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On the regulation of public broadcasting

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Abstract
A hallmark of public broadcasting has been the long-standing restriction on commercial advertisements, a policy that is intended to benefit the viewers. Using a model with a public broadcaster competing against a private counterpart, we show that banning commercials on the public platform actually harms the viewers. In response to this policy, the public broadcaster invests less to improve program quality and raises the subscription fee, which causes the private broadcaster also to price higher. The private broadcaster chooses a higher quality and earns a higher profit but total social welfare is reduced relative to the case of unregulated public broadcasting.

Keywords Program quality · Advertising · Regulation · Two-sided market

JEL Classification L1 · L5 · L8 · H4

1 Introduction

Despite a long tradition of being commercial free, public broadcasters in many countries have moved towards a more market oriented business model as they rely on both public funding and advertising revenue. Nonetheless, the debate remains as to

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whether commercial advertisements should be allowed. As the first stage of a plan to end all advertising on state-owned broadcasters, the French government has since 2009 banned prime-time ads on France Televisions. This policy was intended, as President Nicolas Sarkozy argued, "to give France Televisions the means of offering quality programs to as many viewers as possible."[1]

In this paper, we analyze the effect of banning advertisements on a public media platform—which competes with another platform that is privately owned—on program quality and the viewers' welfare. Building upon Anderson and Coate (2005) but with endogenous quality of programs, we find that the quality of the public program is lowered and the viewers are made strictly worse off by such a policy. With a reduced incentive to improve quality when advertisements are removed, the welfare-maximizing public platform raises its subscription fee so as to shift viewers to the private platform. This causes the latter also to price higher, leading to reduced viewer surplus.

The robustness of the results is examined in two variants of the baseline model. In the first, the private broadcaster does not air commercials.[2] In the second, instead of being a social-welfare maximizer, the public broadcaster takes into account only its own profit plus the welfare of the viewers. Our results remain unchanged, including that such a policy reduces the quality of the public broadcaster's program, causes both broadcasters to raise the subscription fee and harms the viewer and total social welfare.

Since the founding of the British Broadcasting Corporation (BBC) in the 1920s, public broadcasting services have been provided in many countries, with a long tradition of being commercial free. In recent decades many public broadcasters have turned into a mixed business model as they also use commercial advertisements as a source of revenue.[3] However, the concern is still present about whether carrying advertisements harms the welfare of the viewers and thus contradicts the objective of public broadcasting. Indeed, some public broadcasters, including notably the BBC in the United Kingdom and the NHK in Japan, remain commercial free, while some, which used to carry advertisements, are making a turn around.[4]

A number of papers have theoretically investigated the implications of advertising regulations but without considering the quality decisions of the platforms.[5] Stühmeier and Wenzel (2012) evaluate the effects of symmetric and asymmetric regulation of ad levels on firm profits in a mixed duopoly. Rothbauer and Sieg (2014) consider the horizontal differentiation of program content and examine the welfare

[1] See https://www.campaignlive.co.uk/article/sarkozy-ends-advertising-french-public-service-tv/822948.

[2] One notable example is HBO, an American TV network that has produced popular series such as Game of Thrones.

[3] As Hoynes (2003) notes, the Public Broadcasting Service (PBS) system in the United States began such a shift in the mid-1990s.

[4] Besides France, the Spanish government also banned commercials during movies and other programming on public broadcasters in 2010 (https://www.hollywoodreporter.com/news/european-public-broadcasters-crisis-spain-580528). In the Netherlands, there is a new rule that ads will be removed on the public broadcasters by 8 p.m. and the websites of the broadcasters will also go completely ad-free (https://nltimes.nl/2019/06/05/dutch-public-broadcasters-go-mostly-ad-free-new-rules).

[5] Filistrucchi (2012) empirically investigates the effect of the 2009 French advertising ban on the behavior of advertisers and viewers. Based on a dataset of 12 major TV broadcasters in France, Zhang (2018) estimates the impact of ad regulation on viewers and advertisers with exogenous program quality.

effects of commercial ceilings in a free-to-air TV market. Also in a private duopoly, Kerkhof and Münster (2015) study the welfare effect of a cap on advertising in the presence of commercial media bias and find that the cap can be welfare enhancing even when viewers are ad neutral. In a model with (exogenous) vertical differentiation of content, Greiner and Sahm (2018) show that an advertising ban on the high quality medium, which is profit maximizing, reduces welfare. Henriques (2021) notes the importance of the effect of limiting advertising airtime on advertising quality and finds that regulation based on partial information may result in reduced viewer and social welfare.[6]

Media platforms often invest to improve their program quality. In a private duopoly, Lin (2011) compares the market provision of program quality with pay-TV or free-to-air broadcasting or a mixed case with one broadcaster fee-based and the other free. Li and Zhang (2016) find that a pay-TV regime always generates inadequate quality and advertising, whereas free-to-air might produce excessive quality and advertising compared with the social optimum. Battaggion and Drufuca (2020) analyze the impact of entry on quality differentiation in the media market. When one of the broadcasters is public, Armstrong and Weeds (2007) examine the quality choices in a differentiated duopoly similar to ours and find that viewer welfare can be raised compared with the case of both private broadcasters. With exogenous quality and a focus on free-to-air broadcasting, González-Maestre and Martínez-Sánchez (2014) also compare private and mixed duopoly competition, and show the importance of the connection between program quality and advertising incentives. Considering the endogenous choice of platform quality, González-Maestre and Martínez-Sánchez (2015) find that social welfare may or may not be higher with a welfare maximizing public broadcaster. More related to what we do here, they find a commitment of zero advertising by the public broadcaster has an ambiguous effect on social welfare.

This paper has several major differences. First, we focus on pay-TV or subscription-based broadcasters.[7] Second, in modeling the two-sided advertising market we follow Anderson and Coate (2005) and assume that the demand for advertisements is downward sloping, whereas in González-Maestre and Martínez-Sánchez (2015) the price is constant. Third, we are most interested in the policy implication regarding viewer welfare although results on total social welfare are also derived. Finally, we vary the public broadcaster's objective and allow the possibility of zero advertising by the private broadcaster and find consistent welfare implications of the ad ban.

