Strategic Information Disclosure under Common Private Information*

Levent Celik
CERGE-EI†
Politickych veznu 7
111 21, Prague 1, Czech Rep.
levent.celik@cerge-ei.cz

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Abstract

When firms know the attributes of competing products, their advertisements may leak information about them. I analyze this within a duopoly television market that lasts for two periods. Each station may promote its upcoming program by airing a tune-in for it during the first program. Viewers may alternatively acquire program information by sampling it for a few minutes. I find that each station's equilibrium tune-in decision depends on both upcoming programs - thereby revealing more information than the actual content - when the cost of program sampling or the opportunity cost of a tune-in is sufficiently low. Otherwise, advertising decisions are made independently. From a social point of view, it may be welfare improving to ban tune-ins in the latter case but not in the former.

Keywords: Informative Advertising, Tune-ins, Sampling, Information Disclosure, Signaling.
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1 Introduction

In this paper, I analyze the provision of tune-ins (preview advertisements for broadcasters' upcoming programs) in an oligopolistic television (TV) market. Tune-ins constitute a major component of TV advertising. Anand and Shachar [1998] report that three major network stations in the U.S. devoted approximately 2 of 12 minutes of non-program time to tune-ins in 1995. Maybe more strikingly, Kantar Media reports that CBS ran 42 tune-ins for its lineup programming in the 2013 Super Bowl, which made up approximately 20.6% of all advertising time within the event. Considering that the average price for a 30-second commercial was approximately $4 million, this implies quite a large opportunity cost for CBS. Below is a table that summarizes the percentage of the total advertising time allocated to tune-ins and the approximate opportunity cost the network that broadcasted the Super Bowl incurred in the years 2006-2010.

Year	**Time (mm:ss)**	**% of all ad time**	**Value (million)**
2006	7:20	16.6%	$36.7
2007	9:35	22.2%	$45.7
2008	8:35	19.0%	$46.4
2009	7:10	15.9%	$43.0
2010	8:15	17.2%	$49.1

Table 1: Network Self-Promotion in the Super Bowl, 2006-2010.
(*source: Kantar Media*)

Why would TV stations choose to promote their own programs rather than earn several millions of dollars from sponsor ads? Generally speaking, tune-ins are informative signals that help viewers better evaluate their expected utility of watching the promoted program.[1] Upon seeing a tune-in, some viewers will realize a high match with the promoted program and will decide to stay tuned rather than switch to another station (business stealing) or switch off completely (new demand). Similarly, some viewers will realize a bad match and will be deterred away either to another station or to an outside

[1] Although a person can acquire information about the attributes of a program through TV schedules that appear in magazines or through word-of-mouth, an important fraction of viewers remain imperfectly informed due to the costs associated with gaining program information. Individuals also have limited memories.

option. Overall, these two factors determine the effectiveness of a tune-in and whether the expansion it causes in total viewership is enough to offset its opportunity cost. In fact, a week after the 2013 Super Bowl, Nielsen ratings announced that CBS took 8 of the 10 top spots in ratings for the week starting Monday after the Super Bowl, thus justifying to some extent CBS's strategy of airing a high number of tune-ins.

There are a few distinctive features of the TV market that make it unique. First, existence of TV programs is *a priori* known to everyone although potential viewers may have limited information about program attributes. Therefore, a TV station's decision to air or not to air a tune-in must account for the possible inferences its current viewers will draw in the absence of a tune-in. In this regard, the problem of airing tune-ins closely resembles the classical problem of verifiable information disclosure.[2] Second, TV stations are typically much better informed, if not fully, about their rivals' programs. This means that a TV station's decision to air or not to air a tune-in for an upcoming program must also account for the indirect information it conveys about the rivals' upcoming programs. This common private information structure introduces a new dimension to the problem of verifiable information disclosure in oligopolistic environments. Third, TV programs are typically not only vertically but also horizontally differentiated.[3] In other words, there is generally no consensus among viewers about the superiority of any two programs. Forth, potential viewers have the option of learning program attributes by sampling it for a few minutes and switch across different TV stations before they make a final decision. And fifth, by placing a program's tune-in in other similar programs, TV stations can target viewers based on their preferences.

The objective of this paper is to study a simple model that captures these features of the TV market and answers the following questions: What sorts of programs do TV stations promote by tune-ins? What do viewers infer if a TV station does not air a tune-in for its upcoming program? Does the tune-in decision of a TV station for a particular program depend on the attributes of the competing programs in other stations? Do TV stations air too many or too few tune-ins? I am not aware of any former studies of

[2] See section 2 for a brief review of the literature on verifiable information disclosure.

[3] The classical information disclosure literature focuses on goods that are vertically differentiated. See the discussion later.

verifiable information disclosure (or of informative advertising) that address similar issues in an oligopolistic setting with horizontally differentiated goods and common private information. In this sense, although developed in the context of a TV market, I believe the analysis also provides valuable insights into more general problems of information disclosure.

I consider a spatial model with a continuum of potential viewers distinguished by their ideal programs. This is represented by assigning to each potential viewer a unique location along the unit line *à la* Hotelling [1929]. There are two TV stations each airing two consecutive programs that are also represented by possibly different locations over the unit line. Potential viewers know the earlier programs in both stations but are uncertain about the locations of the upcoming programs. TV stations know the location of their own as well as their rival's upcoming program, and viewers know that the stations possess this information. Each TV station may reveal this information to its first-period audience by airing a tune-in at the cost of the forgone revenue that could have been earned from a commercial ad. Viewers may alternatively acquire this information by sampling a few minutes of a program.

The main findings of the paper are as follows. First, competition and the motive for business stealing alone are sufficient to ensure that TV stations air tune-ins in equilibrium. Second, even if TV stations are fully informed about their rival's upcoming program, their tune-in decisions do not necessarily depend on this information. When they do depend, however, aggregate welfare is generally higher. In such an equilibrium, TV stations air fewer tune-ins on average and viewers make interim-stage inferences not only for the upcoming program of the station they watch but also of the other station. In this sense, there can be cross-signaling in equilibrium. Third, an equilibrium without any tune-ins may be socially better because of the opportunity costs it saves on tune-ins. As a result, it may be welfare-improving if the two stations shared a common ownership or if they coordinated their tune-in decisions. However, there are situations when tune-ins can enhance welfare by helping viewers avoid some of the inefficient sampling costs they incur.

Section 2 of the paper reviews the related literature. In section 3, I introduce the main model and characterize the equilibria. Section 4 argues when it may be welfare improving to ban tune-ins. Finally, section 5 discusses the findings and concludes.

2 Related Literature

This paper is closely related to two interrelated strands of literature, directly informative advertising and verifiable information disclosure. Confining attention to product markets, both strands focus on inherently the same problem; firms providing truthful information about their products to incompletely informed consumers. Generally speaking, they depart from each other in two important aspects. The literature on informative advertising commonly assumes that consumers are *a priori* unaware of market existence and that firms reach a random fraction of consumers by ads. Therefore, consumers do not make any inferences about the products for which they have not received any ads. The literature on verifiable information disclosure, on the other hand, assumes that product existence is common knowledge and all consumers receive any disclosed information. As a result, not being exposed to any ads is informative, too.

The pioneering works in the area of informative advertising are Butters [1977] and Grossman and Shapiro [1984]. In the former one, products are homogeneous and advertising conveys information about prices, hence also indirectly about the existence of the products. Grossman and Shapiro [1984] study an extended model in which products are horizontally differentiated, consumers are heterogeneous in their preferences and advertising informs them not only about existence but also about the characteristics of the products. In this respect, my analysis is more similar to Grossman and Shapiro [1984].

More recent papers in this strand that are related are Meurer and Stahl [1994] and Anand and Shachar [2009]. Meurer and Stahl [1994] consider a duopoly market in which only a fraction of buyers are uninformed about product characteristics. There are two distinct types of buyers. One type is ideally matched with one firm and the other type is ideally matched with the other firm. Each firm chooses its advertising intensity and a random fraction of consumers receive the ad. Importantly, if a consumer receives an ad, then she fully learns which product is better for her. In this sense, advertising serves as a public good. They characterize a unique subgame perfect Nash equilibrium in which the level of advertising provided may be more or less than socially optimal. While advertising improves the match between consumers and products, it gives firms a higher market power by increasing brand loyalty. Anand and Shachar [2009] use a similar setup with two main differences. First, a firm can only advertise through one or both of two available media channels, and consumer preferences over product attributes are perfectly correlated with their choice of media channel. If, for instance, consumers of media channel 1 are ideally matched with product 1, then firm 1 can target these consumers by advertising through media channel 1. And second, advertising messages are noisy in the sense that consumers may get the wrong idea from a firm's ad. They characterize a separating equilibrium in which a firm advertises only to those consumers for whom its product is the ideal one. As long as ads are not completely noisy, there exists a threshold amount of advertising which ascertains a consumer that the advertised product is her best match. Thus, regardless of the content of the ad, each consumer purchases the product that she was advertised to.[4]

There are major differences between my model and these two papers. First, products are experience goods in both of these papers, so consumers do not have the option of obtaining product information by a costly search. On the contrary, I treat TV programs as search goods in my analysis and program sampling plays a crucial role for my results. Second, there are only two distinct types of consumers in both papers, one ideally matched with one product and the other with the other product. In Meurer and Stahl [1994], this assumption plays a critical role for the results. In Anand and Shachar [2009], it is a necessary assumption for perfect separation. In my model, on the other hand, there is a continuum of heterogenous viewers and being exposed a tune-in is not sufficient to judge which one of the two upcoming programs is better for them. Third, tune-in ads in my model is purely informative unlike in Anand and Shachar [2009], and reaches a non-random group of consumers unlike in Meurer and Stahl [1994]. In this sense, I use a different advertising technology in this paper.

To the best of my knowledge, there are no previous theoretical papers that analyze tune-ins. There are, however, several empirical studies of the effects of tune-ins on viewing choices of individuals. Anand and Shachar [1998] estimate the differential effects

[4]See also Anand and Shachar [2007] for a similar analysis.

of tune-ins on viewing decisions for regular and special shows, and find a significant difference. Moshkin and Shachar [2002] consider the informational role of tune-ins in inducing viewers to continue watching the same TV station (the so-called 'lead-in' effect) and propose a method to identify it. Using a panel dataset on TV viewing, they find strong evidence for this role of tune-ins. Anand and Shachar [2011] consider tune-ins as noisy signals of program attributes. They find that while exposure to tune-ins improves the matching of viewers and programs, in some cases it decreases a viewer's tendency to watch a program.

Turning to the second strand of literature this paper is related to, the pioneering works on verifiable information disclosure are Grossman [1981], Grossman and Hart [1980] and Milgrom [1981], all of which focus on disclosure of quality in a monopoly environment. They all reach the 'information unraveling' result: quality is fully revealed in all perfect Bayesian equilibria as long as there is a credible and costless way of conveying this information. Several papers have extended verifiable quality disclosure in different directions.[5] Examples that focus on competitive environments are Board [2009], Cheong and Kim [2004], Hotz and Xiao [2013], Janssen and Roy [2012], Levin, Peck and Ye [2009], Milgrom and Roberts [1986] and Stivers [2004]. However, they do not consider disclosure of horizontal attributes nor consumer search.[6]

Balestrieri and Izmalkov [2011], Celik [2012] and Sun [2011] focus on the disclosure of horizontal attributes in a Hotelling framework. They show that equilibria with partial disclosure are possible and characterize their properties. Koessler and Renault [2012] study a model that allows for both horizontal and vertical attributes, and characterize the sufficient conditions under which unraveling is an equilibrium. However, all of these papers consider a monopoly firm. Anderson and Renault [2009] consider comparative advertising in a duopoly setting in which firms can advertise their rival's product characteristics, too. They use a random utility model in which consumers' match values with the products are random draws from a probability distribution that is commonly known. Therefore, consumers make no inferences based on the particular ways the producers

[5] See Dranova and Jin [2010] for an excellent survey.

[6] Hotz and Xiao [2013] and Levin, Peck and Ye [2009] also allow for horizontal product attributes. However, they assume that these are commonly known by consumers.

reveal information. Janssen and Teteryanikova [2012] extend Celik [2011] by introducing a second firm and assuming common private information. They show that unraveling is the unique outcome in this case.

This paper is also related to the scarce literature on quality signaling with multiple senders when firms have common knowledge of product qualities. Hertzendorf and Overgaard [2001a] consider a static duopoly in which nature selects one firm as the high-quality producer and the other as the low-quality producer. Fluet and Garella [2002] consider a static duopoly model in which each firm is informed about the quality of both products (which may be either high or low). Both papers find that a strictly positive spending on advertising is necessary for full separation when the quality difference is small. Bontems and Meunier [2006] consider a duopoly model of quality signaling when the products are both vertically and horizontally differentiated. As in Hertzendorf and Overgaard [2001a], nature assigns only one of the firms as the high-quality producer. However, this assignment occurs after firms choose their locations. In contrast with Hertzendorf and Overgaard [2001a] and Fluet and Garella [2002], the authors find that a positive level of advertising is necessary for separation regardless of the degree of vertical differentiation. Yehezkel [2008] considers a model as in Hertzendorf and Overgaard [2001a], but assumes that a fraction of consumers are fully informed about qualities. He finds that the amount of spending on advertising in a separating equilibrium is declining with the proportion of informed consumers, while firms' profits are highest when the proportion of informed consumers is at an intermediate level.[7]

3 The Model

There are two TV stations, Y and Z, each airing two consecutive programs in two consecutive time periods. The programs are characterized by their locations on the unit interval $[0, 1]$. They are of the same length and have zero production costs. Each station is fully informed about its own as well as its rival's program locations. There are $A \geq 2$ time slots during each program that are available to be allocated to non-program content,

[7]For other studies of signaling when there are multiple senders with common private information, see Bagwell and Ramey [1991], de Bijl [1997], Hertzendorf and Overgaard [2001b] and Matthews and Fertig [1990].

where A is an integer that is exogenously given.[8] I will henceforth refer to these as ads. Thus, the game in this paper may be thought of as a subgame of a larger game where the choices of program locations and the amount of non-program minutes have already been made.

