes. The persuasive view states that advertisements alter consumers' preferences and augment product differentiation and brand loyalty. Both of the advertising views described above coexist in this model.

All viewers are homogeneous to firms so that there is no matching of advertisements to programming, e.g. tennis clubs advertising in a tennis program. Each firm (new product) is indexed by x uniformly distributed on $[0,1]$. Products with a higher x are more likely to be attractive to viewers. All products are produced at a constant cost per unit $c > 0$. A firm x may choose to invest in advertising quality, $q_x \geq 0$. The incentive for firm x to spend resources to improve ad quality is driven by the increase in the demand for the advertised product, $D(x, q_x)$. It is more likely that viewers will remember an advertised product when its ad quality is higher. Moorthy and Zhao (2000) found evidence that advertising expenditure (taken as proxy for ad quality) and perceived quality of the underlying product are in general positively correlated for both durable and nondurable products, even after accounting for objective quality, price and market share. One might expect that there are diminishing returns to ad quality, i.e. as the ad quality level for a given product increases, the increment in the demand for that product becomes smaller. I impose the following conditions on the demand for firm x's product: $\partial D(x, q_x)/\partial x > 0$ (and sufficiently high such that all second-order conditions in this paper are satisfied), $\partial D(x, q_x)/\partial q_x > 0$ and $\partial^2 D(x, q_x)/\partial q_x^2 < 0$ for $0 \leq x \leq 1$ and $q_x \geq 0$. Variable x may be construed as the informative role of advertising since all viewers learn about the existence and features of x's product upon watching the ad. The exogeneity of x reflects that viewers may react differently (in terms of buying behavior) to the information received from different firms. Variable q_x reflects the persuasive effect of advertising chosen by the firm. Firm x pays a cost of implementing quality level q_x equal to βq_x, with $\beta > 0$. The higher the β, the more expensive the ad quality technology. Having received advertising for a particular new product, a viewer knows his willingness to pay for it and will purchase it with some probability if his willingness to pay is no less than its advertised price. A viewer will be willing to pay $\omega > c$ or 0 for advertised products. Thus, all firms will advertise price ω. A lower price does not increase the demand, only better advertising quality will do so. If a firm does not advertise on TV, the product will not be known in the market and thus generates no profit. Formally, firm x's profit is defined by

$$\Pi(x, q_x) \equiv \begin{cases} (\omega - c) D(x, q_x) - \beta q_x - f & \text{if ad on TV} \\ 0 & \text{if no ad on TV} \end{cases} . \tag{3}$$

The average of ad quality across firms that advertise on the TV platform is defined by

$$q(\hat{x}) \equiv \begin{cases} \frac{\int_{1-\hat{x}}^{1} q_x dx}{\hat{x}} & \text{if } \hat{x} > 0 \\ 0 & \text{if } \hat{x} = 0 \end{cases} .$$

Given that $\partial D(x, q_x) / \partial x > 0$, for an advertising volume $\hat{x} > 0$, only firms located at $x \in [1 - \hat{x}, 1]$ will advertise their products and, thus, contribute to q. In an ad-free TV platform, the average quality of advertising is zero. This is an innocuous assumption because for $\hat{x} = 0$, $\hat{x}(1 - \delta q) = 0$ in (2), for any $q \in \mathbb{R}$. A summary of the notation for firms follows in Table 2 below.

TABLE 2: Notation for advertising firms

Exogenous variables	
x	Index for firms.
β	Cost of one unit of ad quality.
ω	Willingness to pay for a product by each consumer.
c	Marginal cost of producing a product.
Endogenous variables	
Π	Profit of a firm.
D	Demand for firm x's product when it advertises on the TV platform.
q_x	Firm x's ad quality.

Sectoral regulator. In carrying out their duties, sectoral regulators in various developed countries take into account the likely impact of regulation on stakeholders such as viewers (consumers), broadcasters and firms, and any others likely to be affected by regulation (Ofcom, 2011). When considering to implement a cap on advertising airtime, $\bar{x}$, a fully informed regulator maximizes social welfare defined by

$$W(\hat{x}, q) \equiv \int_0^1 U(\hat{x}, q, y)\, dy + \int_{1-\hat{x}}^1 \Pi(x, q_x)\, dx + \Pi_{TV}(f)$$
$$= \int_0^1 U(\hat{x}, q, y)\, dy + (\omega - c) \int_{1-\hat{x}}^1 D(x, q_x)\, dx - \beta \int_{1-\hat{x}}^1 q_x dx - K.$$

If the regulator finds that the socially optimal level of advertising airtime is equal or above the unregulated equilibrium, then it leaves the market unregulated. Otherwise, the regulator implements a binding cap on advertising airtime. Section 3 considers a scenario of a partially informed regulator that disregards ad quality effects on viewers' welfare and how does that compare to the scenarios with a fully informed regulator and the unregulated market. The partially informed regulator believes that q is fixed at $\bar{q}^e \geq 0$ regardless of the volumes of ads on TV.