This paper also adds to the literature on innovations in mixed oligopoly markets by incorporating the strategy of advertising. In a setup similar to ours but without advertising, Matsumura and Matsushima (2004) show that, the private firm always

[6] Liu et al. (2021) also consider that advertisers can invest in ad quality and they find that the existence of such strategic agents increase the degree of platform asymmetry and may raise or lower platforms' incentive to invest in content quality.

[7] For example, in Canada, CBC News Network collects subscriber fees. In the UK, BBC launched streaming service BritBox in 2019 to compete with Netflix. New programs are made specifically to Britbox, and a monthly subscription fee is charged to the viewers (https://www.bbc.com/news/entertainment-arts-49037855). In the US, access to premium programs is provided to PBS Passport members who, like paying a fee, donate a certain amount to their local stations (https://help.pbs.org/support/solutions/articles/12000043556-what-is-pbs-passport-).

has a stronger incentive to innovate than the public firm in order to obtain a larger market share. However, with two-sided market and the additional strategy of advertising, we find that the result can be reversed as the public broadcaster may choose a higher quality of program. Nonetheless, banning advertisements on its program reduces the public firm's incentive to improve quality and leads to, again, the private firm choosing a higher level of innovation.

The rest of the paper is organized as follows. In Sect. 2, we set up the model and analyze and compare the market outcomes under the two cases, with or without a ban on advertising by the public broadcaster. Section 3 examines the robustness of the results and Sect. 4 concludes the paper.

2 The model

There are two media platforms or broadcasters, a public broadcaster called 1 and a private broadcaster called 2. They each carry a program that is horizontally differentiated from each other. To characterize this, we assume that the viewers of the programs, their mass normalized to one, are uniformly distributed along the Hotelling line $[0, 1]$ and the platforms are located at the two ends of it. Denote the location of platform i, $i = 1, 2$ as y_i, and we have $y_1 = 0$ and $y_2 = 1$.

Each viewer chooses one of the programs to watch,[8] and advertisements, as they reduce the time allocated to program content, generate a disutility.[9] Unlike Anderson and Coate (2005), we assume that a platform can invest to improve the quality of its program, which raises a viewer's utility from watching the program. Specifically, a viewer located at $x \in [0, 1]$ derives a utility of

$$u_i(x) = V + v_i - s_i - \gamma a_i - t|x - y_i|$$

by watching platform i's program. In the utility function, $V > 0$ is the viewer's reservation utility, $v_i \geq 0$ is the quality level of platform i's program and s_i is the subscription fee charged by i. The fourth component measures the reduction in utility (with the nuisance cost parameter $\gamma > 0$) associated with $a_i \geq 0$ advertisements carried by the program, and the last component is the disutility from not watching the viewer's most ideal program.[10] The parameter t characterizes the level of program differentiation in the market.

Given v_i, s_i and a_i, the marginal viewer who is indifferent between the programs of broadcasters 1 and 2 is at

[8] We have followed the setup of Anderson and Coate (2005) and Crampes et al. (2009), among others, to assume that the viewers must choose between the two programs. This single-homing assumption is particularly reasonable at a given instant of time. However, for a longer period, viewers can mix (multi-homing), when the programs are differentiated enough. If viewers are multi-homing, our results are robust. The proof follows directly from the approach of Anderson and Neven (1989), which has been applied to media markets by Gal-Or and Dukes (2003), Gabszewicz et al. (2004), Hoernig and Valletti (2007). See Peitz and Valletti (2008) for detailed discussions.

[9] Our model is valid even if the viewers like advertisements, as long as they prefer the substantive content of the program.

[10] The results are robust if we instead use a quadratic form of disutility.

$$\hat{x} = \frac{t + (v_1 - v_2) - (s_1 - s_2) - \gamma(a_1 - a_2)}{2t}.$$

So the viewers' demand for the two programs are respectively $D_1 = \hat{x}$ and $D_2 = 1 - \hat{x}$.

Advertisements are placed by sellers of consumer goods who wish to reach the viewers. Following Anderson and Coate (2005) and others, we denote the inverse demand for platform i's per-viewer advertising as $p(a_i)$ with $p'(a_i) < 0$, and assume that $p''(a_i)a_i + 2p'(a_i) < 0$ to ensure the existence of a unique equilibrium. The per-viewer advertising revenue received by platform i is then $R(a_i) = p(a_i)a_i$ and the per-viewer surplus earned by the advertisers is $\int_0^{a_i} [p(a) - p(a_i)]da$. Moreover, we denote $\theta_i \equiv \int_0^{a_i} p(a)da - \gamma a_i$ which is the *per-viewer welfare gain* when the advertising level on platform i is a_i.

Besides the choices of advertisements and subscription fees, the platforms exert effort, for example by hiring better directors, writers, actors and other production inputs, to improve the quality of their programs. The cost of achieving a quality level of v_i is $f(v_i)$ which is strictly increasing and convex. Also, for both platforms, the marginal cost of serving an additional viewer is constant and normalized to zero.

With the above setup, we can write the platforms' profits, the viewer surplus, and total social welfare as, respectively,

$$\pi_i = D_i[R(a_i) + s_i] - f(v_i) \text{ for } i = 1, 2,$$

$$CS = \int_0^{D_1} (V + v_1 - s_1 - \gamma a_1 - tx)dx + \int_{D_1}^1 (V + v_2 - s_2 - \gamma a_2 - t(1 - x))dx, \text{ and}$$

$$W = \sum\nolimits_i \pi_i + CS + \sum\nolimits_i D_i \int_0^{a_i} [p(a) - p(a_i)]da.$$

In reality, a public broadcaster usually also receives government funding, which we treat as exogenous. While the private broadcaster maximizes its profit, the public broadcaster is a social welfare maximizer. This assumption follows closely the literature on mixed oligopoly (e.g., Cremer et al. 1991; Matsumura and Matsushima 2004) and the robustness of our results are checked when the public broadcaster cares only about viewer surplus and its own profit.

The timing of the game is as follows. In the first stage, the broadcasters each chooses how much to invest to improve the program quality. In the second stage, they simultaneously determine their subscription fee s_i charged to each viewer and set the advertising level a_i. If advertising on the public platform is banned, then $a_1 = 0$. In the third stage, the viewers choose to subscribe to one of the broadcasters.

We will analyze and compare two cases, with the public broadcaster allowed or disallowed to air commercial advertisements. To denote the equilibrium outcomes, the superscript *YY* will be used for the first case (meaning that both platform 1 and 2 are allowed to advertise) whereas the superscript *NY* will be used for the second case (meaning that platform 1 is not allowed while platform 2 is).