There is a large number of advertisers that are willing to pay up to $\$p$ per viewer reached for placing a commercial during a program in each period. Each commercial is one time-slot long. In the first period, each TV station may alternatively choose to air a tune-in to promote its upcoming program. Production of a tune-in does not entail any costs. I assume that a tune-in has the same length as a commercial. Each TV station splits the available A ads during the first program between commercials and tune-ins. Hence, TV stations incur an opportunity cost for placing tune-ins. I assume that a TV station cannot lie in a tune-in (i.e., each TV station is legally bound to advertise a preview of the actual program) and that the tune-in is fully informative. The objective of a TV station is to maximize its total advertising revenue which is generated by payments received from advertisers for placing commercials. In each period, the total revenue of a station is the size of its audience in that period, times the per-viewer revenue it earns. If a station airs one tune-in, then its per-viewer revenue is $(A-1)p$. If it does not air any tune-ins, then the per-viewer revenue is Ap.

On the other side of the market, there is a continuum of a unit mass of potential viewers. They are uniformly distributed along the unit interval with respect to their ideal programs. To each possible program location on the unit line, there corresponds a viewer for whom that program is the ideal one. A viewer who is located at $\lambda \in [0,1]$ obtains a net utility $u(\lambda, x) = v - |\lambda - x|$ from watching a program located at x.[9] Viewers' ideal programs stay the same over the periods. Not watching TV yields zero benefits.[10]

[8] While U.S. broadcasters are free to choose the amount of their non-program minutes, advertising ceilings are imposed on broadcasters in most European countries. In most cases, especially in the prime-time, the amount of non-program minutes that mazimizes a broadcaster's revenue falls below the imposed ceiling. There are also technical reasons for making this assumption. First, if TV stations were allowed to choose the amount of non-program minutes, then viewers would rationally form beliefs about it. Second, and most importantly, the amount of non-program minutes in the first period would possibly provide a signal for the location of the second program. Addressing these issues is beyond the scope of this paper, since the main focus is on the role of tune-ins. Doing so is an excellent area for future research.

[9] Alternatively, v can be interpreted as the quality of a program which enters into everyone's utility in the same way.

[10] Given that the value of not watching TV is zero, the degree of disutility associated with a mismatch

Under complete information, the utility of watching a program located at x for a viewer located at λ is non-negative if λ lies within v units away from x. If there are two programs to choose between, $x_Y < x_Z$, then the indifferent viewer will be the one located at the halfway, i.e., $\frac{x_Y + x_Z}{2}$. Viewers with locations $\max\{0, x_Y - v\} \leq \lambda < \frac{x_Y + x_Z}{2}$ will watch program x_Y while the ones with locations $\frac{x_Y + x_Z}{2} < \lambda \leq \min\{x_Z + v, 1\}$ will watch program x_Z.

Since the main focus of this paper is on the optimal tune-in behavior of TV stations for their upcoming programs and how this depends on their knowledge of the rival's program, I assume without loss of generality that viewers have complete information about the first programs in both stations, that all of them watch TV in the first period and that stations Y and Z split viewers equally. For simplicity, assume that viewers with $\lambda \in [0, \frac{1}{2}]$ watch Y and viewers with $\lambda \in (\frac{1}{2}, 1]$ watch Z in the first period. Viewers however do not know where on the unit interval the second programs are located at. Denote the location of the second program of station Y with y and that of Z with z. I assume that viewers' prior beliefs for y and z are independent and are given by a discrete uniform density function that places equal probabilities on three locations, 0, $\frac{1}{2}$ and 1. Viewers know that the stations know the location of their own as well as their rival's program.

A viewer makes a decision at each time that maximizes her total utility. Viewers have the option of switching to the other station or simply turning their TV off after sampling a few minutes of a program. I assume that the amount of time required to learn the true location of a program is constant and the same for both programs and for all viewers. Let k denote this amount of time. The sampling process entails an opportunity cost of $c > 0$, which the viewer incurs for any missed portion of the final choice she makes (watching one of the two programs, or switching off and enjoying the outside option). Thus, this cost becomes sunk once a viewer chooses to sample a program. I will henceforth refer to it as the sampling cost. A viewer incurs the sampling cost in one of the following three situations:

can be captured by varying v. Similarly, one can introduce nuisance costs associated with the amount of non-program minutes a viewer is exposed to. This too can be captured by varying v. Note that tune-ins also create a nuisance in this formulation.

(i) Suppose a viewer samples the programs in both stations and ends up watching the one that yields a higher utility. She incurs $-c$ in this case since she will have missed k minutes of the program she ends up watching.

(ii) Suppose a viewer decides to turn her TV off after sampling only one of the programs. Then her net utility is $-c$ since she has missed k minutes of the outside option.

(iii) Suppose a viewer decides to turn her TV off after sampling both programs. Then her net utility is $-2c$ since she has missed $2k$ minutes of the outside option.

The process of costly sampling plays a crucial role for two reasons. First, sampling cost must be strictly positive for an equilibrium that involves the use of tune-ins to exist. Had it been zero, viewers could costlessly acquire program information in both stations and make their decisions without any uncertainty. Therefore, there would be no need for tune-ins. Second, since the cost of sampling becomes sunk once a viewer chooses to engage in sampling, some viewers may end up watching a program that they would not choose to watch under complete information. By the same token, an individual's final decision may not be the one that maximizes her utility under complete information. Therefore, for a given value of c, the aggregate audience size will typically be higher the more uncertainty viewers have about program attributes. Moreover, as long as c is not too large and viewers have incomplete information about program attributes, aggregate audience size will be increasing in c. In the absence of competition, this would constitute a second reason for a TV station to air fewer tune-ins, along with the opportunity costs they involve.

The timing of the game is as follows. First, Nature selects the values of y and z independently from a discrete uniform density function with support $\left\{0, \frac{1}{2}, 1\right\}$. Each TV station observes y and z, but viewers do not observe them. Then the first programs start and the viewers make their first-period viewing decisions. In the course of the first programs, TV stations decide whether to air a tune-in for their upcoming programs or not. Viewers update their beliefs about the second programs based on the tune-in decision of the station they have watched in the fist period. Then the second programs start and viewers decide on their sampling behavior. In case of indifference, a viewer equally randomizes between the two stations (this applies to both sampling and watching). Once viewers' program sampling is finalized, audience shares of the stations and, in turn, the payoffs are realized. As a tie-breaking rule, I assume that viewers choose to watch TV if they are indifferent between watching and switching off, and stations choose not air a tune-in if they are indifferent between airing one and not airing any.

In general, we can speak of two distinct factors that affect a TV station's tune-in decision: keeping viewers away from switching to the other station, and inducing viewers who would otherwise switch off to stay tuned in. In this paper, I focus on the former of these effects and assume that incompletely informed viewers either continue program sampling or choose to watch one of the stations rather than switch off. In other words, I shut down the 'new demand' channel and focus on 'business stealing' instead. This is ensured by assuming that c is not too large relative to v. I also assume that v is not too large. If it were sufficiently large, all viewers would watch TV in all equilibria under all program configurations, thus making a comparative analysis more difficult. These parameter restrictions are stated in Assumption 1, which I maintain for the rest of the analysis.

Assumption 1 $\frac{1}{4} + c < v < 1 - c$, *where* $c \in \left(0, \frac{1}{8}\right)$.

The equilibrium concept used is perfect Bayesian equilibrium (PBE). That is, the TV stations make optimal tune-in decisions taking the location of their rival's program and the optimal behavior of viewers into account, and viewers make optimal sampling and viewing decisions after observing the tune-in decision of the station they have watched. In particular, people's inferences (or posterior beliefs) after the first period about the locations of the second programs must be correct, and the TV stations should not have any incentive to deviate.

4 Equilibrium provision of tune-ins

In this section, I analyze the optimal tune-in strategies of the TV stations as well as the optimal sampling/viewing decisions of viewers. I start with a benchmark scenario in which I assume that a single media company owns both of the TV stations and seeks to maximize the aggregate advertising revenue. I identify the conditions under which a 'no tune-in' equilibrium can be maintained. I then move on to the competitive case in which each TV station is run by a separate media company. I identify the conditions under which a 'no tune-in' equilibrium does not exist, and then characterize and investigate two types of PBE that may arise.

4.1 Common ownership

Suppose both TV stations are owned by a single media company which aims to maximize the aggregate advertising revenue. Since all advertisers are willing to pay $\$p$ for each viewer who watches their commercial, the media company's goal is to maximize the combined audience size in the second period. Therefore, it does not matter for the media company how the viewers are split between stations Y and Z. This is how a regime of common ownership differs from the competitive case in which each station will try to maximize its own audience size. The main question I seek to answer in this scenario is if and when a 'no tune-in' equilibrium can be maintained.

As assumed earlier, first programs are known and viewers with $\lambda \in [0, \frac{1}{2}]$ watch Y and those with $\lambda \in (\frac{1}{2}, 1]$ watch Z. They do not switch between the two stations in the first period because sampling is costly.[11] Having watched either Y or Z in the first period, viewers update their beliefs about the second programs based on whether or not they were exposed to a tune-in. Once the second programs start, viewers may choose to acquire further information by sampling one or both stations.

Consider a situation in which neither of the stations airs a tune-in for its upcoming program regardless of its location. If these strategies constitute a PBE, then viewers' priors would stay unchanged conditional on seeing no tune-ins in the first period. Assumption 1 ensures that all viewers will engage in sampling in such a case (see the proof of Proposition 1). Given the symmetric priors for the second programs y and z, a random half of viewers will initially sample Y and the remaining half will sample Z. Thus, even

[11] In practice, a viewer may start watching the program that yields a higher utility, then switch to the other station for sampling and hope that she will see a tune-in for the upcoming program (the chances of which could be quite low). In case she does sample and does not see a tune-in, it does not necessarily mean that the station did not air one. In any case, the same viewer has the option of sampling the other station's upcoming program in the second period and learning its location perfectly. In either case, the viewer incurs the same sampling cost. So, switching in the first period is a dominated strategy.

without airing any tune-ins, the media company can get all of the viewers to sample at least one of the stations as long as this is what viewers have anticipated, too. Moreover, while those who find a good enough match will stop sampling, others will continue sampling in hopes of finding a program that matches their tastes better. As a result, given that airing a tune-in involves a positive opportunity cost, a 'no tune-in' PBE exists.

Proposition 1 *A 'no tune-in' PBE exists when both TV stations are owned by a single media company.*

The proof of Proposition 1 (as well as all the remaining proofs) can be found in Appendix A. Given that all viewers sample at least one of the programs and that the cost of sampling becomes sunk once it takes place, some viewers will *ex post* have a negative net utility (which can be as low as $-2c$). As a result, aggregate viewership is higher in a 'no tune-in' PBE compared to a full information scenario. When $v+c<\frac{1}{2}$, the viewer market will not be fully covered in the second period in the sense that there will always be some viewers who switch off after program sampling. When $v+c\geq\frac{1}{2}$, on the other hand, viewer market will be fully covered except for two situations, $(y,z)=(0,0)$ and $(y,z)=(1,1)$. These are the situations in which, by Assumption 1 (i.e., $v+c<1$), viewers with ideal locations close to the opposite end will switch off. For example, when $(y,z)=(0,1)$, the final audience of station Y will comprise viewers with $\lambda\leq\min\left\{v+c,\frac{1}{2}\right\}$ while station Z will be hosting viewers with $\lambda\geq 1-\min\left\{v+c,\frac{1}{2}\right\}$. Similarly, when $(y,z)=\left(0,\frac{1}{2}\right)$, the two stations will split the viewers over $\left[0,\frac{1}{2}\right]$ equally while station Z will additionally have viewers with $\lambda\in(\frac{1}{2},\frac{1}{2}+v+c]$ watching its second program. In both of these situations, some viewers will end up watching the first program they have sampled, some will be less lucky and find a good match only after sampling both programs, whereas some will unluckily sample both programs and turn their TV off at the end. The following table summarizes the expected second-period audience shares of stations Y and Z under each pair of programs (y,z) for $v+c<\frac{1}{2}$ (where the first number in each cell corresponds to station Y and the second one to station Z).[12]

[12] Audience share of a station is the fraction of the whole population watching that station.

	$\mathbf{z=0}$	$\mathbf{z=\frac{1}{2}}$	$\mathbf{z=1}$
$\mathbf{y=0}$	$\frac{v+c}{2},\frac{v+c}{2}$	$\frac{1}{4},v+c+\frac{1}{4}$	$v+c,v+c$
$\mathbf{y=\frac{1}{2}}$	$v+c+\frac{1}{4},\frac{1}{4}$	$v+c,v+c$	$v+c+\frac{1}{4},\frac{1}{4}$
$\mathbf{y=1}$	$v+c,v+c$	$\frac{1}{4},v+c+\frac{1}{4}$	$\frac{v+c}{2},\frac{v+c}{2}$

Table 2. Audience shares of Y and Z in a 'no tune-in' PBE when $v+c<\frac{1}{2}$.

It is helpful to note that the aggregate audience size is much higher than what it would be under complete information. Take, for instance, $(y,z)=(0,0)$. In this case, as Table 2 indicates, the aggregate audience size is $v+c$. If viewers had complete information about program locations, only viewers with $\lambda\leq v$ would watch TV, each station would have an audience size of $\frac{v}{2}$, thus an audience size of v in aggregate. This difference comes from the fact that viewers engage in program sampling in equilibrium and some get held up at the end since the cost of sampling becomes sunk once it takes place.[13] Thus, by airing no tune-ins, the media company does not only save on the opportunity costs tune-ins involve but does it also increase the aggregate audience size. So, it is a win-win situation for the media company.