The timing of the game. The participating agents interact according to the following four-stage game. First, the regulator decides whether to implement a cap on advertising airtime, or leave the market unregulated. Second, the TV platform chooses the advertising fee per slot taking into account regulations in place. Third, the advertising slots are sold and firms with a slot choose on the level of advertising quality. Firms produce their advertisements and decide the price of the products they sell. I assume that firms' expectations of how many viewers there will be in the TV platform watching their ads are fulfilled (rational). Fourth, the TV platform broadcasts content and the advertising slots, and viewers make their choices regarding whether to watch free-to-air TV and which products to buy. When choosing between watching free-to-air TV or not, viewers' have rational expectations regarding the volume and average quality of ads. A summary of the timing of the model follows in Table 3 below.

TABLE 3: Timing of the model

I.	The regulator decides whether to implement an ad cap, or leave the market unregulated.
II.	The TV platform chooses the advertising fee, f, such that it maximizes (1) subject to regulation in place.
III.	Firms decide whether they want to buy an advertising slot from the TV platform, depending on the advertising fee, f, and their (rational) expectations of how many viewers there will be in the platform. Firms choose the ad quality level that maximizes (3) and set the product price at ω.
IV.	Viewers maximize (2) by choosing between watching free-to-air TV or not. When making their choice, they take into account their idiosyncratic value for watching free-to-air TV programmes, the expected advertising airtime and the average ad quality.

3 The subgame perfect Nash equilibrium

In this section, I compare the advertising airtime equilibrium levels obtained under three distinct scenarios: unregulated market, regulatory cap intervention when ad quality effects on viewers' welfare are disregarded (partially informed regulator), and regulatory cap intervention when ad quality effects are fully taken into account (fully informed regulator). A welfare comparison between the partially informed regulator and the unregulated market outcomes is provided. By definition, the fully informed regulator scenario yields the highest social welfare level.

The model in section 2 is solved by backward induction in order to find a subgame perfect Nash equilibrium. In stage IV, viewers, indexed by y, maximize (2). Given that v is sufficiently high to ensure full participation, all viewers choose to watch free-to-air TV. In stage III, each firm x chooses ad quality such that the marginal revenue equals marginal cost, i.e. $(\omega - c)\,\partial D(x, q_x)/\partial q_x = \beta$, given that $\partial^2 D(x, q_x)/\partial q_x^2 < 0$ is satisfied by assumption. The defining condition of the private optimal ad quality underscores the driving forces that affect the decision of firm x to spend resources on advertising quality. First, the incentive to improve quality increases with cheaper technologies (lower β). Second, higher profit margins in the product market increase the return to persuasive ads and, thus, increase the incentive to invest in better ad quality. Third, firms with higher x will invest more if the informative and persuasion effects are complementary inputs, i.e. $\partial^2 D(x, q_x)/\partial q_x \partial x > 0$. Otherwise, if information and persuasion are substitute inputs, i.e. $\partial^2 D(x, q_x)/\partial q_x \partial x < 0$, firms will invest less.

In stage II, the TV platform maximizes profit. Hereafter, a variable with $*$ in superscript refers to the model in the unregulated market scenario, and FOC stands for first-order conditions. If the market is unregulated, the TV platform's problem is equivalent to

$$\max_{\hat{x}} \Pi_{TV}(\hat{x}) = f(\hat{x})\,\hat{x} - K$$
$$\text{FOC: } \frac{d\Pi_{TV}(\hat{x}^*)}{d\hat{x}} = 0 \Leftrightarrow f(\hat{x}^*) = -\frac{df(\hat{x}^*)}{d\hat{x}}\hat{x}^*. \tag{4}$$

If the market is regulated with a cap $\bar{x} < \hat{x}^*$, then the TV platform sets the advertising fee such that the marginal firm at $x = 1 - \bar{x}$ has zero profit: $f(\bar{x}) = (\omega - c)\,D\left(1 - \bar{x}, q^*_{1-\bar{x}}\right) - \beta q^*_{1-\bar{x}}$.