In the first case, given the quality levels of the two broadcasters, v_1 and v_2, broadcaster 1's optimal choices of subscription fee, s_1, and advertisement level, a_1, are characterized by the following first-order conditions:

$$\frac{\partial W}{\partial s_1} = \left[s_1 - s_2 + \int_{a_2}^{a_1} p(x)dx\right]\frac{\partial D_1}{\partial s_1} = 0, \text{ and} \tag{1}$$

$$\frac{\partial W}{\partial a_1} = \left[s_1 - s_2 + \int_{a_2}^{a_1} p(x)dx\right]\frac{\partial D_1}{\partial a_1} + [p(a_1) - \gamma] \cdot D_1 = 0. \tag{2}$$

Since $\partial D_1/\partial a_1 = \gamma \partial D_1/\partial s_1$, (1) and (2) imply that

$$p(a_1^*) - \gamma = 0. \tag{3}$$

To maximize social welfare, the public broadcaster chooses the level of advertising such that the marginal social benefit, measured by $p(\cdot)$, equals the marginal social cost, γ. It is easy to show that $\partial a_1^*/\partial \gamma < 0$. The public broadcaster carries fewer advertisements as the nuisance cost of the viewers caused by ads increases.

For the private platform, in order to maximize profit, it chooses s_2 and a_2 that satisfy

$$\frac{\partial \pi_2}{\partial s_2} = \frac{\partial D_2}{\partial s_2}[R(a_2) + s_2] + D_2 = 0, \text{ and} \tag{4}$$

$$\frac{\partial \pi_2}{\partial a_2} = \frac{\partial D_2}{\partial a_2}[R(a_2) + s_2] + D_2 R'(a_2) = 0, \tag{5}$$

which imply that

$$R'(a_2^*) - \gamma = 0. \tag{6}$$

The private broadcaster chooses the advertising level such that its marginal revenue per viewer equals the marginal cost of advertising to each viewer.[11] An additional advertisement causes a viewer's utility to decrease by γ and to retain the same number of viewers it has to cut the subscription fee by γ. This condition conforms with the notion of Armstrong (2006) that a private platform maximizes the joint surplus of the platform and its consumers. Peitz and Valletti (2008) derive this condition in a model with competing private platforms. With $\partial a_2^*/\partial \gamma < 0$, broadcaster 2's optimal advertising level also decreases with γ.

Two observations are worth noting from the above analysis. First, a broadcaster's optimal advertising level depends on the advertisers' demand and the viewers' nuisance cost, but not on the program quality, the subscription fee, or its rival's advertising choice. Second, as price lies above marginal revenue, (3) and (6) imply

[11] Conditions (3) and (6) are consistent although for the public broadcaster, the marginal benefit includes also the surplus earned by the advertisers.

that the public broadcaster advertises more than the private broadcaster, $a_1^* > a_2^*$, as a higher marginal benefit of advertising is derived by the former.

For expositional purposes, we will defer the importation of the optimal values of advertisements in the subsequent derivations, which apply also to the second case with zero public advertising. Combining (1) and (4) we can write the subscription fees as

$$s_1 = t - v_1 + v_2 - 2\int_0^{a_1} p(x)dx + \gamma a_1 + 2\int_0^{a_2} p(x)dx - \gamma a_2 - R(a_2), \text{ and} \quad (7)$$

$$s_2 = t - v_1 + v_2 - \int_0^{a_1} p(x)dx + \gamma a_1 + \int_0^{a_2} p(x)dx - \gamma a_2 - R(a_2). \quad (8)$$

A higher quality of the public program causes both broadcasters to charge lower fees, and a higher quality of the private program causes both broadcasters to charge higher fees. The intuition is as follows. First, with a higher quality the public broadcaster wants to encourage viewers to subscribe to its program through a lower subscription fee. To compete with the public broadcaster, the private broadcaster also prices lower. On the other hand, a higher quality of its program enables the private broadcaster to charge higher fees. The public broadcaster, which maximizes social welfare, sets higher fees so as to shift viewers to the higher-quality private program.

Using the above expressions, we can write the social welfare, which is also the public broadcaster's objective function, as

$$W = V - \frac{t}{4} + \frac{(v_1 - v_2 + \theta_1 - \theta_2)^2 + 2t(v_1 + v_2 + \theta_1 + \theta_2)}{4t} - f(v_1) - f(v_2),$$

and the private broadcaster's profit as

$$\pi_2 = \frac{(t - v_1 + v_2 - \theta_1 + \theta_2)^2}{2t} - f(v_2).$$

The first order conditions with respect to their choices of program quality are

$$\frac{\partial W}{\partial v_1} = \frac{t + v_1 - v_2 + \theta_1 - \theta_2}{2t} - f'(v_1) = 0, \text{ and} \quad (9)$$

$$\frac{\partial \pi_2}{\partial v_2} = \frac{t - v_1 + v_2 - \theta_1 + \theta_2}{t} - f'(v_2) = 0. \quad (10)$$

It is easy to see that the choices of program quality are strategic substitutes with one's higher quality leading to the rival's decreased incentive to improve program quality.

Let $\theta_i^* \equiv \int_0^{a_i^*} p(a)da - \gamma a_i^*$ denote the per-viewer welfare gain when the advertising level on platform i is at its optimal level. Lemma 1 shows that the condition $f'' > 2/(t - \theta_1^*)$, which we assume, ensures the existence and uniqueness of the equilibrium. (All proofs are in the "Appendix".)

Lemma 1 *For any $\theta_1 \in [0, \theta_1^*]$ and $\theta_2 \in [0, \theta_2^*]$, there exists a unique equilibrium, denoted $(v_1(\theta_1, \theta_2), v_2(\theta_1, \theta_2))$, in the quality choice stage. Moreover, $\partial v_i(\theta_1, \theta_2)/\partial \theta_i > 0$ and $\partial v_j(\theta_1, \theta_2)/\partial \theta_i < 0$ for $i \neq j \in \{1, 2\}$.*

The comparative statics could be understood as follows. The quality of the public program, v_1, increases as the per-viewer social surplus derived from its advertisements, θ_1, increases; and decreases as surplus derived from the private broadcaster's advertisements, θ_2, increases. With a higher θ_1, the public broadcaster has more incentive to improve program quality so that it can carry more commercials and attract more viewers. Conversely, with a higher θ_2, the public broadcaster cuts its quality investment to push viewers to choose the private program, which enables the private broadcaster to place more commercials, creating a higher welfare gain.