One may wonder if there are other PBE under common ownership. Perhaps interestingly, the answer is yes. Suppose viewers anticipate that station Y airs a tune-in when $(y,z)\in\left\{(0,1),\left(\frac{1}{2},1\right)\right\}$, and Z airs a tune-in when $(y,z)\in\left\{(0,1),\left(0,\frac{1}{2}\right)\right\}$. Now suppose that $y=0$ or $\frac{1}{2}$, and that station Y decides not to air a tune-in. The inferences of the first-period viewers of station Y (i.e., $\lambda\leq\frac{1}{2}$) will be such that

$$(y,z)\in\left\{(0,0),\left(0,\frac{1}{2}\right),\left(\frac{1}{2},\frac{1}{2}\right),\left(\frac{1}{2},0\right),(1,0),\left(1,\frac{1}{2}\right),(1,1)\right\},$$

where each possibility will be assigned an equal probability. These inferences favor the program in station Z since it is less likely that $z=1$ than $y=1$. Therefore, in the absence of a tune-in, all Y-viewers switch to Z. If they find out that $z=0$ or $z=\frac{1}{2}$, some will stay at Z while some will switch back to Y. In these cases, the media company has nothing to lose by not airing a tune-in. However, when $z=1$ and the viewers who have switched from Y find this out, they will infer that $y=1$ based on their beliefs.

[13]The expansion in the audience size would be smaller if $1-c\leq v<1$, and completely absent if $v\geq1$. Assumption 1 ensures a non-zero expansion at least for some program pairs. When $v<\frac{1}{2}$, there is expansion for all program pairs.

When $v+c<\frac{1}{2}$, for instance, this will induce all of them to turn their TVs off without a need to switch back to Y. But if station Y aired a tune-in when $y=0$ or $\frac{1}{2}$, then its viewers would conclude that $z=1$ and those with $\lambda \leq v$ ($\frac{1}{2}-v \leq \lambda \leq \frac{1}{2}$ in case of $y=\frac{1}{2}$) would watch Y while the rest would switch off. Hence, by airing a tune-in, the media company gets an additional audience of Nv and earns an additional revenue of $ANpv$. The opportunity cost of the tune-in is what station Y could have earned by selling the same time slot to an advertiser. Given that the first-period audience share of station Y is $\frac{1}{2}$, the cost amounts to $Np\frac{1}{2}$. Thus, as long as $v>\frac{1}{2A}$, the media company is better off airing a tune-in when $(y,z) \in \left\{(0,1), \left(\frac{1}{2},1\right)\right\}$. Given that $v>\frac{1}{4}+c$ by Assumption 1 and that $A \geq 2$, it follows that $v>\frac{1}{2A}$.

4.2 Separate ownership

In this subsection, I assume that stations Y and Z are owned by two separate media companies. As a result, each station's goal will be to maximize its own audience share in the second period. Because of the common private information assumption, equilibrium tune-in behavior of a TV station may indirectly reveal information about its rival's upcoming program, too. I characterize one such equilibrium along with a non-revealing one and investigate their properties.

I first start with stating the conditions under which a 'no tune-in' PBE cannot be maintained. When the stations do not air any tune-ins and viewers do not anticipate seeing any tune-ins, the audience shares are as those given in Table 2. A 'no tune-in' PBE exists only if neither station has any incentive to deviate. Next proposition characterizes when it is profitable to deviate.

Proposition 2 *A 'no tune-in' PBE does not exist under separate ownership if* $\max\left\{\frac{1}{2}-v, c\right\} > \frac{1}{A}$.

To see this result, suppose $v+c<\frac{1}{2}$ and suppose station Y aired a tune-in when $(y,z)=(0,0)$ in contrast to what viewers were anticipating. Viewers' beliefs about z would remain unchanged in response to this unanticipated tune-in. Take a viewer $\lambda \in \left[\frac{1}{4}, v\right]$. Having unexpectedly seen a tune-in for $y=0$, this viewer may consider checking out station Z in hopes of finding out $z=\frac{1}{2}$. If it turns out that $z=0$, she would still stay at Z, because doing so would give her a utility of $v-\lambda$, whereas switching to Y would yield $v-\lambda-c$ and switching off would yield $-c$. If it turns out that $z=1$, on the other hand, switching back to station Y gives her a utility of $v-\lambda-c$, whereas switching off yields $-c$. She would switch back to Y in such a case. Thus, conditional on seeing a tune-in for $y=0$, switching to Z yields a higher expected utility than staying at Y if

$$\frac{1}{3}(v-\lambda)+\frac{1}{3}\left(v-\frac{1}{2}+\lambda\right)+\frac{1}{3}(v-\lambda-c)>v-\lambda$$
$$\Leftrightarrow \lambda>\frac{1}{4}+\frac{c}{2}.$$

This is the location of the marginal viewer to switch to Z; viewers with $\lambda<\frac{1}{4}+\frac{c}{2}$ would stay at Y while those with $\lambda\in\left[\frac{1}{4}+\frac{c}{2},\frac{1}{2}\right]$ would switch to Z. Given the presumption that $(y,z)=(0,0)$, this means that station Y would end up with an audience size of $\frac{1}{4}+\frac{c}{2}$ by unexpectedly airing a tune-in for $y=0$. If it did not air a tune-in, on the other hand, its audience size would be $\frac{v+c}{2}$ as given in Table 2. Deviation is then profitable if

$$ApN\left[\left(\frac{1}{4}+\frac{c}{2}\right)-\left(\frac{v+c}{2}\right)\right]>pN\frac{1}{2}$$
$$\frac{1}{2}-v>\frac{1}{A}.$$

A similar result can be obtained for $v+c\geq\frac{1}{2}$. What changes in this case is the decomposition of the audience in the 'no tune-in' regime. Station Y achieves an audience share of $\frac{v+c}{2}$ for $(y,z)=(0,0)$, but only $\frac{1}{4}$ of this results from its own first-period viewers (and the remaining $\frac{v+c}{2}-\frac{1}{4}$ from viewers who have watched Z in the first period). Since, by airing a tune-in, station Y can only influence the behavior of its own first-period viewers, the marginal revenue gain is $ApN\left[\left(\frac{1}{4}+\frac{c}{2}\right)-\frac{1}{4}\right]$, which leads to the conclusion that a deviation is profitable if $c>\frac{1}{A}$. I will henceforth make the following assumption.

Assumption 2 $\max\left\{\frac{1}{2}-v,c\right\}>\frac{1}{A}$.

This assumption would be easily satisfied if the TV stations have access to a high amount of non-program minutes, or if they can promote their upcoming programs in a cheaper way. For example, if TV stations are able to communicate program information in 'crawls,' which are scrolling texts at the bottom of the TV screen, then the opportunity cost of a tune-in would be zero. In such a case, Assumption 2 would be satisfied for any non-zero value of c. The intuition is parallel to the one in the classical 'quality unraveling' story. When it is costless for the seller to disclose information, consumers will tend to have pessimistic beliefs in which they will interpret silence as a negative sign for the product quality. As a result, all seller types will disclose their quality. In the current context, if a station fails to air a tune-in, its viewers will tend to have more negative opinions for its upcoming program. However, as I show below, the outcome of staying silent is not necessarily full unraveling as in the 'quality unraveling' approach.

To ease notation, for the remainder of the analysis, let $q_j(y,z)$ be a binary variable that summarizes the tune-in strategy of station j, $j = Y$, Z, where $q_j(y,z) = 1$ if station j airs a tune-in when the two programs are located at (y,z), and 0 otherwise. For instance, if station Y airs a tune-in for $y = 0$ when $z = 0$, then we have $q_Y(0,0) = 1$.

Having established that all PBE involve a non-zero number of tune-ins, I proceed with determining the extent to which a TV station informs its first-period audience of its upcoming program. A second feature that is common to all PBE is that $q_Y(1,z) = 0$ for all z, and $q_Z(y,0) = 0$ for all y; i.e., regardless of the rival's upcoming program, neither station will air a tune-in for the program location that offers the poorest match for its own first-period audience. This is immediate because a TV station could only gain (and not lose) by concealing the least favorable information. However, this does not mean that viewers will never infer this information. In fact, as the next proposition establishes, there is always a PBE in which each station's upcoming program fully unravels (to its *own* first-period audience).

Proposition 3 *Under separate ownership, there exists a symmetric PBE in which* $q_Y(y,z) = 1$ *for all* z *and* $y \neq 1$*, and* $q_Z(y,z) = 1$ *for all* y *and* $z \neq 0$*.*

In this PBE, station Y airs a tune-in as long as $y = 0$ or $\frac{1}{2}$, and station Z airs a tune-in as long as $z = \frac{1}{2}$ or 1. Most importantly, strategies do not depend on the rival's program. Therefore, viewers' priors for the other station's upcoming program remain unchanged. In the remainder of the analysis, given that there will be no information revealed about the rival's upcoming program, I will refer to this particular PBE as a 'non-revealing' PBE.

To see the working of this PBE, suppose $y = 0$ and station Y airs a tune-in. Given that the viewers of Y will still believe that z is equally likely to be 0, $\frac{1}{2}$ or 1, the marginal viewer who is indifferent between staying at Y and switching to Z will be the one with an ideal program $\lambda = \frac{1}{4} + \frac{c}{2}$. If Y instead does not air a tune-in, then its viewers will rationally infer that $y = 1$. As a result, all will switch to Z in the hopes of finding a program that matches their tastes better.[14] Since the worst they can find out in station Z is $z = 1$, none of them will ever switch back to Y. In this sense, punishment for not airing a tune-in is quite large. By airing a tune-in, station Y can ensure that $\left(\frac{1}{4} + \frac{c}{2}\right) N$ of its first-period viewers will stay with Y and not switch to Z. Since $A\left(\frac{1}{4} + \frac{c}{2}\right) > \frac{1}{2}$ both by Assumption 2 and the fact that $A > 1$, station Y will never want to deviate and pass up on airing a tune-in for $y = 0$ (and similarly for $y = \frac{1}{2}$). This is true for any value of v and c in the range defined by Assumption 1 and therefore this 'non-revealing' PBE always exists. The following table provides the audience shares of stations Y and Z in this PBE for $v + c < \frac{1}{2}$.

	$\mathbf{z = 0}$	$\mathbf{z = \frac{1}{2}}$	$\mathbf{z = 1}$
$\mathbf{y = 0}$	$\frac{1}{4} + \frac{c}{2}, v - \frac{1}{4} + \frac{c}{2}$	$\frac{1}{4} + \frac{c}{2}, v + \frac{1}{4} - \frac{c}{2}$	v, v
$\mathbf{y = \frac{1}{2}}$	$v + \frac{1}{4} + \frac{3c}{2}, \frac{1}{4} - \frac{c}{2}$	$v + c, v + c$	$v + \frac{1}{4} - \frac{c}{2}, \frac{1}{4} + \frac{c}{2}$
$\mathbf{y = 1}$	$v + c, v + c$	$\frac{1}{4} - \frac{c}{2}, v + \frac{1}{4} + \frac{3c}{2}$	$v - \frac{1}{4} + \frac{c}{2}, \frac{1}{4} + \frac{c}{2}$

Table 3. Audience shares of Y and Z in a 'non-revealing' PBE when $v + c < \frac{1}{2}$.

It is useful to note that the aggregate audience size is smaller in three cases in a 'non-revealing' PBE compared to a 'no tune-in' regime. These are when a station airs a tune-in for a program that is unanimously more superior for its first-period viewers than the rival station's upcoming program, namely when $(y, z) \in \left\{\left(\frac{1}{2}, 1\right), (0, 1), \left(0, \frac{1}{2}\right)\right\}$. Take $(y, z) = \left(\frac{1}{2}, 1\right)$ for example. After seeing a tune-in for $y = \frac{1}{2}$, viewers with $\lambda \leq \frac{1}{4} - \frac{c}{2}$ switch to Z. Once they find out that $z = 1$, those with $\frac{1}{2} - v \leq \lambda \leq \frac{1}{4} - \frac{c}{2}$ switch back to Y, but the rest switch off. The difference with the 'no tune-in' PBE is that, now, the viewers with $\frac{1}{2} - v - c \leq \lambda < \frac{1}{2} - v$ choose the outside option (and have a utility of $-c$) rather than switch back to Y (and have a utility of $v - c - \left(\frac{1}{2} - \lambda\right)$) since they

[14] See the proof of Proposition 3.

have been informed that $y = \frac{1}{2}$ and they have already missed the first k minutes of it. The argument is similar for $(y, z) = (0, 1)$ and for $(y, z) = \left(0, \frac{1}{2}\right)$. The same argument does not apply, for instance, when $(y, z) = \left(\frac{1}{2}, 0\right)$. In this case, the viewers who switch from Z to Y are not pre-informed that $y = \frac{1}{2}$, so viewers with $\frac{1}{2} + v < \lambda \leq \frac{1}{2} + v + c$ end up watching Y rather than switching off. This is exactly the opposite of the win-win situation discussed in the common ownership scenario. Now, in a 'non-revealing' PBE, stations find themselves in a lose-lose situation due to competition: air more tune-ins and get fewer viewers on average.