In stage I, the regulator maximizes social welfare. Hereafter, a variable with a bar on top refers to the model with a partially informed regulator who ignores ad quality effects on viewers. The partially informed regulator's problem is

$$\max_{\hat{x}} W(\hat{x}, \bar{q}^e) \equiv \int_0^1 U(\hat{x}, \bar{q}^e, y)\,dy + (\omega - c)\int_{1-\hat{x}}^1 D(x, q_x)\,dx - \beta \int_{1-\hat{x}}^1 q_x dx - K$$
$$\text{FOC: } \frac{\partial}{\partial \hat{x}}\left(\int_0^1 U(\bar{x}, \bar{q}^e, y)\,dy\right) + (\omega - c)\,D(1 - \bar{x}, q_{1-\bar{x}}) - \beta q_{1-\bar{x}} = 0 \Leftrightarrow f(\bar{x}) = \gamma(1 - \delta \bar{q}^e), \tag{5}$$

given that $\frac{\partial}{\partial \hat{x}}\left(\int_0^1 U(\bar{x}, \bar{q}^e, y)\,dy\right) = -\gamma(1 - \delta \bar{q}^e)$, and $(\omega - c)\,D(1 - \bar{x}, q_{1-\bar{x}}) - \beta q_{1-\bar{x}} = f(\bar{x})$ by the zero-profit condition for the marginal firm located at $x = 1 - \bar{x}$. Comparing

(4) versus (5) it is unclear which solution holds the highest level of advertising airtime.

Proposition 1 *If* $-\frac{df(\hat{x}^*)}{d\hat{x}}\hat{x}^* < (=)[>]\gamma(1-\delta\bar{q}^e)$*, then* $\hat{x}^* > (=)[<]\bar{x}$*.*

The term $-\frac{df(\hat{x}^*)}{d\hat{x}}\hat{x}^*$ represents the private opportunity cost (inframarginal revenue loss) for the TV platform to sell a marginal ad slot. The term $\gamma(1-\delta\bar{q}^e)$ represents the expectation of a partially informed regulator on the social opportunity cost of a marginal ad slot. Note that the private benefit and the social benefit of a marginal ad slot are the same, $f(\bar{x})$. This is due to the simplifying assumption that firms extract the full surplus in the product market which is then fully passed on to the TV platform by the marginal firm. Therefore, when the private opportunity cost of advertising is lower (higher) than the social opportunity cost, the privately optimal volume of ads is above (below) the social optimum.

Hereafter, a variable with a bar on top and o in superscript refers to the model with a fully informed regulator. A fully informed regulator is able to achieve the socially optimal advertising airtime, $\bar{x}^o$. The fully informed regulator's problem is

$$\max_{\hat{x}} W(\hat{x}, q(\hat{x})) \equiv \int_0^1 U(\hat{x}, q(\hat{x}), y)\, dy + (\omega - c)\int_{1-\hat{x}}^1 D(x, q_x)\, dx - \beta\int_{1-\hat{x}}^1 q_x dx - K$$

$$\text{FOC: } \frac{\partial}{\partial\hat{x}}\left(\int_0^1 U(\bar{x}^o, q(\bar{x}^o), y)\, dy\right) + \frac{\partial}{\partial q}\left(\int_0^1 U(\bar{x}^o, q(\bar{x}^o), y)\, dy\right)\frac{dq(\bar{x}^o)}{d\hat{x}} + f(\bar{x}^o) = 0$$

$$\Leftrightarrow f(\bar{x}^o) = \gamma(1 - \delta q(\bar{x}^o)) - \gamma\delta\bar{x}^o\frac{dq(\bar{x}^o)}{d\hat{x}}. \tag{6}$$

If the derivative with respect to $\hat{x}$ is strictly positive for any $\hat{x} \in [0,1]$, then the socially optimal solution entails $\bar{x}^o = 1$. Under such circumstances the regulator does not intervene because a cap cannot improve social welfare. In Proposition 2 below I consider how the substitution or complementarity between information and persuasion may affect the relation between advertising volume and advertising quality, as well as the relation between the socially optimal advertising volume and the advertising volume set by a partially informed regulator.

Proposition 2 *(i) If* $\frac{\partial^2 D(x,q_x)}{\partial q_x \partial x} \geq 0$ *and* $q(\bar{x}^o) \geq \bar{q}^e$*, then* $\frac{dq}{d\hat{x}} \leq 0$ *and is unclear whether* $\bar{x}^o$ *is higher or lower than* $\bar{x}$*. (ii) If* $\frac{\partial^2 D(x,q_x)}{\partial q_x \partial x} \geq 0$ *and* $q(\bar{x}^o) \leq \bar{q}^e$*, then* $\frac{dq}{d\hat{x}} \leq 0$ *and* $\bar{x}^o \leq \bar{x}$*. (iii) If* $\frac{\partial^2 D(x,q_x)}{\partial q_x \partial x} \leq 0$ *and* $q(\bar{x}^o) \geq \bar{q}^e$*, then* $\frac{dq}{d\hat{x}} \geq 0$ *and* $\bar{x}^o \geq \bar{x}$*. (iv) If* $\frac{\partial^2 D(x,q_x)}{\partial q_x \partial x} \leq 0$ *and* $q(\bar{x}^o) \leq \bar{q}^e$*, then* $\frac{dq}{d\hat{x}} \geq 0$ *and is unclear whether* $\bar{x}^o$ *is higher or lower than* $\bar{x}$*.*