Conversely, the quality of the private program, v_2, increase in θ_2 and decreases in θ_1. An increase in θ_1 induces the public broadcaster to lower its subscription fee, which makes the private program less attractive, and in turn reduces the private broadcaster's incentive to improve program quality. Conversely, an increase in θ_2 induces the public broadcaster to raise its subscription fee, which makes the private program more attractive and encourages the private broadcaster to innovate.

With uniqueness of the equilibrium, we can then write the equilibrium quality levels as $v_1^{YY} = v_1(\theta_1^*, \theta_2^*)$ and $v_2^{YY} = v_2(\theta_1^*, \theta_2^*)$. The following lemma compares the two broadcasters' quality, subscription fee and demand.

Lemma 2 *When the public broadcaster is allowed to carry advertisements, (i) $v_1^{YY} > v_2^{YY}$ if $t < 3(\theta_1^* - \theta_2^*)$ and $v_1^{YY} \leq v_2^{YY}$ otherwise; (ii) $s_1^{YY} < s_2^{YY}$; and (iii) $D_1^{YY} > D_2^{YY}$ if $\theta_1^* - \theta_2^* > \frac{1}{2f''(\cdot)}$ and $D_1^{YY} \leq D_2^{YY}$ otherwise.*

In a one-sided market, Matsumura and Matsushima (2004) show that the private firm always has a stronger incentive to innovate than the public firm, in order to gain a larger market share. Here with the additional strategy of advertising, the incentive for quality investment may be reversed. As was discussed, the public broadcaster's advertising creates a higher benefit (the welfare gain) than its private counterpart's (the profit gain), resulting in a stronger incentive to improve program quality in order to advertise more. When t, the parameter that characterizes the level of program differentiation in the market, is relatively small ($t < 3(\theta_1^* - \theta_2^*)$), this second effect dominates and causes the public broadcaster to spend more on quality improvement.[12] In addition, the public broadcaster charges a lower subscription fee and has more viewers in equilibrium than the private broadcaster unless the difference between the two ad levels is sufficiently small ($\theta_1^* - \theta_2^* < 1/(2f'')$).

We move next to the second case with the public broadcaster banned from carrying advertisements. That is, now we have $a_1 = 0$ and $\theta_1 = 0$. Except for these restrictions, all the derivations are identical to the first case. Specifically, the optimal level of advertisements chosen by the private broadcaster is still a_2^*, as implicitly defined by (6), and the subscription fees are given by (7) and (8). The optimal

[12] Specifically, a lower degree of differentiation increases the viewers' incentive to shift to the low-advertising private platform, which causes the public platform, to retain the viewers, to invest more in program quality.

qualities, which are denoted $v_1^{NY} = v_1(0, \theta_2^*)$ and $v_2^{NY} = v_2(0, \theta_2^*)$, are by (9) and (10). Similarly, we compare the quality of the program, the subscription fee and the number of viewers of the two broadcasters.

Lemma 3 *When the public broadcaster is not allowed to carry advertisements, (i) $v_1^{NY} < v_2^{NY}$; (ii) $s_1^{NY} > s_2^{NY}$; and (iii) $D_1^{NY} < D_2^{NY}$.*

In this case, the private broadcaster chooses a higher quality of program than the public broadcaster. When it is the sole platform to carry commercials, the private broadcaster's incentive to improve program quality is even larger, compared with that in the model of Matsumura and Matsushima (2004). And to encourage the viewers to subscribe to the higher-quality program, the public broadcaster charges a higher subscription fee and has fewer viewers in equilibrium.

Having solved the market outcomes in the two cases, we can now make a comparison and identify the implications of banning advertisements on the public platform. Our first result compares the equilibrium quality levels.

Proposition 1 *Banning advertisements on the public platform causes the public broadcaster to choose a lower quality of its program and the private broadcaster to choose a higher quality of its program. That is, $v_1^{NY} < v_1^{YY}$ and $v_2^{NY} > v_2^{YY}$.*

These comparisons are implied by Lemma 1 and the intuition also carries over. Without the social benefit of advertising, i.e., the excess of providing the viewers with product information over the nuisance cost, the public broadcaster chooses a lower quality of its program to push viewers to the private broadcaster which still carries ads. This increases the incentive for the private broadcaster to improve program quality and, with strategic substitutability, a higher quality level is chosen.

Next we compare the equilibrium subscription fees.

Proposition 2 *Banning advertisements on the public platform causes both broadcasters to charge a higher subscription fee. That is, $s_1^{NY} > s_1^{YY}$ and $s_2^{NY} > s_2^{YY}$.*

Under the ad ban, the public broadcaster invests less in program quality and, as a social welfare maximizer, it charges a higher subscription fee to induce viewers to choose the private program. As has been discussed, the private program is of higher quality with the ad ban on the public platform than without. This causes the private broadcaster also to price higher. Thus to the viewers, although they watch fewer advertisements and enjoy more content, the benefit has to be weighed against the higher fees that they have to pay.

To compare viewer surplus and total social welfare, we write them as functions of θ_1 and θ_2. Specifically, for any $\theta_1 \in [0, \theta_1^*]$ and $\theta_2 \in [0, \theta_1^*]$, we write

$$CS(\theta_1, \theta_2) = V + \frac{2t(3v_1 - v_2 + 3\theta_1 - 3\theta_2) + (v_1 - v_2 + \theta_1 - \theta_2)^2 - 5t^2}{4t} - \gamma a_2(\theta_2) + R(a_2(\theta_2)), \quad (11)$$

where $a_2(\theta_2)$ is the inverse function of $\theta_2(a_2)$, and

$$W(\theta_1,\theta_2) = V + \frac{(v_1 - v_2 + \theta_1 - \theta_2)^2 + 2t(v_1 + v_2 + \theta_1 + \theta_2) - t^2}{4t} - f(v_1) - f(v_2). \tag{12}$$

Using the same superscripts to denote the two cases, $CS^{YY} \equiv CS(\theta_1^*, \theta_2^*)$, $W^{YY} \equiv W(\theta_1^*, \theta_2^*)$, $CS^{NY} \equiv CS(0, \theta_2^*)$, and $W^{NY} \equiv W(0, \theta_2^*)$, the following proposition shows that banning advertisements has unwanted welfare implications.