The 'non-revealing' PBE described in Proposition 3 is what one would naturally expect in an environment in which TV stations are privately informed only about their own upcoming programs.[15] However, the additional knowledge of the rival's upcoming program may lead to other PBE. Consider, for example, a profile that consists of partially-revealing as well as fully-revealing strategies. Suppose viewers anticipate that station Y airs a tune-in only when $(y, z) \in \left\{(0, 0), \left(\frac{1}{2}, \frac{1}{2}\right)\right\}$, and Z does so only when $(y, z) \in \left\{\left(\frac{1}{2}, \frac{1}{2}\right), (1, 1)\right\}$. When $(y, z) = (0, 0)$ and station Y airs a tune-in, its viewers infer that $z = 0$ as well. Consequently, out of Y's first-period audience, viewers with $\lambda \leq \min\left\{v, \frac{1}{2}\right\}$ watch TV, and the two stations equally split them. However, it is in fact optimal for station Y to deviate and not air any tune-ins in such a case. Given that the first-period viewers of Y anticipate seeing a tune-in when $(y, z) \in \left\{(0, 0), \left(\frac{1}{2}, \frac{1}{2}\right)\right\}$, their inferences for y and z in the absence of a tune-in will be symmetric, so they will be indifferent between where to start sampling. Eventually, since the cost of sampling is sunk, those first-period Y-viewers with $\lambda \leq \min\left\{v + c, \frac{1}{2}\right\}$ will end up watching TV and stations Y and Z will equally split this audience. As a result, even without accounting for the opportunity cost of a tune-in, station Y is at least as well off without a tune-in as it would be with one.[16]

As another example, suppose viewers expect station Y (symmetric for Z) to air a

[15] Given the symmetry of $y = 0$ and $y = \frac{1}{2}$ for station Y (and of $z = \frac{1}{2}$ and $z = 1$ for Z), the only other possible PBE under pure private information is one without any tune-ins. Analogous to Proposition 1, it can be shown that such a 'no tune-in' PBE does not exist if $\frac{1}{3}\left(\frac{1}{2} - v - c\right) > \frac{1}{A}$ when $v + c < \frac{1}{2}$, and if $\frac{1}{3}\min\left\{v + c - \frac{1}{2}, c\right\} > \frac{1}{A}$ when $v + c \geq \frac{1}{2}$. See below for more details.

[16] The assumption that viewers equally randomize between Y and Z when they are indifferent may seem to be driving this result. However, the result goes through even if one assumes that viewers do not switch stations when indifferent. In this case, station Y would deviate and air a tune-in when $(y, z) = \left(0, \frac{1}{2}\right)$. This would bring an additinal audience share of $\min\left\{v, \frac{1}{2}\right\} - \frac{1}{4}$, which is greater than $\frac{1}{2A}$ by Assumptions 1 and 2.

tune-in when $(y,z) \in \left\{(0,0),(0,1),\left(\frac{1}{2},\frac{1}{2}\right),\left(\frac{1}{2},1\right)\right\}$. But then station Y would deviate and also air a tune-in when $(y,z)=\left(0,\frac{1}{2}\right)$ so as to (incorrectly) signal to its viewers that z is either 0 or 1. In this case, no first-period viewer of Y would switch to Z, and thus Y would capture all $\lambda \leq \min\left\{v,\frac{1}{2}\right\}$. If station Y did not air a tune-in – as would be anticipated by viewers – the inferences would favor the program in station Z since it is less likely that $z=1$ than $y=1$. Therefore, in the absence of a tune-in, all Y-viewers would switch to Z. When they find out that $z=\frac{1}{2}$, they would infer that y is either 0 or 1. In this case, those viewers with $\lambda<\frac{1}{4}-c$ would switch back to Y and stay there upon discovering $y=0$. So, airing a tune-in is profitable when $\min\left\{v,\frac{1}{2}\right\}-\left(\frac{1}{4}-c\right)>\frac{1}{2A}$, which is true by Assumptions 1 and 2 (a similar deviation exists for $(y,z)=\left(\frac{1}{2},0\right)$ too).

Arguing along similar lines for other possible scenarios, one can eliminate all but one particular set of strategies: air a tune-in unless your **or** your rival's upcoming program is a poor match for your current audience.

Proposition 4 *Under separate ownership, there exists a symmetric PBE in which* $q_Y(y,z)=1$ *for all* $y,z\neq 1$ *and* $q_Z(y,z)=1$ *for all* y, $z\neq 0$ *if* $\frac{1}{2}-v-c\geq\frac{1}{A}$.

How would viewers behave in this PBE? If station Y airs a tune-in for $y=0$ or $y=\frac{1}{2}$, its viewers infer that z equals 0 or $\frac{1}{2}$ with equal probabilities. If Y does not air any tune-ins, on the other hand, it could be that Y did not air a tune-in because either $y=1$ or $z=1$ (or both). So, there is a total of five equally likely possibilities, symmetric for y and z:

$$(y,z)\in\left\{(0,1),\left(\frac{1}{2},1\right),(1,0),\left(1,\frac{1}{2}\right),(1,1)\right\}.$$

Having observed that Y did not air any tune-ins, viewers will be indifferent between where to start sampling. Suppose a viewer samples station Y first. If it turns out that $y=0$, then she will perfectly infer that $z=1$, and therefore there is no need to continue sampling station Z. But when she observes that $y=1$, she can say nothing about z, so she samples station Z, too.

Given that there will be some information revealed about the rival's upcoming program in this particular PBE, I will name it a 'partially-revealing' PBE. Table 4 provides the audience shares of stations Y and Z in this PBE when $v+c<\frac{1}{2}$.

	$\mathbf{z=0}$	$\mathbf{z=\frac{1}{2}}$	$\mathbf{z=1}$
$\mathbf{y=0}$	$\frac{1}{4}, v+c-\frac{1}{4}$	$\frac{1}{4}, v+c+\frac{1}{4}$	$v+c, v+c$
$\mathbf{y=\frac{1}{2}}$	$v+c+\frac{1}{4}, \frac{1}{4}$	$v+c, v+c$	$v+c+\frac{1}{4}, \frac{1}{4}$
$\mathbf{y=1}$	$v+c, v+c$	$\frac{1}{4}, v+c+\frac{1}{4}$	$v+c-\frac{1}{4}, \frac{1}{4}$

Table 4. Audience shares of Y and Z in a 'partially-revealing' PBE when $v+c<\frac{1}{2}$.

As described in Proposition 4, the 'partially-revealing' PBE can be maintained only if $\frac{1}{2}-v-c \geq \frac{1}{A}$. To see this, suppose that $v+c<\frac{1}{2}$, that $(y,z)=(0,0)$ and that Y deviates and does not air a tune-in. Then, based on the symmetry of the posteriors for y and z, those first-period Y-viewers with $\lambda \leq v+c$ will end up watching TV and stations Y and Z will equally split this audience. Thus, deviation is not profitable if $\frac{1}{4}-\frac{v+c}{2} \geq \frac{1}{2A}$, or if $\frac{1}{2}-v-c \geq \frac{1}{A}$. Intuitively, a larger value of v is associated with a higher audience size since more viewers end up watching TV. A higher sampling cost means that if sampling occurs in the absence of a tune-in, a higher fraction of those who sample stay tuned. When the number of non-program minutes is small, the marginal benefit of promoting the upcoming program is lower. So, in all three cases, the incentive for passing up on airing a tune-in is higher when $(y,z)=(0,0)$. As a result, the 'partially-revealing' PBE breaks down and only the 'non-revealing' PBE survives.

An important feature of the 'partially-revealing' PBE is that it has the same aggregate audience size as in a 'no tune-in' regime. In contrast to the 'non-revealing' PBE, now, neither station airs a tune-in for a program that is unanimously more superior for its first-period viewers than its rival's upcoming program. When, for instance, station Y airs a tune-in for $y=0$, it understood that z is either 0 or $\frac{1}{2}$. If it turns out that $z=0$, those who have switched to Z and have locations $v<\lambda \leq v+c$ will find themselves in a hold-up situation and will stay tuned in rather than switch off. Thus, in a 'partially-revealing' PBE, stations only lose on the forgone revenue they could have earned from commercials, but otherwise maintain the same *ex ante* expected audience size as in a 'no tune-in' regime.

Confining attention to the set of parameter values where $\frac{1}{4}+c<v<\frac{1}{2}-c$, the following results have been established so far:

(i) All PBE involve tune-ins if $\frac{1}{2}-v>\frac{1}{A}$ (Proposition 2);

(ii) A 'non-revealing' PBE always exists (Proposition 3);

(iii) A 'partially-revealing' PBE exists if $\frac{1}{2} - v - c \geq \frac{1}{A}$ (Proposition 4).

If TV stations were instead privately informed only about their own upcoming programs, a 'no tune-in' PBE could be maintained if and only if $\frac{1}{3}\left(\frac{1}{2} - v - c\right) \leq \frac{1}{A}$. To see this, suppose viewers anticipate seeing no tune-ins in equilibrium. On the equilibrium path, the audience share of station Y will be as in Table 2. If station Y unexpectedly airs a tune-in for $y = 0$, then first-period Y-viewers with $\lambda \leq \frac{1}{4} + \frac{c}{2}$ would stay at Y and the rest would switch to Z. Those who have switched to Z would stay there if $z = 0$ or $\frac{1}{2}$. If $z = 1$, then viewers compare the utility of switching back to Y, $(v - c - \lambda)$, with the utility of switching off, $(-c)$, so those viewers with $\lambda \leq v$ switch back. As a result, airing a tune-in for $y = 0$ is profitable if

$$\frac{1}{3}\left(\frac{1}{4} + \frac{c}{2} - \frac{v+c}{2}\right) + \frac{1}{3}\left(\frac{1}{4} + \frac{c}{2} - \frac{1}{4}\right) + \frac{1}{3}\left(v - (v+c)\right) > \frac{1}{2A}$$

$$\Leftrightarrow \frac{1}{3}\left(\frac{1}{2} - v - c\right) > \frac{1}{A}.$$

This means that if $\frac{1}{3}\left(\frac{1}{2} - v - c\right) > \frac{1}{A}$, then the only PBE under pure private information is the 'non-revealing' PBE. Under common private information, on the other hand, a second PBE – the 'partially-revealing' PBE – exists along with the 'non-revealing' one.

From viewers' point of view, the *ex ante* expected per-viewer revenue of station Y is the average of the revenues in each of the possible nine (y, z) pairs. Per-viewer revenue in the first period is $pA\frac{1}{2}$ in each case. Per-viewer revenue in the second period in a 'non-revealing' PBE is the average of the audience shares for all of the nine cases given in Table 3, multiplied with pA. Since Y is expected to air a tune-in in six of the nine cases, its expected per-viewer (opportunity) cost is $\frac{6p}{9}$, multiplied with the audience share in the first period. So, the *ex ante* expected per-viewer revenue of station Y can be expressed as

$$E[\Pi_Y^{NR}] = \left[\frac{A}{2} + \frac{(6v + 4c + 1)\,A}{9} - \frac{1}{3}\right] p, \tag{1}$$

where the superscript NR stands for 'non-revealing.' Since stations Y and Z are *ex ante* identical in every manner, $E[\Pi_Z^{NR}] = E[\Pi_Y^{NR}]$.

Arguing along similar lines and noting that station Y is expected to air a tune-in in four of the nine possible (y, z) pairs in a 'partially-revealing' PBE, the *ex ante* expected per-viewer revenue of each station in this case will be

$$E[\Pi_Y^{PR}] = E[\Pi_Z^{PR}] = \left[\frac{A}{2} + \frac{(6v + 6c + 1)\, A}{9} - \frac{2}{9}\right] p, \tag{2}$$

where the superscript PR stands for 'partially-revealing.'

Simple comparison yields that $E\left[\Pi_j^{PR}\right]$ is always greater than $E\left[\Pi_j^{NR}\right]$. Actually, the 'partially-revealing' PBE is not only less costly because it involves fewer tune-ins, but also is it associated with a higher expected audience size in the second period. As described earlier, this is because of the fact that viewers will have less precise information about the upcoming programs and therefore will engage in more program sampling. As a result, given that the cost of sampling becomes sunk once it happens, a higher fraction of those who do sampling will stay tuned. Even though $E\left[\Pi_j^{PR}\right] > E\left[\Pi_j^{NR}\right]$, the existence of profitable deviations for particular (y, z) pairs may induce TV stations to ignore their information about their rival's upcoming program, and play the 'non-revealing' PBE instead.

These observations suggest that, even though both the 'non-revealing' and the 'partially-revealing' PBE co-exist when $\frac{1}{2} - v - c < \frac{1}{A}$, the latter will be more likely to be played if viewers anticipate the TV stations to coordinate on the less costly strategies. However, if the viewers are pessimistic in the sense that they only expect the worse when they do not see a tune-in, then the unique PBE will be the 'non-revealing' one.

5 Social Value of Tune-ins

In this section, I analyze the social value of tune-ins and consider the effects of a possible ban on their use. The classical quality disclosure literature typically finds excessive information disclosure. Celik [2012] shows that voluntary level of disclosure may be insufficient when the product has horizontal attributes. In the current context, along with horizontal differentiation, one needs to account for competition and program sampling. While one would expect competition to induce a higher level of information disclosure, a higher cost for program sampling may lower disclosure incentives. Therefore, it is *a priori* unclear whether there is any need for intervention.

I compare the expected social welfare under a 'no tune-in' regime with those that have no restrictions. I assume $\frac{1}{4} + c < v < \frac{1}{2} - c$ in this section so that the 'partially-revealing'

PBE exists for a non-empty set of parameter values. In Appendix B, I find the *ex ante* expected utility of a random viewer in all of the possible three equilibria: the 'no tune-in' PBE (NT), the 'non-revealing' PBE (NR), and the 'partially-revealing' PBE (PR).