If the informative and persuasive effects are complementary inputs in the demand for a product (i.e. $\partial^2 D(x, q_x)/\partial q_x \partial x \geq 0$), the marginal firm will exhibit lower ad quality compared to inframarginal firms with a higher informative effect. A tighter advertising cap confines ad slots to the firms with a higher informative effect, which are those with higher willingness to pay for an ad slot. Consequently, a tighter advertising cap will increase the average quality of ads. In such case, a partially informed regulator that underestimates the positive effect of a tighter cap on the average ad quality may set a cap above the social optimum. However, if the partially informed regulator expects a level of average ad quality "too low" (i.e. $q(\bar{x}^o) \geq \bar{q}^e$), it will overestimate the viewers' nuisance of watching TV ads. Therefore, the cap may be set below the social optimum. In Proposition 2 (i) it is unclear whether the partially informed regulator sets a cap above or below the social optimum level because it makes two offsetting errors. On the one hand, it underestimates the positive effect of a tighter cap on the average ad quality. On the other hand, it overestimates the viewers' nuisance of watching TV ads. In Proposition 2 (ii) the partially informed regulator sets a cap that is "too high" because it makes two errors that reinforce each other. First, it underestimates the positive effect of a tighter cap on the average ad quality. Second, it underestimates the viewers' nuisance of watching TV ads.

Analogously, if the informative and persuasive effects are substitute inputs (i.e. $\partial^2 D(x, q_x) / \partial q_x \partial x \leq 0$), a tighter advertising cap will decrease the average quality of ads. In Proposition 2 (iii) the partially informed regulator sets a cap that is "too low" because it makes two errors that reinforce each other. First, it underestimates the negative effect of a tighter cap on the average ad quality. Second, it overestimates the viewers' nuisance of watching TV ads. In Proposition 2 (iv) it is unclear whether the partially informed regulator sets a cap above or below the social optimum level because it makes two offsetting errors, but different from those in Proposition 2 (i). On the one hand, it underestimates the negative effect of a tighter cap on the average ad quality. On the other hand, it underestimates the viewers' nuisance of watching TV ads. In Proposition 3 below we consider the welfare effects of an advertising cap set by a partially informed regulator compared to the unregulated market.

Proposition 3 *Compared to the unregulated market, a partially informed regulator that does not take into account the effect of ad quality on viewers' welfare when regulating the market will: (i) decrease the TV platform's profit; (ii) decrease the firms' profits; and (iii) have an ambiguous impact both on the viewers' utility and on social welfare.*

The free-to-air TV platform is worse off through being constrained in advertising airtime given that the cap is binding by assumption. Note that this result depends on the TV platform being a monopolist. In a market with multiple competing platforms, a restriction on the supply of advertising slots could lead to an increase in the industry profit towards the monopoly outcome (Stühmeier and Wenzel, 2012).

Under an advertising cap a lower advertising fee does not expand the advertising airtime. As a result, a lower advertising cap will incentivize the TV platform to increase their advertising fees. From (3) it is clear that firms' profits are decreasing with respect to advertising fees. A lower advertising cap hurts firms' profits for two reasons. First, a set of firms will be unable to advertise their products as there are not enough advertising slots under a binding regulatory cap. Second, since a lower advertising cap incentivizes the TV platform to set higher advertising fees, the firms that benefit from an advertising slot will face higher costs.

Viewers' utility is decreasing in the volume of advertisements but increasing in the average advertising quality. It is, thus, difficult, without knowledge of the exact parameters of the model, to unambiguously rank the unregulated market and the partially informed regulator solution in terms of viewers' welfare. On the one hand, if viewer's valuation of average ad quality, δ, is negligible, then, the nuisance effect of ads airtime will dominate the ad quality effect, and viewers will be better off with an advertising cap $\bar{x} < \hat{x}^*$. On the other hand, if δ is sufficiently high, the ad quality effect dominates the nuisance effect of ads and viewers may be worse off with an advertising cap. Put differently, if δ is sufficiently high and information and persuasion are substitutes, a tighter cap may hurt viewers because this might entail a reduction of the average ad quality which may more than offset the direct benefit of a reduced nuisance from advertisements themselves.