Proposition 3 *Banning advertisements on the public platform causes both the viewer surplus and total social welfare to decrease. That is,* $CS^{NY} < CS^{YY}$ *and* $W^{NY} < W^{YY}$.

It could also be calculated that $\pi_2^{NY} > \pi_2^{YY}$, so the only party that benefits from this policy is the private broadcaster. Our analysis thus demonstrates that, contrary to what policy makers may have believed, prohibiting advertisements on the public platform actually harms the viewers. While it does reduce the nuisance cost of the viewers by increasing the substantive content of the program, it discourages the public broadcaster from exerting effort to improve program quality. Although the private broadcaster reacts by choosing a higher quality level, the lower-quality program of the public broadcaster has a larger impact as its decisions take into account the viewers' welfare. It charges a higher subscription fee to shift viewers to the private broadcaster, which causes the latter also to charge a higher fee. The viewers are made worse off as a result.

3 Robustness of the results

Our previous analysis has rested on a couple of assumptions. First, the private broadcaster carries commercials. It is possible that the private broadcaster, like HBO, chooses not to advertise. Second, consistent with mixed duopoly models in the literature, the public platform maximizes social welfare which includes the profit of its rival and the profit of the advertisers. It may also be reasonable to assume that it only cares about its own profit and the viewer surplus. In this section, we conduct robustness checks of our results in these alternative setups.

3.1 The private broadcaster does not advertise

When the private broadcaster does not advertise, we again compare two cases, with or without the policy ban on public advertising. The analysis is similar to what we have done in Sect. 2, with the only difference being that now we have $a_2 = 0$ and $\theta_2 = 0$. Using superscripts *YN* and *NN* to denote the two cases, we can write the equilibrium qualities as $v_1^{YN} \equiv v_1(\theta_1^*, 0)$ and $v_2^{NN} \equiv v_2(0, 0)$ with the functions defined as before, by (9) and (10). The viewer surplus and total social welfare in the two cases are $CS^{YN} \equiv CS(\theta_1^*, 0)$, $W^{YN} \equiv W(\theta_1^*, 0)$, $CS^{NN} \equiv CS(0, 0)$, and $W^{NN} \equiv W(0, 0)$ respectively, with the functions defined correspondingly by (11) and (12). We summarize the comparison of the two cases in Proposition 4.

Proposition 4 *When the private broadcaster does not carry advertisements, banning advertisements on the public platform causes (i) the public broadcaster to choose a lower quality and the private broadcaster to choose a higher quality, i.e.,* $v_1^{NN} < v_1^{YN}$ *and* $v_2^{NN} > v_2^{YN}$*; (ii) both broadcasters to charge a higher subscription fee, i.e.,* $s_1^{NN} > s_1^{YN}$ *and* $s_2^{NN} > s_2^{YN}$*; and (iii) causes both the viewer surplus and social welfare to decrease, i.e.,* $CS^{NN} < CS^{YN}$ *and* $W^{NN} < W^{YN}$*.*

The main results are all consistent with those in our basic model and the intuition is similar. Not airing advertisements reduces the public broadcaster's incentive, and increases the private broadcaster's, to invest in program quality.[13] The public broadcaster sets a higher subscription fee to motivate the viewers to choose the private program, which allows the private broadcaster also to set a higher fee. These higher subscription fees dominate the effect of the ad ban on viewers and social welfare.

3.2 The public broadcaster cares only about viewer surplus and own profit

While we have followed the literature on mixed oligopoly by assuming that the public broadcaster maximizes social welfare, it is plausible that it cares only about its own profit and the viewer surplus. For tractability, we assume that the cost of quality improvement is quadratic with $f(v_i) = \eta v_i^2/2$. Moreover, we normalize t to 1 to simplify notation. To satisfy the second order conditions, we need $\eta > 1/(1-\rho^*)$ where $\rho^* = R(a_2^*) - \gamma a_2^*$. Adding letter c to the superscripts to indicate that this new setup has a focus on consumers (the viewers), we have:

Proposition 5 *When the public broadcaster maximizes its own profit plus viewer surplus, banning advertisements on the public platform causes (i) the public broadcaster to choose a lower quality and the private broadcaster to choose a higher quality, i.e.,* $v_1^{cNY} < v_1^{cYY}$ *and* $v_2^{cNY} > v_2^{cYY}$*; (ii) both broadcasters to charge a higher subscription fee, i.e.,* $s_1^{cNY} > s_1^{cYY}$ *and* $s_2^{cNY} > s_2^{cYY}$*; and (iii) both the viewer surplus and social welfare to decrease, i.e.,* $CS^{cNY} < CS^{cYY}$ *and* $W^{cNY} < W^{cYY}$*.*

Consequently, all of the results derived in the baseline model are still robust, including that banning advertisements on the public platform harms both viewer and total welfare. Although not all of the social benefit of advertising enters the public broadcaster's objective, it still has a gain of $R(a_1^*) - \gamma a_1^*$ from advertising. Removing this gain lowers the public broadcaster's incentive to improve program quality and causes it to charge a higher subscription fee, leading to welfare effects that are similar to those in the baseline model.

[13] Compared with the baseline model, although the private broadcaster does not carry ads, the public broadcaster's incentive to improve program quality (and attract more viewers) is still reduced without the social benefit of advertising.

4 Conclusion

While a policy to remove advertisements from public media platforms is usually thought to improve program quality and benefit the viewers, we find the exact opposite. Not airing commercials reduces the public broadcaster's incentive to improve program quality and it sets a higher subscription fee so as to encourage some of its viewers to switch to the private program, which is of higher quality. This enables the private broadcaster also to charge a higher subscription fee, making the viewers worse off despite the improved quality of the private program. Total social welfare is decreased as well.

Critical to our analysis in this paper are the incentive to invest in program quality and the associated price effect when the public broadcaster chooses to invest less under the advertising ban. We thus identify an overlooked channel through which a well-intended policy can have bad consequences, and shed some light on the ongoing debate on the regulation of public broadcasting.