In a regime of no tune-ins, *ex ante* expected per-viewer revenue of a station in the second period is simply the average of the audience shares given in Table 2, multiplied with the number of commercials and the per-viewer price. The stations are symmetric in every manner, so the total *ex ante* expected per-viewer revenue of station j, $j = Y$, Z, is given by

$$E[\Pi_j^{NT}] = A\left[\frac{1}{2} + \frac{6\,(v+c)+1}{9}\right]p. \tag{3}$$

Let W^j denote the expected social welfare under regime j, $j = NT$, NR, PR. I use the conventional approach and let W^j equal the *ex ante* expected total revenue of the two stations plus the *ex ante* expected aggregate viewer utility. In Appendix B, I show that

$$E\left[U^{NR} - U^{NT}\right] = \frac{1}{9}\left(\frac{15}{2} - 6v - 10c\right)c, \tag{4}$$

$$E\left[U^{PR} - U^{NT}\right] = \left(\frac{1}{3} - c\right)c, \tag{5}$$

where $E[U^j]$ refers to the expected utility of a random viewer in regime j, $j = NT$, NR, PR. Given that $c < \frac{1}{8}$ and $v - c < \frac{1}{2}$, it is easy to see that both of these terms are strictly positive. It is also straightforward to verify that $E\left[U^{NR} - U^{NT}\right] > E\left[U^{PR} - U^{NT}\right]$. Hence, not surprisingly, expected viewer utility is highest under the equilibrium configuration with the highest number of tune-ins, and lowest under the one with no tune-ins. Given the expected viewer utility difference in (4) and the expected revenues in (1) and (3), the difference in the expected social welfare between NR and NT regimes can be expressed as

$$\begin{aligned}
W^{NR} - W^{NT} &= N\left[E\left[U_\lambda^{NR} - U_\lambda^{NT}\right] + 2E[\Pi_j^{NR} - \Pi_j^{NT}]\right] \\
&= N\left[\left(\frac{15}{2} - 6v - 10c\right)\frac{c}{9} - 2\left(\frac{p}{3} + \frac{2cA}{9}\right)\right] \\
&= N\left[\left(\frac{15}{2} - 6v - 10c - 4A\right)\frac{c}{9} - \frac{2p}{3}\right].
\end{aligned}$$

Note that $\left(\frac{15}{2} - c - 6v - 4A\right) < 0$ for any $A \geq 2$, so $W^{NR} < W^{NT}$ for all parameter values. This means that it is welfare improving to ban tune-ins if the resulting PBE is the 'non-revealing' PBE. This is especially relevant for $\frac{1}{2} - \frac{1}{A} < v + c < \frac{1}{2}$, when 'non-revealing' PBE is the unique outcome. Even though viewers are better off in the 'non-revealing' PBE, the average amount of revenue stations lose is too high. This is due not only to the opportunity costs stations incur to air tune-ins, but also to the reduced aggregate audience size since viewers make better-informed decisions with more information provided.

The same result does not carry over to the case of 'partially-revealing' PBE. The expected aggregate audience size in this case is the same as in the 'no tune-in' regime. Hence, the only comparison is between the utility difference and the revenue difference between the two regimes. Given the expected viewer utility difference in (5) and the expected revenues in (2) and (3), the difference in the expected social welfare between PR and NT regimes is

$$\begin{aligned} W^{PR} - W^{NT} &= N\left[E\left[U_\lambda^S - U_\lambda^{NT}\right] + 2E[\Pi_j^S - \Pi_j^{NT}]\right] \\ &= N\left[\left(\frac{1}{3} - c\right)c - \frac{4p}{9}\right]. \end{aligned}$$

which is positive when $p < \frac{9c}{4}\left(\frac{1}{3} - c\right)$. These findings are summarized in the next proposition.

Proposition 5 *The 'partially-revealing' PBE produces the highest ex ante expected welfare when* $p < \frac{9c}{4}\left(\frac{1}{3} - c\right)$. *In all other situations, it is welfare improving to ban tune-ins.*

It immediately follows from Proposition 5 that it may be welfare improving if the two stations were owned by the same media company which maximized total ad revenues. By Proposition 1, a PBE with no tune-ins exists in such a case. Thus, as long as the conditions of Proposition 5 hold, common ownership may be better for the society as a whole. This is formally stated in the next proposition.

Proposition 6 *Common ownership of the two stations may improve the ex ante expected welfare when* $p \geq \frac{9c}{4}\left(\frac{1}{3} - c\right)$.

Tune-ins clearly benefit viewers. Without tune-ins, viewers would engage in too much inefficient program sampling and some would end up watching TV although it yields a negative utility. If viewers had complete information about program attributes, TV stations would serve a smaller audience size because of the informed decisions viewers would make. However, incomplete information about program attributes creates a competition for viewers that induces TV stations to promote their upcoming programs. In a 'non-revealing' PBE, TV stations are forced by market conditions to air too many tune-ins. The higher the number of tune-ins, the better choices people make, which implies a smaller audience size in the second period. As a result, the stations are double jeopardized; on the one hand, they lose revenues on the tune-ins they air, on the other hand, they get fewer viewers on average. The resulting revenue loss is larger than the increase in the well-being of viewers. Therefore, banning tune-ins is welfare improving.

The former one of the two factors above is also present in the 'partially-revealing' PBE; stations lose revenues on the tune-ins they air. However, now, stations promote their programs only when their own as well as their rival's program is a good match for their first-period audiences, leading to fewer tune-ins on average. When a station airs a tune-in, it helps its first-period viewers avoid any inefficient program sampling they would make without a tune-in, thus improving the average viewer surplus, but otherwise do not change how many of them stay tuned at the end. The situations when viewers do not see a tune-in are those when one or both of the stations offer a badly-matching program. As a result, in these situations, viewers engage in as many inefficient program samplings as they would in a 'no tune-in' regime, and therefore the expected aggregate audience size is the same as in a 'no tune-in' regime. When the per-viewer commercial price is low relative to the sampling cost, the increase in the well-being of viewers is higher than the revenue loss of the TV stations due to tune-ins, and therefore no intervention is necessary.

In summary, although TV stations generally air too many tune-ins, one cannot say if banning tune-ins all together improves the *ex ante* expected welfare or not. If the sampling costs viewers incur are relatively low, then an equilibrium without any tune-ins would generate a higher welfare. Otherwise, an equilibrium that provides 'just enough' information to viewers may be welfare superior.

6 Conclusion

Information disclosure decision of a firm may reveal indirect information about the attributes of a rival firm's product. I have formally analyzed this problem in the context of a horizontally differentiated duopoly TV market that last for two periods. The motive for business stealing induces TV stations to air a tune-in for their upcoming programs. Depending on the parameter values, there may be two types of equilibria. In the first one, referred to as the 'non-revealing' equilibrium, each station's tune-in decision depends only on its own program, independently of the rival's program. This is the unique equilibrium when either the sampling cost is relatively high and/or the TV stations have a small number of ads. Otherwise, there is a second equilibrium, referred to as the 'partially-revealing' equilibrium, in which each station's tune-in decision depends on its own as well as its rival's program. In this equilibrium, a station chooses to air a tune-in only when its rival has a comparable upcoming program that some of its first-period viewers may prefer.

The 'partially-revealing' equilibrium is not only associated with fewer tune-ins but also does it generate a higher aggregate audience size compared to the 'non-revealing' equilibrium since viewers engage in more program sampling. At the same time, it helps viewers avoid some of the inefficient program sampling they would do in an environment without any tune-ins. From an *ex ante* welfare perspective, it may therefore dominate a 'no tune-in' regime. The same, however, is not true for the 'non-revealing' equilibrium. Therefore, it may sometimes be socially better if the stations had a common ownership and did not air any tune-ins.

The TV industry has some attractive features that made the analysis analytically tractable. Most importantly, it is a segmented market in terms of viewer preferences which facilitates targeting of tune-ins, network stations do not price their programs, and tune-ins are exclusive in the sense that a TV station cannot advertise to the other station's audience. The analysis can be extended to other media markets that are segmented in terms of the preferences of the customers they serve. The market for movies is a perfect example; cinemas promote their upcoming movies exclusively to the customers of an ongoing movie at the beginning of the screening. Another example is the market for newspapers which is highly segmented in terms of the political views of readers. The analysis also provides valuable insights into some product markets. If, for instance, two competing food stores differ in terms of the age groups of their main clientele, then an in-store promotion for Coke in one may indirectly mean that the other probably has an in-store promotion for Coke, too, rather than for Pepsi.

Appendix A: Proofs

Proof of Proposition 1. Suppose viewers do not anticipate any tune-ins and assume $v + c < \frac{1}{2}$. It suffices to analyze the behavior of viewers with locations $\lambda \in \left[0, \frac{1}{4}\right]$. The remaining possibilities are simply symmetric. Suppose a λ-type viewer chooses to sample one of the two upcoming programs. If $\lambda \leq \frac{1}{2} - v - c$, then this viewer knows that she would only watch a program located at 0. Suppose the program that she samples first is not at 0 and she also samples the program in the other station. Unless the other program happens to be located at 0, she would turn her TV off and her net utility would be $-2c$ since she would have sampled both programs and ended up taking the outside option. So, the expected utility of sampling the other station is $\frac{1}{3}(v - c - \lambda) + \frac{2}{3}(-2c)$. On the other hand, if she switches off without sampling the other station, she would enjoy a utility of $-c$. She should engage in a second sampling if $\frac{1}{3}(v - c - \lambda) + \frac{2}{3}(-2c) \geq -c$, or equivalently if $v - \lambda \geq 2c$. Given that left-hand side is decreasing in λ and $v - \left(\frac{1}{2} - v - c\right) \geq 2c$ by Assumption 1, it is true for all $\lambda \leq \frac{1}{2} - v - c$. We also need to check if engaging in the first sampling is optimal at all for this person. Expected utility of doing so is $\frac{1}{3}(v - \lambda) + \frac{2}{3}\left[\frac{1}{3}(v - c - \lambda) + \frac{2}{3}(-2c)\right]$, where the second term is due to the fact that it is also optimal to sample the other station when the first program sampled is not at 0. Rearranging, this term becomes $\frac{5}{9}[v - \lambda - 2c]$, which is non-negative if $v - \lambda \geq 2c$, the same condition as above. Therefore, expected utility of first sampling is non-negative.

Now, take a viewer with location $\lambda \in \left[\frac{1}{2} - v - c, \frac{1}{4}\right]$ and suppose that this viewer samples station Y. She stays at Y if y is located at 0. If it turns out that $y = \frac{1}{2}$, she may also want to check out station Z in the hopes of finding out $z = 0$. But there is also the chance that z is $\frac{1}{2}$ or 1. If $z = 1$, she would switch back to station Y. If, on the other hand, $z = \frac{1}{2}$, she would be indifferent between the two stations. Thus, the expected utility of switching to Z when $y = \frac{1}{2}$ is $\frac{1}{3}(v - c - \lambda) + \frac{2}{3}(v - c - \frac{1}{2} + \lambda)$. If this expression is greater than the utility of staying at Y, $v - (\frac{1}{2} - \lambda)$, she should switch and sample the program at station Z. This is satisfied when $\lambda < \frac{1}{4} - \frac{3c}{2}$. So, when $y = \frac{1}{2}$, it is optimal to also sample Z for viewers with locations $\frac{1}{2} - v - c \leq \lambda < \frac{1}{4} - \frac{3c}{2}$. Finally, suppose it turns out that $y = 1$. In this case, the expected utility of switching to Z is

$\frac{1}{3}(v-c-\lambda)+\frac{1}{3}(v-c-\frac{1}{2}+\lambda)+\frac{1}{3}(-2c)$ which equals $\frac{1}{3}(2v-4c-\frac{1}{2})$. This is greater than the utility switching off, $-c$, when $2v-c>\frac{1}{2}$, which is again true by Assumption 1. As before, we also need to check if sampling Y was optimal at all at the first place. Following similar steps as above, it is straightforward to show that the expected utility of doing so is non-negative for all $\lambda \in \left[\frac{1}{2}-v-c, \frac{1}{4}\right]$.

Hence, all viewers with locations $\lambda \in \left[0, \frac{1}{4}\right]$ sample at least one of the stations. If the location of the program a viewer samples first is less than $\frac{1}{4}+\frac{3c}{2}$ units away from her location, then that viewer stops sampling. Otherwise, she samples the program at the other station, too (and switch off at the end if she cannot find anything she likes). The media company cannot do any better by airing tune-ins. So, a 'no tune-in' PBE exists.

To reach Table 2, take as an example $(y,z)=(0,\frac{1}{2})$. A random half of the viewers sample station Y first. Among these viewers, those with $\lambda \leq \frac{1}{4}+\frac{3c}{2}$ stay at Y while the rest switch to Z. Since $z=\frac{1}{2}$, those with $\lambda > \frac{1}{2}+v+c$ turn their TVs off. From among the other half who chose to sample Z first, the ones with $\lambda \in \left[\frac{1}{4}-\frac{3c}{2}, \frac{3}{4}+\frac{3c}{2}\right]$ stay at Z while the others switch to Y. Those with $\lambda < \frac{1}{4}-\frac{3c}{2}$ stay at Y. The same is not true for $\lambda > \frac{3}{4}+\frac{3c}{2}$. The program $y=0$ is not favorable for them, so those with locations $\lambda \in \left[\frac{3}{4}+\frac{3c}{2}, \frac{1}{2}+v+c\right]$ switch back to station Z while the rest switch off. So, all together, we get an audience share of $\frac{1}{2}(\frac{1}{4}+\frac{3c}{2})+\frac{1}{2}(\frac{1}{4}-\frac{3c}{2})=\frac{1}{4}$ for station Y. Similarly, it is $\frac{1}{2}(\frac{1}{2}+v+c-(\frac{1}{4}+\frac{3c}{2}))+\frac{1}{2}(\frac{1}{2}+v+c-(\frac{1}{4}-\frac{3c}{2}))=v+c$ for station Z. Audience shares for other program pairs follow similar arguments.

Above calculations were made for $v+c<\frac{1}{2}$. When $v+c \geq \frac{1}{2}$, similar calculations lead to the following table:

	$\mathbf{z=0}$	$\mathbf{z=\frac{1}{2}}$	$\mathbf{z=1}$
$\mathbf{y=0}$	$\frac{v+c}{2}, \frac{v+c}{2}$	$\frac{1}{4}, \frac{3}{4}$	$\frac{1}{2}, \frac{1}{2}$
$\mathbf{y=\frac{1}{2}}$	$\frac{3}{4}, \frac{1}{4}$	$\frac{1}{2}, \frac{1}{2}$	$\frac{3}{4}, \frac{1}{4}$
$\mathbf{y=1}$	$\frac{1}{2}, \frac{1}{2}$	$\frac{1}{4}, \frac{3}{4}$	$\frac{v+c}{2}, \frac{v+c}{2}$

Table 2b. Audience shares of Y and Z in a 'no tune-in' PBE when $v+c \geq \frac{1}{2}$.