The social effects of an advertising cap depend on both the advertising provision level and the average level of ad quality. In an extreme case, the introduction of an advertising cap may leave all the economic agents in the model worse off. This suggests that a regulator which is trying to increase welfare via restrictions on the advertising airtime should also take the effect of advertising quality on viewers' welfare into consideration. See Table A.1 in the Appendix for numerical simulations.

4 Discussion

This section discusses two of the assumptions used in the model and addresses the robustness of the main conclusions. First, the full coverage assumption for viewers. Second, the assumption that the firms' choices regarding advertising slots are binary.

4.1 Partial participation of viewers

I assumed that viewers were fully covered by the free-to-air TV platform. However, in reality, TV viewers have been gradually switching from free-to-air broadcasting to cable TV and on demand services such as Netflix and Amazon Prime Video. These and other substitutes to free-to-air broadcasting are implicitly considered in the outside option for viewers (with utility normalized to zero). The outside option only becomes active when viewers are partially covered by the free-to-air TV platform.

Under partial participation, we have the following model modifications. The mass of viewers on free-to-air TV is measured by $\hat{y}(\hat{x},q) = (v - \gamma\hat{x}(1-\delta q))/t < 1$. The firms' profit when advertising on the TV platform becomes $(\omega - c) D(x, q_x) \hat{y}(\hat{x},q) - \beta q_x - f$. The demand for ads on TV is, thus, defined by $f(\hat{x}) = (\omega - c) D(1-\hat{x}, q_{1-\hat{x}}) \hat{y}(\hat{x}, q(\hat{x})) - \beta q_{1-\hat{x}}$. A fully informed regulator maximizes $W(\hat{x},q) \equiv \int_0^{\hat{y}(\hat{x},q)} U(\hat{x},q,y)\, dy + \int_{1-\hat{x}}^{1} \Pi(x,q_x)\, dx + \Pi_{TV}(f)$.

The results set out in section 3 can be broadly extended to partially covered viewers. The expressions (4), (5) and (6) are adjusted to take into account that the mass of viewers varies with the volume of ads, but without changing qualitatively Proposition 1 and 2. Proposition 3 still applies to the free-to-air TV platform, viewers and social welfare. The firms excluded from advertising on TV post-cap will be worse off. However, the firms that still advertise post-cap may be worse off or better off. This is because with partial coverage there are two opposite welfare forces on firms. On the one hand, firms pay more for the ad slot, which also happens under full coverage. On the other hand, the mass of viewers may increase due to a lower advertising volume and an improved average ad quality.

4.2 Multiple ad slots per firm

I assumed that firms faced a binary choice regarding advertising slots: to buy, or not to buy. The model can be adapted to the more realistic case where firms can buy multiple ad slots. Consider that firms are homogeneous with respect to the effect of ads, and their profits are defined by

$$\Pi(n_x, q_x) \equiv \begin{cases} (\omega - c) D(n_x, q_x) - f n_x - \beta q_x & \text{if ads on TV} \\ 0 & \text{if no ad on TV} \end{cases},$$

where n_x is the number of ad slots purchased by a representative firm x. From the FOC of the profit maximization problem for firms and the implicit function theorem, $\frac{dq_x}{dn_x} = -\frac{\frac{\partial^2 \Pi(n_x,q_x)}{\partial q_x \partial n_x}}{\frac{\partial^2 \Pi(n_x,q_x)}{\partial q_x^2}}$, where $\frac{\partial^2 \Pi(n_x,q_x)}{\partial q_x^2} = (\omega - c) \frac{\partial^2 D(n_x,q_x)}{\partial q_x^2} < 0$ by assumption (concavity), and $\frac{\partial^2 \Pi(n_x,q_x)}{\partial q_x \partial n_x} = (\omega - c) \frac{\partial^2 D(n_x,q_x)}{\partial q_x \partial n_x}$. Thus, if ad quality and number of ad slots are complements (substitutes), $\frac{\partial^2 D(n_x,q_x)}{\partial q_x \partial n_x} > (<) 0$, that implies $\frac{dq_x}{dn_x} > (<) 0$, i.e. firms will decrease (increase) their ad quality when facing a tighter cap (lower n_x). The welfare results set out in Proposition 3 can qualitatively extend to multiple ad slots per firm.