Appendix

A1: Proof of Lemma 1

Equations (9) and (10) imply that

$$v_2 = t + v_1 + \theta_1 - \theta_2 - 2tf'(v_1) \equiv F(v_1) \text{ and} \tag{13}$$

$$v_1 = t + v_2 - \theta_1 + \theta_2 - tf'(v_2) \equiv H(v_2). \tag{14}$$

To complete the proof, we need to show that v_1 and v_2 are respectively determined by $K_1(x) \equiv x - H(F(x)) = 0$ and $K_2(x) \equiv x - F(H(x)) = 0$. By $f''(\cdot) > \frac{2}{t-\theta_1^*} > \frac{2}{t}$, we have

$$K_1'(x) = 1 - H'(F(x))F'(x) = 1 - (1 - tf''(F(x))) \cdot (1 - 2tf''(x)) < 0 \text{ and}$$

$K_2'(x) = 1 - F'(H(x))H'(x) = 1 - (1 - 2tf''(H(x))) \cdot (1 - tf''(x)) < 0.$ Therefore $K_1(x)$ and $K_2(x)$ are strictly decreasing functions.

If $0 \leq \theta_1 \leq \theta_1^*$, $0 \leq \theta_2 \leq \theta_2^*$, and $t > \theta_1^*$, $f'(0) = 0$ implies that

$$F(0) = t + \theta_1 - \theta_2 > 0 \text{ and } H(0) = t - \theta_1 + \theta_2 > 0.$$

Using Mean Value Theorem and $f''(\cdot) > \frac{2}{t-\theta_1^*}$ we obtain

$$\begin{aligned} \frac{F(H(0))}{2t} &= 1 - f'(H(0)) = 1 - f''(\xi_1)H(0) < 1 - \frac{2H(0)}{t - \theta_1^*} \\ &= \frac{2\theta_1 - \theta_1^* - t - 2\theta_2}{t - \theta_1^*} < 0, \end{aligned}$$

$$\frac{H(F(0))}{t} = 2 - f'(F(0)) = 2 - f''(\xi_2)F(0) < 2 - \frac{2F(0)}{t - \theta_1^*} = \frac{2(\theta_2 - \theta_1^* - \theta_1)}{t - \theta_1^*} < 0,$$

where $\xi_1 \in (0, H(0))$ and $\xi_2 \in (0, F(0))$. Furthermore, $K_1(0) = -H(F(0)) > 0$ and $K_2(0) = -F(H(0)) > 0$.

Observe that $H'(\cdot) = 1 - tf''(\cdot) < 0$ and $F'(\cdot) = 1 - 2tf''(\cdot) < 0$, which imply that $K_1(H(0)) = H(0) - H(F(H(0))) < 0$ and $K_2(F(0)) = F(0) - F(H(F(0))) < 0$.

The Intermediate Value Theorem and the monotonicity of $K_i(x)$ imply that there is a unique $v_1 \in (0, H(0))$ such that $K_1(v_1) = 0$ and a unique $v_2 \in (0, F(0))$ such that $K_2(v_2) = 0$.

Equations (13) and (14) suggest that

$$2 - 2f'(v_1) - f'(v_2) = 0. \tag{15}$$

Applying the Implicit Theorem yields the following:

$$\frac{\partial v_1}{\partial \theta_1} = -\frac{\partial v_1}{\partial \theta_2} = \frac{f''(v_2)}{2f''(v_1)[tf''(v_2) - 1] - f''(v_2)} \text{ and} \tag{16}$$

$$\frac{\partial v_2}{\partial \theta_1} = -\frac{\partial v_2}{\partial \theta_2} = \frac{-2f''(v_1)}{2f''(v_1)[tf''(v_2) - 1] - f''(v_2)}. \tag{17}$$

Also, the property of $f(\cdot)$ implies that $2f''(v_1)[tf''(v_2) - 1] - f''(v_2) > 0$. Therefore we have $\frac{\partial v_1}{\partial \theta_1} > 0$, $\frac{\partial v_1}{\partial \theta_2} < 0$, $\frac{\partial v_2}{\partial \theta_1} < 0$ and $\frac{\partial v_2}{\partial \theta_2} > 0$.□

A2: Proof of Lemma 2

Proof of Lemma 2(i)

Equations (9) and (10) suggest that

$$-\frac{t - 3(v_1 - v_2 + \theta_1 - \theta_2)}{2t} - f'(v_1) + f'(v_2) = 0. \tag{18}$$

Using the Intermediate Value Theorem, Eq. (18) can be rewritten as

$$-\frac{t - 3(v_1 - v_2 + \theta_1 - \theta_2)}{2t} - f''(\cdot)(v_1 - v_2) = 0 \Leftrightarrow v_1 - v_2 = \frac{3(\theta_1 - \theta_2) - t}{2tf''(\cdot) - 3}, \tag{19}$$

Observe that $v_1^{YY} = v_1(\theta_1^*, \theta_2^*)$ and $v_2^{YY} = v_2(\theta_1^*, \theta_2^*)$, which imply that

$$v_1^{YY} - v_2^{YY} = \frac{3(\theta_1^* - \theta_2^*) - t}{2tf''(\cdot) - 3}. \tag{20}$$

The assumptions on $f(\cdot)$ imply that $2tf''(\cdot) - 3 > 0$, therefore, we have $v_1^{YY} > v_2^{YY}$ if $t < 3(\theta_1^* - \theta_2^*)$ and $v_1^{YY} \le v_2^{YY}$ otherwise.

Proof of Lemma 2(ii)

Equations (7) and (8) suggest that

$$s_2(v_1, v_2) - s_1(v_1, v_2) = \int_{a_2}^{a_1} p(x)dx.$$

When both platforms can advertise, $a_1 = a_1^* = p^{-1}(\gamma)$, $a_2 = a_2^* = R^{-1}(\gamma)$ and $a_1^* > a_2^*$, therefore, we have $s_2^{YY} - s_1^{YY} = \int_{a_2^*}^{a_1^*} p(x)dx > 0$.