■

Proof of Proposition 2. Suppose there is a 'no tune-in' PBE and the audience shares are as those given in Table 1. Suppose Y aired a tune-in when $(y,z)=(0,0)$. For the indifferent viewer from the first-period audience of station Y, the expected utility of switching to Z is $\frac{1}{3}(v-\lambda)+\frac{1}{3}(v-\frac{1}{2}+\lambda)+\frac{1}{3}(v-c-\lambda)$, where the first term is the utility she would enjoy at Z when $z=0$, the second term is the utility she would enjoy at Z when $z=\frac{1}{2}$, and the third term is the utility she would enjoy at Y when $z=1$. This expression equals the utility of staying at Y, $v-\lambda$, for the viewer located at $\frac{1}{4}+\frac{c}{2}$, so the viewers with $\lambda \leq \frac{1}{4}+\frac{c}{2}$ do not switch to Z. Since this is a unilateral deviation, the behavior of the first-period viewers of station Z remains the same. The ones who switch to Z do not come back to Y since they would incur the sampling cost in such a case. So, station Y would gain an extra audience of $(\frac{1}{4}+\frac{c}{2})-\frac{v+c}{2}=\frac{1-2v}{4}$ by airing a tune-in, and thus its second-period advertising revenue would go up by $ANp\frac{1-2v}{4}$. The cost of airing a tune-in is the revenue forgone in the first period from a single commercial, which is $Np\frac{1}{2}$. Thus, it is profitable to deviate as long as $\frac{1}{2}-v>\frac{1}{A}$. Repeating the same analysis for $(y,z)=\left(0,\frac{1}{2}\right)$, station Y would gain an extra audience of $(\frac{1}{4}+\frac{c}{2})-\frac{1}{4}=\frac{c}{2}$ by airing a tune-in, and thus its second-period advertising revenue would go up by $ANp\frac{c}{2}$. Thus, it is profitable to deviate as long as $ANp\frac{c}{2}>Np\frac{1}{2}$, or if $c>\frac{1}{A}$.

Suppose now $v+c\geq\frac{1}{2}$ and the audience shares are as those given in Table 1b. Suppose Y aired a tune-in when $(y,z)=(0,0)$. Similar arguments as above establish that station Y would gain an extra audience of $\left(\frac{1}{4}+\frac{c}{2}+\frac{1}{2}\left(v+c-\frac{1}{2}\right)\right)-\frac{v+c}{2}=\frac{c}{2}$ by airing a tune-in, and thus its second-period advertising revenue would go up by $ANp\frac{c}{2}$. Again, it would be profitable to deviate as long as $c>\frac{1}{A}$. The same result prevails for $(y,z)=\left(0,\frac{1}{2}\right)$ in this case, too. Hence, the result follows. ■

Proof of Proposition 3. Proof is obvious since punishment in case of a deviation is too high, as described in the main text. If, for instance, station Y does not air a tune-in, all of its viewers infer that $y=1$ and switch to station Z. They will never switch back to Y because even $z=1$ provides a utility that is as high.

One needs to check if, conditional on seeing no tune-ins in one of the stations, a viewer samples the other TV or not. Assume $v+c<\frac{1}{2}$ and take a first-period Y-viewer. Given $q_Y=0$, expected utility of switching to Z for $\lambda<\frac{1}{2}-v-c$ is

$$\frac{1}{3}(v-\lambda)+\frac{2}{3}(-c)=\frac{1}{3}(v-2c-\lambda).$$

Evaluated at $\lambda=\frac{1}{2}-v-c$, this is equal to $\frac{1}{3}\left(2v-c-\frac{1}{2}\right)$, which is positive by Assumption

1. So, it must be positive for all $\lambda < \frac{1}{2} - v - c$. Similarly, for $\frac{1}{2} - v - c \leq \lambda \leq \frac{1}{4}$, expected utility of switching to Z is

$$\frac{1}{3}(v - \lambda) + \frac{1}{3}(v - \frac{1}{2} + \lambda) + \frac{1}{3}(-c) = \frac{1}{3}\left(2v - c - \frac{1}{2}\right).$$

This term is again positive by Assumption 1. So, all $\lambda \leq \frac{1}{4}$ engage in sampling. The analysis for $\lambda \in \left[\frac{1}{4}, \frac{1}{2}\right]$ is symmetric.

Table 3 can be reached by calculating the total viewership in each case. Again, take as an example $(y, z) = (0, \frac{1}{2})$. In this case, both stations air a tune-in. As in the proof of Proposition 2, viewers with $\lambda < \frac{1}{4} + \frac{c}{2}$ stay at Y while the rest switch to Z and stay there once they find out that $z = \frac{1}{2}$. Similarly, viewers with $\frac{1}{2} < \lambda < \frac{3}{4} + \frac{c}{2}$ stay at Z while the rest switch to Y. When they find out that $y = 0$, those with $\frac{3}{4} + \frac{c}{2} \leq \lambda \leq \frac{1}{2} + v$ switch back to Z and the rest switch off. As a result, station Y gets an audience size of $\frac{1}{4} + \frac{c}{2}$, and Z gets $\left(v + \frac{1}{4} - \frac{c}{2}\right)$. Audience shares for other program pairs follow similar arguments.

When $v + c \geq \frac{1}{2}$, similar calculations lead to the following table:

	$\mathbf{z = 0}$	$\mathbf{z = \frac{1}{2}}$	$\mathbf{z = 1}$
$\mathbf{y = 0}$	$v - \frac{1}{4} + \frac{3c}{2}, \frac{1}{4} - \frac{c}{2}$	$\frac{1}{4} + \frac{c}{2}, \min\left\{v + \frac{1}{4}, \frac{3}{4}\right\} - \frac{c}{2}$	$\min\left\{v, \frac{1}{2}\right\}, \min\left\{v, \frac{1}{2}\right\}$
$\mathbf{y = \frac{1}{2}}$	$\frac{3}{4} + \frac{c}{2}, \frac{1}{4} - \frac{c}{2}$	$\frac{1}{2}, \frac{1}{2}$	$\min\left\{v + \frac{1}{4}, \frac{3}{4}\right\} - \frac{c}{2}, \frac{1}{4} + \frac{c}{2}$
$\mathbf{y = 1}$	$\frac{1}{2}, \frac{1}{2}$	$\frac{1}{4} - \frac{c}{2}, \frac{3}{4} + \frac{c}{2}$	$\frac{1}{4} - \frac{c}{2}, v - \frac{1}{4} + \frac{3c}{2}$

Table 3b. Audience shares of Y and Z in a 'non-revealing' PBE when $v + c \geq \frac{1}{2}$.

■

Proof of Proposition 4. Take Table 4 as given and assume $v + c < \frac{1}{2}$. To show that there are no profitable deviations, suppose $(y, z) = (0, 0)$. If station Y deviates and does not air a tune-in, then a random half of its viewers stay with it while the other half switch. Those who stayed would think that $z = 1$ upon seeing that $y = 0$, and the ones with locations less than $v + c$ would continue staying. Those who initially switched to Z would think that $y = 1$ upon seeing $z = 0$, and therefore none of them would switch back to Y. So, station Y would end up with an audience share of $\frac{v+c}{2}$. It is profitable to deviate if

$$A\left(\frac{1}{4} - \frac{v + c}{2}\right) < \frac{1}{2},$$

where the left hand side is the marginal per-viewer revenue of a tune-in and the right hand side is the per-viewer cost of a tune-in. So, Y would not deviate if $v + c + \frac{1}{A} \leq \frac{1}{2}$. The same is true for $(y, z) = (0, \frac{1}{2}), (\frac{1}{2}, 0)$ and $(\frac{1}{2}, \frac{1}{2})$. Note that deviation is not profitable when $y = 1$ since station Y can only communicate with its own viewers, and none of them would watch a program located at 1. It remains to analyze if it is profitable for Y to deviate when $(y, z) = (0, 1)$ or $(\frac{1}{2}, 1)$. In both cases, station Y is already getting the highest possible audience share from its first period without a tune-in. So, airing a tune-in cannot increase Y's audience size. Therefore, deviation is not profitable in these two cases, either.

To construct Table 4, we look at three distinct cases separately:

Case (1): *Y airs a tune-in for $y = 0$.*

In this case, the viewers of Y infer that $z \in \{0, \frac{1}{2}\}$. Those with locations closer to $\frac{1}{2}$ will switch to Z. Whatever the location of z turns out, none of these viewers would come back to Y. So, the solution is simple; $\lambda \leq \frac{1}{4}$ stay with Y, the others switch to Z. Those who switch to Z will have the sampling cost sunk, and therefore $\frac{1}{4} < \lambda \leq v + c$ will stay with Z when $z = 0$. The others just switch off in this case. If z turns out $\frac{1}{2}$, then all of them stay with Z.

Case (2): *Y airs a tune-in for $y = \frac{1}{2}$.*

In this case, the viewers of Y infer that $z \in \{0, \frac{1}{2}\}$. Those with locations closer to 0 will have a tendency to switch to Z. Similar with case (1), $\lambda \geq \frac{1}{4}$ stay with Y, the others switch to Z. Those who switch to Z will have the sampling cost sunk, and therefore $\frac{1}{2} - (v + c) < \lambda \leq \frac{1}{2}$ will stay with Z when $z = \frac{1}{2}$. If z turns out 0, then all of them stay with Z.

Case (3): *Y does not air a tune-in.*

The inference of viewers in this case is that Y did not air a tune-in because either $y = 1$ and/or $z = 1$. There are five possibilities:

$$(y, z) \in \{(0, 1), (\frac{1}{2}, 1), (1, 0), (1, \frac{1}{2}), (1, 1)\}.$$

So the posterior probability that $y = 0$ is same with the probability that $z = 0$, which is $\frac{1}{5}$. Similarly, $\Pr(y = \frac{1}{2}) = \Pr(z = \frac{1}{2}) = \frac{1}{5}$, and $\Pr(y = 1) = \Pr(z = 1) = \frac{3}{5}$. This means that viewers are indifferent between the two stations, and a random half will choose Z first. For those who stayed with Y, the actual location of y will determine their further behavior.

If $y = 0$, they infer that $z = 1$. So viewers with locations less than $v + c$ stay with Y, and the rest switch off. If $y = \frac{1}{2}$, they infer that $z = 1$. So viewers with locations $\frac{1}{2} - (v + c) \leq \lambda \leq \frac{1}{2}$ stay with Y, and the rest switch off. If $y = 1$, they infer that $z \in \{0, \frac{1}{2}, 1\}$, each with equal probability. If the viewers with locations $\lambda < \frac{1}{2} - v - c$ choose to sample the program at station Z, they will stay there only when $z = 0$. So, the expected utility of sampling Z for a generic λ-viewer from this interval, denoted by $E\left[U_\lambda^Z\right]$, given that station Y did not air a tune-in is

$$\begin{aligned} E\left[U_\lambda^Z \mid q_Y = 0,\, y = 1\right] &= \frac{1}{3}(v - c - \lambda) - \frac{2}{3}(2c) \\ &= \frac{1}{3}(v - 5c - \lambda). \end{aligned}$$

Viewers would stay tuned in if this expression is not less than $-c$. Otherwise they turn their TVs off right after the first program ends. Evaluated at $\lambda = \frac{1}{2} - (v + c)$, the expected utility of sampling Z becomes $\frac{1}{3}(2v - \frac{1}{2}) - \frac{2}{3}(2c)$,. This is greater than $-c$ if $2v - \frac{1}{2} \geq c$, which is true by Assumption 1. Since $E\left[U_\lambda^Z \mid q_Y = 0\right]$ is decreasing in λ, all of these viewers would choose to sample Z. Viewers with locations $\frac{1}{2} - (v + c) < \lambda \leq \frac{1}{4}$ would stay with Z unless $z = 1$. So, their expected utility is

$$\begin{aligned} E\left[U_\lambda^Z \mid q_Y = 0,\, y = 1\right] &= \frac{1}{3}\left[(v - c - \lambda) + (v - c - (\frac{1}{2} - \lambda)) - (2c)\right] \\ &= \frac{1}{3}(2v - 4c - \frac{1}{2}). \end{aligned}$$

This expression is greater than or equal to $-c$ when $2v - \frac{1}{2} \geq c$, which is the same condition as before. Hence, it is satisfied for all $\lambda \in [0, \frac{1}{4}]$. The choices of viewers with locations on $[\frac{1}{4}, \frac{1}{2}]$ are just symmetric with those on $[0, \frac{1}{4}]$, so when $y = 1$, they all sample Z as well. If it turns out that $z = 0$ or $\frac{1}{2}$, station Z gets an audience size of $N(v + c)$. If $z = 1$, all first-period viewers of station Y would switch off after sampling both programs. For those of forst-period Y-viewers who switched to Z initially, the subsequent choices are similar.

Now, we need to check if sampling one of the stations is desirable at all, conditional on not seeing a tune-in. For $\lambda < \frac{1}{2} - (v + c)$, the expected utility of sampling station Y

is

$$E\left[U_\lambda^Y \mid q_Y = 0\right] = \frac{1}{5}(v-\lambda) + \frac{1}{5}(-c) + \frac{3}{5}\left[\frac{1}{3}(v - 5c - \lambda)\right].$$

Similarly, for $\frac{1}{2} - (v+c) \leq \lambda < \frac{1}{4}$, it is

$$E\left[U_\lambda^Y \mid q_Y = 0\right] = \frac{1}{5}(v-\lambda) + \frac{1}{5}(v - \frac{1}{2} + \lambda) + \frac{3}{5}\left[\frac{1}{3}(2v - 4c - \frac{1}{2})\right].$$

We need this value to be non-negative for a viewer to sample Y. For $\lambda < \frac{1}{2} - (v+c)$, $E\left[U_\lambda^Y \mid q_Y = 0\right] \geq 0$ when $\frac{1}{5}(2v - 6c - 2\lambda) \geq 0$, or when $\lambda \leq v - 3c$. Given that $\frac{1}{2} - (v+c) \leq v - 3c$ by Assumption 1, all $\lambda < \frac{1}{2} - (v+c)$ engage in sampling. For $\frac{1}{2} - (v+c) \leq \lambda < \frac{1}{4}$, $E\left[U_\lambda^Y \mid q_Y = 0\right] \geq 0$ when $\frac{1}{5}(4v - 4c - 1) \geq 0$, or when $v - c \geq \frac{1}{4}$, which is again true by Assumption 1. So, all $\lambda \leq \frac{1}{4}$ engage in sampling conditional on $q_Y = 0$. Everything is symmetric for station Z.