5 Conclusions

This paper showed how the average ad quality broadcasted by a TV platform may be increasing or decreasing in the volume of ads. The relation between volume and quality of ads depends on the complementarity or substitutability between the informative and persuasion effects of ads, and between the volume of slots and ad quality. For example, when information and persuasion are substitute inputs in the demand for a product, the marginal product of ad quality is lower for firms with a higher informative effect. In such case, the marginal firm advertising on the TV platform exhibits higher ad quality compared to the inframarginal firms with a higher informative effect. Consequently, a TV platform selling more ad slots will broadcast higher ad quality on average. In such circumstances, an advertising cap may cause the average ad quality to decrease.

A tighter cap incentivizes the TV platform to set higher advertising fees, which will hurt firms' profits. However, insofar a tighter cap expands the TV audience, the firms that are not excluded from advertising on TV due to the cap may observe a boost in their sales. The effect on viewers' welfare is ambiguous because there might be an ad quality reduction resulting from a cap, which would offset the direct viewers' gain from watching fewer ads. When viewers are sufficiently sensitive to ad quality and the quality reduction outweighs the direct effect of the cap, a cap may even reduce the social welfare level. The results suggest that a regulator that is trying to increase welfare via an ad cap should take the impact on ad quality into consideration. Otherwise, a cap may result in lower social welfare than leaving advertising airtime unregulated.

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7 Appendix

7.1 Proofs

Proof of Proposition 1 The advertising fee per slot for any given volume of advertising $\hat{x}$ is defined by $f(\hat{x}) = (\omega - c) D\left(1-\hat{x}, q^*_{1-\hat{x}}\right) - \beta q^*_{1-\hat{x}}$. Thus,

$$\frac{df(\hat{x})}{d\hat{x}} = (\omega - c)\left(-\frac{\partial D\left(1-\hat{x}, q^*_{1-\hat{x}}\right)}{\partial x} + \frac{\partial D\left(1-\hat{x}, q^*_{1-\hat{x}}\right)}{\partial q_x}\frac{dq^*_{1-\hat{x}}}{d\hat{x}}\right) - \beta\frac{dq^*_{1-\hat{x}}}{d\hat{x}}$$
$$= -(\omega - c)\frac{\partial D\left(1-\hat{x}, q^*_{1-\hat{x}}\right)}{\partial x} < 0$$

by the FOC for ad quality in the firm's problem, and the assumptions that $\omega - c > 0$ and $\partial D(x, q_x)/\partial x > 0$. Since $f(\hat{x})$ is a downward sloping function, it is straightforward that the lower the intersection with $f(\hat{x})$, the higher the level of $\hat{x}$. Thus, if $-\frac{df(\hat{x}^*)}{d\hat{x}}\hat{x}^* < (=)[>]\gamma(1-\delta\bar{q}^e)$, then $\hat{x}^* > (=)[<]\bar{x}$ by (4) and (5). □

Proof of Proposition 2 (i) The privately optimal condition that determines q_x is defined by $\partial\Pi(x, q_x)/\partial q_x = 0$, given that $\partial^2\Pi(x, q_x)/\partial q_x^2 < 0$. By the implicit function theorem, $\frac{dq_x}{dx} = -\frac{\partial^2\Pi(x,q_x)/\partial q_x\partial x}{\partial^2\Pi(x,q_x)/\partial q_x^2} = -\frac{\partial^2 D(x,q_x)/\partial q_x\partial x}{\partial^2 D(x,q_x)/\partial q_x^2}$. Thus, the signal of $\frac{dq_x}{dx}$ is the same as the signal of the cross-derivative. If $\partial^2 D(x, q_x)/\partial q_x\partial x \geq 0$, then $dq_x/dx \geq 0$. Intuitively, the ad quality of the marginal firm x is lower than the ad quality of the inframarginal firms with higher x. Therefore, q is decreasing with the volume of ads, i.e. $dq(\hat{x})/d\hat{x} \leq 0$. If $dq(\hat{x})/d\hat{x} \leq 0$ and $q(\bar{x}^o) \geq \bar{q}^e$, it is unclear whether the right-hand side in (5) is higher or lower than the right-hand side in (6). Consequently, it is unclear whether $\bar{x}^o$ is higher or lower than $\bar{x}$.

(ii) As per (i) above, if $\partial^2 D(x, q_x)/\partial q_x\partial x \geq 0$, then $dq(\hat{x})/d\hat{x} \leq 0$. If $dq(\hat{x})/d\hat{x} \leq 0$ and $q(\bar{x}^o) \leq \bar{q}^e$, the right-hand side in (5) is lower than the right-hand side in (6). Since $f(\hat{x})$ is a downward sloping function (shown in the Proof of Proposition 1), thus $\bar{x}^o \leq \bar{x}$.