Proof of Lemma 2(iii)

Observe that $D_1 - D_2 = 2\hat{x} - 1$. Substitute (7) and (8) into the expression of $\hat{x}$ and we have

$$D_1 - D_2 = 2\hat{x} - 1 = (v_1 - v_2 + \theta_1 - \theta_2)/t.$$

When both platforms can advertise, $D_1^{YY} - D_2^{YY} = \left(v_1^{YY} - v_2^{YY} + \theta_1^* - \theta_2^*\right)/t$, along with (20), we have

$$t \cdot \left(D_1^{YY} - D_2^{YY}\right) = \frac{3(\theta_1^* - \theta_2^*) - t}{2tf''(\cdot) - 3} + \theta_1^* - \theta_2^* = \frac{t}{2tf''(\cdot) - 3} \cdot \left(2f''(\cdot)(\theta_1^* - \theta_2^*) - 1\right),$$

The assumptions on $f(\cdot)$ imply that $2tf''(\cdot) - 3 > 0$, therefore, we have $D_1^{YY} > D_2^{YY}$ if $\theta_1^* - \theta_2^* > \frac{1}{2f''(\cdot)}$ and $D_1^{YY} \le D_2^{YY}$ otherwise. □

A3: Proof of Lemma 3

When the public broadcaster is not allowed to carry advertisements, then $\theta_1 = 0$ and $\theta_2 = \theta_2^*$, thus (19) implies that

$$v_1^{NY} - v_2^{NY} = \frac{-3\theta_2^* - t}{2tf''(\cdot) - 3} < 0 \Rightarrow v_1^{NY} < v_2^{NY}.$$

For the subscription fee, note that $a_1 = 0$ and $a_2 = a_2^*$. Thus we have

$$s_2^{NY} - s_1^{NY} = \int_{a_2^*}^{0} p(x)dx < 0 \Rightarrow s_1^{NY} > s_2^{NY}.$$

Similar to the proof of Lemma 2, we have

$$t \cdot \left(D_1^{NY} - D_2^{NY}\right) = \frac{-3\theta_2^* - t}{2tf''(\cdot) - 3} - \theta_2^* = \frac{-t\left(2f''(\cdot)\theta_2^* + 1\right)}{2tf''(\cdot) - 3}.$$

The assumptions on $f(\cdot)$ imply that $2tf''(\cdot) - 3 > 0$, and thus $D_1^{NY} < D_2^{NY}$. □

A4: Proof of Proposition 1

Note that $v_1^{YY} = v_1(\theta_1^*, \theta_2^*)$, $v_2^{YY} = v_2(\theta_1^*, \theta_2^*)$, $v_1^{NY} = v_1(0, \theta_2^*)$ and $v_2^{NY} = v_2(0, \theta_2^*)$.

Since $\partial v_1(\theta_1, \theta_2)/\partial\theta_1 > 0$ and $\partial v_2(\theta_1, \theta_2)/\partial\theta_1 < 0$ by Lemma 1, then we have $v_1^{NY} < v_1^{YY}$ and $v_2^{NY} > v_2^{YY}$.□

A5: Proof of Proposition 2

Note that $s_1^{NY} = s_1(0, \theta_2^*)$,$s_1^{YY} = s_1(\theta_1^*, \theta_2^*)$,$s_2^{NY} = s_2(0, \theta_2^*)$ and $s_2^{YY} = s_2(\theta_1^*, \theta_2^*)$, thus we only need to show that $\frac{\partial s_1}{\partial \theta_1} < 0$ and $\frac{\partial s_2}{\partial \theta_1} < 0$.

In fact, if $0 \le \theta_1 \le \theta_1^*$, $0 \le \theta_2 \le \theta_2^*$, Eqs. (7) and (8) imply that

$$\frac{\partial s_2}{\partial \theta_1} = -1 - \frac{\partial v_1}{\partial \theta_1} + \frac{\partial v_2}{\partial \theta_1} \text{ and } \frac{\partial s_1}{\partial \theta_1} = \frac{\partial s_2}{\partial \theta_1} - p(a_1) \cdot \frac{da_1}{d\theta_1}.$$

The definition of $\theta_1 \equiv \int_0^{a_1} p(a)da - \gamma a_1$ implies that $\frac{da_1}{d\theta_1} > 0$. Combining Eqs. (16) and (17) and taking into account $f''(\cdot) > \frac{2}{t-\theta_1^*}$ we have

$$\frac{\partial s_2}{\partial \theta_1} = -\frac{2f''(v_1)f''(v_2)}{2f''(v_1)[tf''(v_2) - 1] - f''(v_2)} < 0 \text{ and } \frac{\partial s_1}{\partial \theta_1} < 0.$$

□

A6: Proof of Proposition 3

Similarly we show that $\frac{\partial CS}{\partial \theta_1} > 0$ and $\frac{\partial W}{\partial \theta_1} > 0$. When $0 \le \theta_1 \le \theta_1^*$ and $0 \le \theta_2 \le \theta_2^*$, taking the first derivative of (12) leads to

$$\frac{\partial W}{\partial \theta_1} = \frac{t + \Omega + \partial v_1/\partial \theta_1 \cdot (t + \Omega - 2tf'(v_1)) + \partial v_2/\partial \theta_1 \cdot (t - \Omega - 2tf'(v_2))}{2t}, \quad (21)$$

where $\Omega = v_1 - v_2 + \theta_1 - \theta_2$. Using Eqs. (9) and (10) to rewrite (21) as

$$\frac{\partial W}{\partial \theta_1} = \frac{t + \Omega - (t - \Omega) \cdot \partial v_2/\partial \theta_1}{2t}. \quad (22)$$

Substitute (7) and (8) into $D_1 = \frac{t + v_1 - v_2 + s_2 - s_1 + \gamma(a_2 - a_1)}{2t}$ imply that $\Omega = t(2D_1 - 1)$. Combing $\Omega = t(2D_1 - 1)$ and $\frac{\partial v_2}{\partial \theta_1} < 0$, (22) lead to.

$\frac{\partial W}{\partial \theta_1} = D_1 - D_2 \cdot \frac{\partial v_2}{\partial \theta_1} > 0.$

Taking the first derivative of (11) leads to

$$\frac{\partial CS}{\partial \theta_1} = \frac{(3t + \Omega)(1 + \partial v_1/\partial \theta_1) - (t + \Omega) \cdot \partial v_2/\partial \theta_1}{2t}, \quad (23)$$

Use $\Omega = t(2D_1 - 1)$, and note that $\frac{\partial v_1}{\partial \theta_1} > 0$, $\frac{\partial v_2}{\partial \theta_1} < 0$, then (23) implies that

$$\frac{\partial CS}{\partial \theta_1} = (1 + D_1) \cdot \frac{\partial v_1}{\partial \theta_1} - D_1 \cdot \frac{\partial v_2}{\partial \theta_1} > 0.$$

□

A7: Proof of Proposition 4

Proof of Proposition 4 (i)

Note that $v_1^{NN} = v_1(0,0)$, $v_2^{NN} = v_2(0,0)$, $v_1^{YN} = v_1(\theta_1^*,0)$ and $v_2^{YN} = v_2(\theta_1^*,0)$. Since we have $\partial v_1(\theta_1,\theta_2)/\partial\theta_1 > 0$ and $\partial v_2(\theta_1,\theta_2)/\partial\theta_1 < 0$ from Lemma 1, then $v_1^{NN} < v_1^{YN}$ and $v_2^{NN} > v_2^{YN}$.