Given the sampling and viewing behavior of viewers, the audience shares in Table 4 can be reached by calculating the total viewership in each case. Again, take as an example $(y,z) = (0, \frac{1}{2})$. In this case, only station Y airs a tune-in. Now, first-period viewers of Y infer that z is either 0 or $\frac{1}{2}$, so those with $\lambda \geq \frac{1}{4}$ switch to Z and stay there once they find out $z = \frac{1}{2}$. First-period viewers of Z do not see a tune-in, so they infer that

$$(y,z) \in \{(0,1), (\frac{1}{2},1), (1,0), (1,\frac{1}{2}), (1,1)\}.$$

Since these beliefs place symmetric probabilities on y and z, half of the viewers of Z stay in Z while the rest switch Y. Eventually, however, those with $\frac{1}{2} < \lambda \leq \frac{1}{2} + v + c$ end up in station Z. As a result, station Y gets an audience size of $\frac{1}{4}$, and Z gets $v + c + \frac{1}{4}$. Audience shares for other program pairs follow similar arguments.

When $v + c \geq \frac{1}{2}$, similar calculations lead to the following table:

	$\mathbf{z=0}$	$\mathbf{z=\frac{1}{2}}$	$\mathbf{z=1}$
$\mathbf{y=0}$	$\frac{v+c}{2}, \frac{v+c}{2}$	$\frac{1}{4}, \frac{3}{4}$	$\frac{1}{2}, \frac{1}{2}$
$\mathbf{y=\frac{1}{2}}$	$\frac{3}{4}, \frac{1}{4}$	$\frac{1}{2}, \frac{1}{2}$	$\frac{3}{4}, \frac{1}{4}$
$\mathbf{y=1}$	$\frac{1}{2}, \frac{1}{2}$	$\frac{1}{4}, \frac{3}{4}$	$\frac{v+c}{2}, \frac{v+c}{2}$

Table 4b. Audience shares of Y and Z in a 'non-revealing' PBE when $v + c \geq \frac{1}{2}$.

Note that the audience shares in this case are identical with those in Table 2b. ■

Proof of Proposition 5. Expected viewer utility is calculated in Appendix B. Expected revenues of the stations in each regime and the construction of the expected welfare functions are given in the main text. Hence, the result follows from the fact that $W^{NR} - W^{NT}$ is always negative while $W^{PR} - W^{NT}$ is positive when $p < \frac{9c}{4}\left(\frac{1}{3} - c\right)$. ■

Proof of Proposition 6. Proof is obvious by Propositions 1 and 5. ■

Appendix B

In this section of the Appendix, I find the expected utility of a random viewer under three specifications; the 'non-revealing' PBE (NR), the 'partially-revealing' PBE (PR), and the 'no tune-in' PBE (NT). Derivations are made under the assumption that $v + c < \frac{1}{2}$. Only five cases are analyzed in detail. The remaining four cases are symmetric with the first four cases.

Case 1 $(y, z) = (0, 0)$.

NR: Station Y does, Z does not air a tune-in. Among those who watched Y in the first period, $\lambda \leq \frac{1}{4} + \frac{c}{2}$ stay with Y after seeing a tune-in for $y = 0$ while the others switch to Z. The ones who watched Z in the first period only sample Y since they infer that $z = 0$. But they eventually turn their TVs off. So,

$$U_\lambda^{NR} = \begin{cases} v - \lambda & \text{,if } 0 \leq \lambda \leq v + c \\ -c & \text{,if } v + c < \lambda \leq 1 \end{cases}.$$

PR: Station Y does, Z does not air a tune-in. Among those who watched Y in the first period, $\lambda \leq \frac{1}{4}$ stay with Y while the others switch to Z before the second period starts. After seeing that $z = 0$, $\lambda > v + c$ switch off. The ones who watched Z in the first period end up sampling both stations and eventually turn their TVs off. So,

$$U_\lambda^{PR} = \begin{cases} v - \lambda & \text{,if } 0 \leq \lambda \leq v + c \\ -c & \text{,if } v + c < \lambda \leq \frac{1}{2} \\ -2c & \text{,if } \frac{1}{2} < \lambda \leq 1 \end{cases}.$$

NT: A random half of viewers start with Y and the other half with Z. Viewers with locations $\lambda \leq \frac{1}{4} + \frac{3c}{2}$ settle on the first station they sample, thus incurring no sampling cost, while those with $\frac{1}{4}+\frac{3c}{2} \leq \lambda < v+c$ sample both stations and choose one at random. All others switch off after sampling both stations. So,

$$U_\lambda^{NT} = \begin{cases} v-\lambda & ,\text{if } 0 \leq \lambda \leq \frac{1}{4}+\frac{3c}{2} \\ v-c-\lambda & ,\text{if } \frac{1}{4}+\frac{3c}{2} < \lambda \leq v+c \\ -2c & ,\text{if } v+c < \lambda \leq 1 \end{cases}.$$

Taking the differences, we have the following:

$$U_\lambda^{NR} - U_\lambda^{NT} = \begin{cases} 0 & ,\text{if } 0 \leq \lambda \leq \frac{1}{4}+\frac{3c}{2} \\ c & ,\text{if } \frac{1}{4}+\frac{3c}{2} < \lambda \leq 1 \end{cases},$$

$$U_\lambda^{PR} - U_\lambda^{NT} = \begin{cases} 0 & ,\text{if } 0 \leq \lambda \leq \frac{1}{4}+\frac{3c}{2} \\ c & ,\text{if } \frac{1}{4}+\frac{3c}{2} < \lambda \leq \frac{1}{2} \\ 0 & ,\text{if } \frac{1}{2} < \lambda \leq 1 \end{cases}.$$

Integrating over λ, we get:

$$\begin{aligned} E\left[U^{NR} - U^{NT} \mid (y,z) = (0,0)\right] &= \left(\frac{3}{4} - \frac{3c}{2}\right)c, \\ E\left[U^{PR} - U^{NT} \mid (y,z) = (0,0)\right] &= \left(\frac{1}{4} - \frac{3c}{2}\right)c. \end{aligned}$$

Case 2 $(y,z) = (0, \frac{1}{2})$.

NR: Both stations air a tune-in. Among those who watched Y in the first period, $\lambda \leq \frac{1}{4}+\frac{c}{2}$ stay with Y after seeing a tune-in for $y=0$ while the others switch to Z and stay there. Behavior of the ones who watched Z in the first period is similar. Those with $\lambda > \frac{3}{4}+\frac{c}{2}$ initially switch to Y in the hope of finding out $y=1$. After discovering that $y=0$, $\frac{3}{4}+\frac{c}{2} < \lambda \leq \frac{1}{2}+v$ come back to Z while the others turn their TVs off. So,

$$U_\lambda^{NR} = \begin{cases} v-\lambda & ,\text{if } 0 \leq \lambda \leq \frac{1}{4}+\frac{c}{2} \\ v-(\frac{1}{2}-\lambda) & ,\text{if } \frac{1}{4}+\frac{c}{2} < \lambda \leq \frac{1}{2} \\ v-(\lambda-\frac{1}{2}) & ,\text{if } \frac{1}{2} < \lambda \leq \frac{3}{4}+\frac{c}{2} \\ v-c-(\lambda-\frac{1}{2}) & ,\text{if } \frac{3}{4}+\frac{c}{2} < \lambda \leq \frac{1}{2}+v \\ -c & ,\text{if } \frac{1}{2}+v < \lambda \leq 1 \end{cases}.$$

PR: Station Y does, Z does not air a tune-in. Among those who watched Y in the first period, $\lambda \leq \frac{1}{4}$ stay with Y while the others switch to Z and stay there. Among those who watched Z in the first period, a random half stay with Z. After seeing that $z=\frac{1}{2}$, they infer that $y=0$, so $\frac{1}{2} \leq \lambda \leq \frac{1}{2}+v+c$ stay and the others switch off. The other half start sampling with Y. After seeing that $y = 0$, they infer $z \in \{0, \frac{1}{2}, 1\}$, so all switch to Z. Those with $\frac{1}{2} \leq \lambda \leq \frac{1}{2} + v + c$ stay, the others switch off. So,

$$U_\lambda^{PR} = \begin{cases} v - \lambda & \text{,if } 0 \leq \lambda \leq \frac{1}{4} \\ v - (\frac{1}{2} - \lambda) & \text{,if } \frac{1}{4} < \lambda \leq \frac{1}{2} \\ \frac{1}{2}(v - \lambda + \frac{1}{2}) + \frac{1}{2}(v - c - \lambda + \frac{1}{2}) & \text{,if } \frac{1}{2} < \lambda \leq \frac{1}{2} + v + c \\ \frac{1}{2}(-c) + \frac{1}{2}(-2c) & \text{,if } \frac{1}{2} + v + c < \lambda \leq 1 \end{cases}.$$

NT: A random half of viewers start with Y and the other half with Z. Viewers with locations $\frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{1}{4} + \frac{3c}{2}$ settle on the first station they sample, thus incurring no sampling cost, while the others may end up sampling both stations. For $\lambda \leq \frac{1}{4} - \frac{3c}{2}$, if the viewer is lucky and started with Y, she stays there. If she started with Z, then she also samples Y. Similarly, $\frac{1}{4} + \frac{3c}{2} \leq \lambda \leq \frac{3}{4} + \frac{3c}{2}$ end up at Z either immediately or after initially sampling Y. All others sample both stations and those with $\frac{3}{4} + \frac{3c}{2} \leq \lambda \leq \frac{1}{2} + v + c$ stay tuned. So,

$$U_\lambda^{NT} = \begin{cases} \frac{1}{2}(v - \lambda) + \frac{1}{2}(v - c - \lambda) & \text{,if } 0 \leq \lambda < \frac{1}{4} - \frac{3c}{2} \\ \frac{1}{2}(v - \lambda) + \frac{1}{2}(v - \frac{1}{2} + \lambda) & \text{,if } \frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{1}{4} + \frac{3c}{2} \\ \frac{1}{2}(v - \frac{1}{2} + \lambda) + \frac{1}{2}(v - c - \frac{1}{2} + \lambda) & \text{,if } \frac{1}{4} + \frac{3c}{2} < \lambda \leq \frac{1}{2} \\ \frac{1}{2}(v - \lambda + \frac{1}{2}) + \frac{1}{2}(v - c - \lambda + \frac{1}{2}) & \text{,if } \frac{1}{2} < \lambda \leq \frac{3}{4} + \frac{3c}{2} \\ v - c - (\lambda - \frac{1}{2}) & \text{,if } \frac{3}{4} + \frac{3c}{2} < \lambda \leq \frac{1}{2} + v + c \\ -2c & \text{,if } \frac{1}{2} + v + c < \lambda \leq 1 \end{cases}.$$

Taking the differences, we have the following:

$$U_\lambda^{NR} - U_\lambda^{NT} = \begin{cases} \frac{c}{2} & \text{,if } 0 \leq \lambda < \frac{1}{4} - \frac{3c}{2} \\ \frac{1}{4} - \lambda & \text{,if } \frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{1}{4} + \frac{c}{2} \\ \lambda - \frac{1}{4} & \text{,if } \frac{1}{4} + \frac{c}{2} < \lambda \leq \frac{1}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{,if } \frac{1}{4} + \frac{3c}{2} < \lambda \leq \frac{3}{4} + \frac{c}{2} \\ -\frac{c}{2} & \text{,if } \frac{3}{4} + \frac{c}{2} < \lambda \leq \frac{3}{4} + \frac{3c}{2} \\ 0 & \text{,if } \frac{3}{4} + \frac{3c}{2} < \lambda \leq \frac{1}{2} + v \\ (\lambda - \frac{1}{2}) - v & \text{,if } \frac{1}{2} + v < \lambda \leq \frac{1}{2} + v + c \\ c & \text{,if } \frac{1}{2} + v + c < \lambda \leq 1 \end{cases},$$

$$U_\lambda^{PR} - U_\lambda^{NT} = \begin{cases} \frac{c}{2} & \text{,if } 0 \leq \lambda < \frac{1}{4} - \frac{3c}{2} \\ \frac{1}{4} - \lambda & \text{,if } \frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{1}{4} \\ \lambda - \frac{1}{4} & \text{,if } \frac{1}{4} < \lambda \leq \frac{1}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{,if } \frac{1}{4} + \frac{3c}{2} < \lambda \leq \frac{1}{2} \\ 0 & \text{,if } \frac{1}{2} < \lambda \leq \frac{3}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{,if } \frac{3}{4} + \frac{3c}{2} < \lambda \leq 1 \end{cases}.$$

Integrating over λ, we get:

$$\begin{aligned}
E\left[U^{NR} - U^{NT} \mid (y,z) = \left(0, \frac{1}{2}\right)\right] &= \left(\frac{3}{4} - \frac{7c}{2}\right)\frac{c}{2} + \frac{3c^2}{2} + \left(\frac{1}{2} - v\right)c \\
&= \left(\frac{7}{8} - \frac{c}{4} - v\right)c, \\
E\left[U^{PR} - U^{NT} \mid (y,z) = \left(0, \frac{1}{2}\right)\right] &= \left(\frac{3}{4} - \frac{9c}{2}\right)\frac{c}{2} + \frac{9c^2}{4} \\
&= \frac{3c}{8}.
\end{aligned}$$

Case 3 $(y,z) = (0,1)$.