(iii) Following the reasoning in (i) above, if $\partial^2 D(x, q_x)/\partial q_x \partial x \leq 0$, then $dq(\hat{x})/d\hat{x} \geq 0$. If $dq(\hat{x})/d\hat{x} \geq 0$ and $q(\bar{x}^o) \geq \bar{q}^e$, the right-hand side in (5) is higher than the right-hand side in (6). Since $f(\hat{x})$ is a downward sloping function (shown in the Proof of Proposition 1), thus $\bar{x}^o \geq \bar{x}$.

(iv) As per (iii) above, if $\partial^2 D(x, q_x)/\partial q_x \partial x \leq 0$, then $dq(\hat{x})/d\hat{x} \geq 0$. If $dq(\hat{x})/d\hat{x} \geq 0$ and $q(\bar{x}^o) \leq \bar{q}^e$, it is unclear whether the right-hand side in (5) is higher or lower than the right-hand side in (6). Consequently, it is unclear whether $\bar{x}^o$ is higher or lower than $\bar{x}$. □

Proof of Proposition 3 (i) In the absence of regulation the TV platform chooses an advertising volume defined by (4), while a partially informed regulator chooses a cap according to (5). The Proof of Proposition 1 shows that, in general, the privately optimal and the partially informed regulator choices differ. By definition, compared to the unregulated market, a monopolist TV platform cannot increase the profit when faced with a regulatory cap.

(ii) Recall from the Proof of Proposition 1 that $df(\hat{x})/d\hat{x} < 0$. This means that a lower advertising cap will incentivize the TV platform to increase the advertising fee. From (3) it is clear that firms' profits are decreasing in advertising fees. Thus, a lower advertising cap will exclude some firms from advertising on TV while it decreases the profits of those that still advertise, due to the higher fee set by the TV platform.

(iii) The utility of a viewer y with a partially informed regulator is given by $U(\bar{x}, q(\bar{x}), y) = v - \gamma\bar{x}(1 - \delta q(\bar{x})) - ty$ if watching TV. Therefore,

$$\frac{dU(\bar{x}, q(\bar{x}), y)}{d\bar{x}} = -\gamma\left(1 - \delta q(\bar{x}) - \delta\bar{x}\frac{dq(\bar{x})}{d\bar{x}}\right).$$

Note that $dU(\bar{x}, q(\bar{x}), y)/d\bar{x} < 0$ if $\left(q(\bar{x}) + \bar{x}\frac{dq(\bar{x})}{d\bar{x}}\right)^{-1} > \delta$. Otherwise, the utility of viewers will increase with a less stringent advertising cap. Examples where a partially informed regulator increases or decreases the viewers' utility and social welfare, compared to the unregulated market, are provided in the numerical simulations in this appendix. □

7.2 Specialized model

This appendix sets out a specialized model intended to generate numerical simulations for illustration. I assume that information and persuasion are substitute inputs in the demand for a product. In particular, if a firm of type x invests in q_x units of ad quality, the demand for firm x's product when it advertises on TV will be given by $D(x, q_x) \equiv x + (1 - x)\sqrt{q_x}$. The term x corresponds to the informative role of advertising since all viewers learn about the existence and features of x's product upon watching the ad, while

$(1-x)\sqrt{q_x}$ captures the persuasive effect of advertising. Moreover, I assume that the cost of ad quality, β, is sufficiently high such that $\beta > \omega - c$ to guarantee that in equilibrium $\partial D(x, q_x^*)/\partial x > 0$, i.e. ad quality does not have an "explosive" effect on the demand. Despite that firms with a low x have further incentives to invest in ad quality, the demand faced by a firm with a low x will not be higher than the demand faced by a firm with a high x. In other words, ad quality will help firms to sell more (namely those with a low x), though, not to a point where a low x firm sells more than a firm with a higher x. A table with the results of numerical simulations based on this specialized model is presented further below under the heading "Numerical simulations".

Stage IV: viewers' choice

Given that v is sufficiently high to ensure full participation, all viewers choose to watch TV.

Stage III: firms' choice

The profit of firm x is defined as follows

$$\Pi(x, q_x) \equiv \begin{cases} (\omega - c)\left(x + (1-x)\sqrt{q_x}\right) - \beta q_x - f & \text{if ad on TV} \\ 0 & \text{if no ad on TV} \end{cases}.$$

If a firm x chooses to advertise on TV, then from the FOC for ad quality it sets

$$q_x^* = \left(\frac{(\omega - c)(1-x)}{2\beta}\right)^2.$$

Plugging q_x^* in firm x's profit, and then setting $\Pi(x, q_x^*) = 0$ (profit of the marginal firm located at $x = 1 - \hat{x}$), the firms' demand function for advertising slots on the TV platform is

$$\hat{x}(f) = 2\beta \frac{1 - \sqrt{\frac{1}{\beta}\left(\beta - (\omega - c) + f\right)}}{\omega - c}$$

insofar $0 \leq \hat{x} \leq 1$ is satisfied. The candidate solution $\hat{x}(f) = 2\beta \frac{1 + \sqrt{\frac{1}{\beta}(\beta - (\omega - c) + f)}}{\omega - c}$ is ruled out given that the assumption $\beta > \omega - c$ implies $\hat{x} > 1$.