Proof of Proposition 4 (ii)

Note that $s_1^{NN} = s_1(0,0)$,$s_1^{YN} = s_1(\theta_1^*,0)$,$s_2^{NN} = s_2(0,0)$ and $s_2^{YN} = s_2(\theta_1^*,0)$, In appendix A5, we have shown that $\frac{\partial s_1}{\partial\theta_1} < 0$ and $\frac{\partial s_2}{\partial\theta_1} < 0$. Then we have $s_1^{NN} > s_1^{YN}$ and $s_2^{NN} > s_2^{YN}$ by monotonicity.

Proof of Proposition 4 (iii)

Note that $CS^{NN} = CS(0,0)$,$CS^{YN} = CS(\theta_1^*,0)$,$W^{NN} = W(0,0)$ and $W^{YN} = W(\theta_1^*,0)$. In Appendix A6, we have shown that $\frac{\partial CS}{\partial\theta_1} > 0$ and $\frac{\partial W}{\partial\theta_1} > 0$, which lead to $CS^{NN} < CS^{YN}$ and $W^{NN} < W^{YN}$. □

A8: Proof of Proposition 5

Proof of Proposition 5 (i)

In the second stage, repeating the same analysis as in Sect. 3.1, we have that if platform i advertises, then its advertising intensity is determined by $R'(a_i) = \gamma$, implying that $a_1^{c*} = a_2^{c*} = a_2^*$. The subscription fees are

$$s_1 = -R(a_1)\,\text{and}\,s_2 = \frac{1}{2}(1 - v_1 + v_2 + \gamma a_1 - \gamma a_2 - R(a_1) - R(a_2)). \tag{24}$$

In the first stage, we need to solve the equilibrium quality levels. Denote

$$v_1(\rho_1,\rho_2) = \frac{\eta(7+\rho_1-\rho_2)-2}{\eta(8\eta-3)}\,\text{and}\,v_2(\rho_1,\rho_2) = \frac{2\eta(1+\rho_2-\rho_1)-2}{\eta(8\eta-3)}. \tag{25}$$

We have

$$v_1^{cYY} = v_1(\rho^*,\rho^*)\,\text{and}\,v_2^{cYY} = v_2(\rho^*,\rho^*), \tag{26}$$

$$v_1^{cNY} = v_1(0,\rho^*)\,\text{and}\,v_2^{cNY} = v_2(0,\rho^*), \tag{27}$$

where $\rho^* = R(a_2^*) - \gamma a_2^*$. From Eqs. (25)–(27), we have that

$$v_1^{cNY} < v_1^{cYY}\,\text{and}\,v_2^{cNY} > v_2^{cYY}.$$

Proof of Proposition 5 (ii)

From Eqs. (24)–(27), we have

$$s_1^{cNY} = 0,\ s_1^{cYY} = -R(a_2^*),\ s_2^{cNY} = \frac{\gamma(3-8\eta)a_2^* - 4 - 4\eta(\rho^*-1) + 3\rho^*}{8\eta-3}\ \text{and}$$

$$s_2^{cYY} = \frac{\gamma(3-8\eta)a_2^* - 4 + \eta(4-8\rho^*) + 3\rho^*}{8\eta - 3}.$$

Then we have that $s_1^{cNY} - s_1^{cYY} = R(a_2^*) > 0$ and $s_2^{cNY} - s_2^{cYY} = \frac{4\eta\rho^*}{8\eta-3} > 0$.

Proof of Proposition 5 (iii)

First we denote that

$$CS(\rho_1,\rho_2) = V + \frac{1}{2\eta(8\eta-3)^2}\{12 - 75\eta + 6\eta(2\rho_1+\rho_2) + 8\eta^2\left[\eta(\rho_1-\rho_2)^2 - 4(2\rho_1+\rho_2) + 2(9+7\eta\rho_1+\eta\rho_2) - 7\eta\right]\}, \text{and}$$

$$W(\rho_1,\rho_2,\theta_1,\theta_2) = V + \frac{1}{2\eta(8\eta-3)^2}\{(1-\eta)(4+\eta(40\eta-19)) + \eta^2(7-8\eta)(\rho_1-\rho_2)^2 + 2\eta(8\eta-3)(\theta_1(6\eta-1) + 2\eta(\rho_1-\rho_2)(\theta_1-\theta_2) + 2\theta_2(\eta-1)) + 2\eta(\rho_2-\rho_1)(\eta-1)(1+8\eta)\}.$$

Since $\rho^* = R(a_2^*) - \gamma a_2^*$ and $\theta_2^* = \int_0^{a_2^*} p(x)dx - \gamma a_2^*$, then we have that $\theta_2^* - \rho^* = \int_0^{a_2^*}\left(p(x) - p(a_2^*)\right)dx > 0$. To simplify notations, we denote $k = \theta_2^*/\rho^* > 1$. Note that $\eta > \frac{1}{1-\rho^*}$, thus we have that

$$CS^{cYY} - CS^{cNY} = CS(\rho^*,\rho^*) - CS(0,\rho^*) = \frac{2\rho^*(3+2\eta(14\eta-8-\eta\rho^*))}{(3-8\eta)^2} > 0 \text{ and}$$

$$\begin{aligned} W^{cYY} - W^{cYN} &= W(\rho^*,\rho^*,\theta_2^*,\theta_2^*) - W(\rho^*,0,\theta_2^*,0) \\ &= \frac{\rho^*}{2(8\eta-3)^2}\{4k(8\eta-3)(\eta(1-\rho^*)-1) + \eta(8\eta-7)(2+\rho^*) - 2\} > 0. \end{aligned}$$

□

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