Stage II: TV platform's choice

The TV platform's profit is $\Pi_{TV}(f) \equiv f\hat{x}(f) - K$. If advertising airtime is unregulated or subject to a non-binding cap, from the FOC of the TV platform's problem, $f^* = \frac{2}{3}(\omega - c) - \frac{4}{9}\beta + \frac{2}{9}\sqrt{\beta\left(4\beta - 3(\omega - c)\right)}$. Hence, $\hat{x}^* = 2\beta \frac{1 - \sqrt{\frac{1}{\beta}(\beta - (\omega - c) + f^*)}}{\omega - c}$. If advertising airtime is subject to a binding cap $\bar{x}$, then the TV platform sets $f(\bar{x}) = (\omega - c)(1 - \bar{x}) + \frac{1}{\beta}\left(\frac{(\omega - c)\bar{x}}{2}\right)^2$.

Stage I: Regulator's choice with partial information

The partially informed regulator solves $\max_{\hat{x}} W(\hat{x}, \bar{q}^e)$. I assume that, without loss of generality, $\bar{q}^e = q^*$, i.e. the regulator expects the average ad quality to remain at the unregulated equilibrium level. The cap $\bar{x}$ is set according to $dW(\hat{x}, \bar{q}^e)/d\hat{x} = 0$ if a solution is found in $0 \leq \hat{x} \leq 1$ and the welfare function is concave at that point. If $dW(\hat{x}, \bar{q}^e)/d\hat{x} > 0$ in $0 \leq \hat{x} \leq 1$ or the solution entails $\bar{x} > \hat{x}^*$, then the regulator leaves the market unregulated. If $dW(\hat{x}, \bar{q}^e)/d\hat{x} < 0$ in $0 \leq \hat{x} \leq 1$, then $\bar{x} = 0$.

Stage I revisited: Regulator's choice with full information

The fully informed regulator solves $\max_{\hat{x}} W(\hat{x}, q(\hat{x}))$. The cap $\bar{x}^o$ is set according to $dW(\hat{x}, q(\hat{x}))/d\hat{x} = 0$ if a solution is found in $0 \leq \hat{x} \leq 1$ and the welfare function is concave at that point. If $dW(\hat{x}, q(\hat{x}))/d\hat{x} > 0$ in $0 \leq \hat{x} \leq 1$ or the solution entails $\bar{x}^o > \hat{x}^*$, then the regulator leaves the market unregulated. If $dW(\hat{x}, q(\hat{x}))/d\hat{x} < 0$ in $0 \leq \hat{x} \leq 1$, then $\bar{x}^o = 0$.

7.3 Numerical simulations

Table A.1 below shows the results of numerical simulations based on the appendix "Specialized model" set out above.

Table A.1: Numerical simulations

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
v	500	500	500	500
γ	5	5	8.50	5
δ	40	2	5	1
ω	20	20	20	20
c	10	10	10	10
β	12	12	12	12
t	0.10	0.10	0.10	0.10
$\hat{x}^*$	62.02%	62.02%	62.02%	62.02%
$\bar{x}$	NA	59.64%	25.85%	58.16%
$\bar{x}^o$	NA	NA	18.10%	60.97%
q^*	2.23%	2.23%	2.23%	2.23%
$\bar{q}$	2.23%	2.06%	0.39%	1.96%
$\bar{q}^o$	2.23%	2.23%	0.19%	2.15%
U^*	499.61	496.99	495.27	496.92
$\bar{U}$	499.61	497.09	497.79	497.10
$\bar{U}^o$	499.61	496.99	498.43	496.97
$\Pi^*_{TV} + K$	2.85	2.85	2.85	2.85
$\bar{\Pi}_{TV} + K$	2.85	2.85	1.95	2.84
$\bar{\Pi}^o_{TV} + K$	2.85	2.85	1.49	2.85
W^*	504.05	501.43	499.71	501.36
$\bar{W}$	504.05	501.42	500.06	501.36
$\bar{W}^o$	504.05	501.43	500.08	501.36

Note: NA means that a cap is not applicable. All second-order conditions verified.