NR: Both stations air a tune-in. So, $\lambda \leq \frac{1}{4} + \frac{c}{2}$ continue to stay with Y while $\frac{1}{4} + \frac{c}{2} < \lambda \leq v$ come back to Y after initially sampling Z. Behavior of the viewers who watched Z in the first period is just symmetric. So,

$$U_\lambda^{NS} = \begin{cases} v - \lambda & \text{,if } 0 \leq \lambda \leq \frac{1}{4} + \frac{c}{2} \\ v - c - \lambda & \text{,if } \frac{1}{4} + \frac{c}{2} < \lambda \leq v \\ -c & \text{,if } v < \lambda < 1 - v \\ v - c - (1 - \lambda) & \text{,if } 1 - v \leq \lambda < \frac{3}{4} - \frac{c}{2} \\ v - (1 - \lambda) & \text{,if } \frac{3}{4} - \frac{c}{2} \leq \lambda \leq 1 \end{cases}.$$

PR: Neither station airs a tune-in. Among those who watched Y in the first period, a random half stay with Y and infer that $z = 1$ after seeing $y = 0$. So, $0 \leq \lambda \leq v + c$ stay and the others switch off. The other half initially switch to Z. All of these viewers also sample Y after discovering that $z = 1$ and $0 \leq \lambda \leq v + c$ stay. Behavior of the viewers who watched Z in the first period is just symmetric. So,

$$U_\lambda^{PR} = \begin{cases} \frac{1}{2}(v - \lambda) + \frac{1}{2}(v - c - \lambda) & \text{,if } 0 \leq \lambda \leq v + c \\ \frac{1}{2}(-c) + \frac{1}{2}(-2c) & \text{,if } v + c < \lambda < 1 - (v + c) \\ \frac{1}{2}(v - 1 + \lambda) + \frac{1}{2}(v - c - 1 + \lambda) & \text{,if } 1 - (v + c) \leq \lambda \leq 1 \end{cases}.$$

NT: The viewing choices here are similar with the previous case.

$$U_\lambda^{NT} = \begin{cases} \frac{1}{2}(v - \lambda) + \frac{1}{2}(v - c - \lambda) & \text{,if } 0 \leq \lambda \leq \frac{1}{4} + \frac{3c}{2} \\ v - c - \lambda & \text{,if } \frac{1}{4} + \frac{3c}{2} < \lambda \leq v + c \\ -2c & \text{,if } v + c < \lambda < 1 - (v + c) \\ v - c - (1 - \lambda) & \text{,if } 1 - (v + c) \leq \lambda < \frac{3}{4} - \frac{3c}{2} \\ \frac{1}{2}(v - 1 + \lambda) + \frac{1}{2}(v - c - 1 + \lambda) & \text{,if } \frac{3}{4} - \frac{3c}{2} \leq \lambda \leq 1 \end{cases}.$$

Taking the differences, we have the following:

$$U_\lambda^{NR} - U_\lambda^{NT} = \begin{cases} \frac{c}{2} & \text{,if } 0 \le \lambda \le \frac{1}{4} + \frac{c}{2} \\ -\frac{c}{2} & \text{,if } \frac{1}{4} + \frac{c}{2} < \lambda \le \frac{1}{4} + \frac{3c}{2} \\ 0 & \text{,if } \frac{1}{4} + \frac{3c}{2} < \lambda \le v \\ \lambda - v & \text{,if } v < \lambda \le v + c \\ c & \text{,if } v + c < \lambda < 1 - (v + c) \\ 1 - \lambda - v & \text{,if } 1 - (v + c) < \lambda < 1 - v \\ 0 & \text{,if } 1 - v < \lambda < \frac{3}{4} - \frac{3c}{2} \\ -\frac{c}{2} & \text{,if } \frac{3}{4} - \frac{3c}{2} \le \lambda < \frac{3}{4} - \frac{c}{2} \\ \frac{c}{2} & \text{,if } \frac{3}{4} - \frac{c}{2} \le \lambda \le 1 \end{cases},$$

$$U_\lambda^{PR} - U_\lambda^{NT} = \begin{cases} 0 & \text{,if } 0 \le \lambda \le \frac{1}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{,if } \frac{1}{4} + \frac{3c}{2} \le \lambda < \frac{3}{4} - \frac{3c}{2} \\ 0 & \text{,if } \frac{3}{4} - \frac{3c}{2} \le \lambda \le 1 \end{cases}.$$

Integrating over λ, we get:

$$\begin{aligned} E\left[U^{NR} - U^{NT} \mid (y,z) = (0,1)\right] &= \left(\frac{5}{4} - \frac{3c}{2} - 2v\right) c, \\ E\left[U^{PR} - U^{NT} \mid (y,z) = (0,1)\right] &= \left(\frac{1}{4} - \frac{3c}{2}\right) c. \end{aligned}$$

Case 4 $(y,z) = (\frac{1}{2}, 0)$.

NR: Station Y does, Z does not air a tune-in. Among those who watched Y in the first period, $\lambda \ge \frac{1}{4} - \frac{c}{2}$ stay with Y while the others initially switch to Z and stay there after seeing that $z = 0$. The viewers who watched Z in the first period switch to Y and those with $\frac{1}{2} \le \lambda \le \frac{1}{2} + v + c$ stay there. So,

$$U_\lambda^{NR} = \begin{cases} v - \lambda & \text{, if } 0 \le \lambda < \frac{1}{4} - \frac{c}{2} \\ v - (\frac{1}{2} - \lambda) & \text{, if } \frac{1}{4} - \frac{c}{2} \le \lambda \le \frac{1}{2} \\ v - (\lambda - \frac{1}{2}) & \text{, if } \frac{1}{2} < \lambda \le \frac{1}{2} + v + c \\ -c & \text{, if } \frac{1}{2} + v + c < \lambda \le 1 \end{cases}.$$

PR: Station Y does, Z does not air a tune-in. Among those who watched Y in the first period, $\lambda \ge \frac{1}{4}$ stay with Y while the others initially switch to Z and stay there after seeing that $z = 0$. Among those who watched Z in the first period, the random half that started sampling with Y are lucky as they infer that $z = 0$. So, those with $\frac{1}{2} \le \lambda \le \frac{1}{2} + v + c$ stay, the others turn their TVs off. The other half sample both stations and those with $\frac{1}{2} \le \lambda \le \frac{1}{2} + v + c$ end up watching Y. So,

$$U_\lambda^{PR} = \begin{cases} v - \lambda & \text{, if } 0 \le \lambda < \frac{1}{4} \\ v - \left(\frac{1}{2} - \lambda\right) & \text{, if } \frac{1}{4} \le \lambda \le \frac{1}{2} \\ \frac{1}{2}\left(v - \lambda + \frac{1}{2}\right) + \frac{1}{2}\left(v - c - \lambda + \frac{1}{2}\right) & \text{, if } \frac{1}{2} < \lambda \le \frac{1}{2} + v + c \\ \frac{1}{2}(-c) + \frac{1}{2}(-2c) & \text{, if } \frac{1}{2} + v + c < \lambda \le 1 \end{cases}.$$

NT: Same with Case (2). So,

$$U_\lambda^{NT} = \begin{cases} \frac{1}{2}(v-\lambda) + \frac{1}{2}(v-c-\lambda) & \text{, if } 0 \le \lambda < \frac{1}{4} - \frac{3c}{2} \\ \frac{1}{2}(v-\lambda) + \frac{1}{2}(v - \frac{1}{2} + \lambda) & \text{, if } \frac{1}{4} - \frac{3c}{2} \le \lambda \le \frac{1}{4} + \frac{3c}{2} \\ \frac{1}{2}(v - \frac{1}{2} + \lambda) + \frac{1}{2}(v - c - \frac{1}{2} + \lambda) & \text{, if } \frac{1}{4} + \frac{3c}{2} < \lambda \le \frac{1}{2} \\ \frac{1}{2}(v - \lambda + \frac{1}{2}) + \frac{1}{2}(v - c - \lambda + \frac{1}{2}) & \text{, if } \frac{1}{2} < \lambda \le \frac{3}{4} + \frac{3c}{2} \\ v - c - (\lambda - \frac{1}{2}) & \text{, if } \frac{3}{4} + \frac{3c}{2} < \lambda \le \frac{1}{2} + v + c \\ -2c & \text{, if } \frac{1}{2} + v + c < \lambda \le 1 \end{cases}.$$

Taking the differences, we have the following:

$$U_\lambda^{NR} - U_\lambda^{NT} = \begin{cases} \frac{c}{2} & \text{, if } 0 \le \lambda < \frac{1}{4} - \frac{3c}{2} \\ \frac{1}{4} - \lambda & \text{, if } \frac{1}{4} - \frac{3c}{2} \le \lambda < \frac{1}{4} - \frac{c}{2} \\ \lambda - \frac{1}{4} & \text{, if } \frac{1}{4} - \frac{c}{2} \le \lambda < \frac{1}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{, if } \frac{1}{4} + \frac{3c}{2} < \lambda \le \frac{3}{4} + \frac{3c}{2} \\ c & \text{, if } \frac{3}{4} + \frac{3c}{2} < \lambda \le 1 \end{cases},$$

$$U_\lambda^{PR} - U_\lambda^{NT} = \begin{cases} \frac{c}{2} & \text{, if } 0 \le \lambda < \frac{1}{4} - \frac{3c}{2} \\ \frac{1}{4} - \lambda & \text{, if } \frac{1}{4} - \frac{3c}{2} \le \lambda < \frac{1}{4} \\ \lambda - \frac{1}{4} & \text{, if } \frac{1}{4} \le \lambda \le \frac{1}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{, if } \frac{1}{4} + \frac{3c}{2} < \lambda \le \frac{1}{2} \\ 0 & \text{, if } \frac{1}{2} < \lambda \le \frac{3}{4} + \frac{3c}{2} \\ \frac{c}{2} & \text{, if } \frac{3}{4} + \frac{3c}{2} < \lambda \le 1 \end{cases}.$$

Integrating over λ, we get:

$$\begin{aligned} E\left[U^{NR} - U^{NT} \mid (y,z) = \left(\frac{1}{2}, 0\right)\right] &= \left(\frac{5}{4} - \frac{9c}{2}\right)\frac{c}{2} + 2c^2 \\ &= \left(\frac{5}{8} - \frac{c}{4}\right)c, \\ E\left[U^{PR} - U^{NT} \mid (y,z) = \left(\frac{1}{2}, 0\right)\right] &= \left(\frac{3}{4} - \frac{9c}{2}\right)\frac{c}{2} + \frac{9c^2}{4} \\ &= \frac{3c}{8}. \end{aligned}$$

Case 5 $(y,z) = (\frac{1}{2}, \frac{1}{2})$.

NR: Both stations air a tune-in. $\frac{1}{4} - \frac{c}{2} \le \lambda \le \frac{3}{4} + \frac{c}{2}$ stay with the stations they watched in the in the first period. The others switch to the other station and stay there, except for $\lambda < \frac{1}{2} - v - c$ and $\lambda > \frac{1}{2} + v + c$, who switch off. So,

$$U_\lambda^{NR} = \begin{cases} -c & \text{, if } 0 \le \lambda < \frac{1}{2} - v - c \\ v - (\frac{1}{2} - \lambda) & \text{, if } \frac{1}{2} - v - c \le \lambda \le \frac{1}{2} \\ v - (\lambda - \frac{1}{2}) & \text{, if } \frac{1}{2} < \lambda \le \frac{1}{2} + v + c \\ -c & \text{, if } \frac{1}{2} + v + c < \lambda \le 1 \end{cases}.$$

PR: Both stations air a tune-in. $\frac{1}{4} \leq \lambda \leq \frac{3}{4}$ stay with the stations they watched in the first period. The others switch to the other station; those with $\lambda < \frac{1}{2} - v - c$ and $\lambda > \frac{1}{2} + v + c$ switch off while the others stay there. So, U_λ^{PR} remains the same as above, i.e., $U_\lambda^{PR} = U_\lambda^{NR}$.

NT: Those with $\frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{3}{4} + \frac{3c}{2}$ stay with the stations they sample first. Others sample both stations and those with $\frac{1}{2} - v - c \leq \lambda \leq \frac{1}{4} - \frac{3c}{2}$ and $\frac{3}{4} + \frac{3c}{2} \leq \lambda \leq \frac{1}{2} + v + c$ choose to watch one of them at random. The others turn their TVs off. So,

$$U_\lambda^{NT} = \begin{cases} -2c & \text{, if } 0 \leq \lambda < \frac{1}{2} - v - c \\ v - c - (\frac{1}{2} - \lambda) & \text{, if } \frac{1}{2} - v - c \leq \lambda < \frac{1}{4} - \frac{3c}{2} \\ v - (\frac{1}{2} - \lambda) & \text{, if } \frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{1}{2} \\ v - (\lambda - \frac{1}{2}) & \text{, if } \frac{1}{2} < \lambda \leq \frac{3}{4} + \frac{3c}{2} \\ v - c - (\lambda - \frac{1}{2}) & \text{, if } \frac{3}{4} + \frac{3c}{2} < \lambda \leq \frac{1}{2} + v + c \\ -2c & \text{, if } \frac{1}{2} + v + c < \lambda \leq 1 \end{cases}.$$

Taking the differences, we have the following:

$$U_\lambda^{NR} - U_\lambda^{NT} = U_\lambda^{PR} - U_\lambda^{NT} = \begin{cases} c & \text{,if } 0 \leq \lambda < \frac{1}{4} - \frac{3c}{2} \\ 0 & \text{,if } \frac{1}{4} - \frac{3c}{2} \leq \lambda \leq \frac{3}{4} + \frac{3c}{2} \\ c & \text{,if } \frac{3}{4} + \frac{3c}{2} < \lambda \leq 1 \end{cases}.$$

Integrating over λ, we get:

$$\begin{aligned} E\left[U^{NR} - U^{NT} \mid (y, z) = \left(\frac{1}{2}, \frac{1}{2}\right)\right] &= E\left[U^{PR} - U^{NT} \mid (y, z) = \left(\frac{1}{2}, \frac{1}{2}\right)\right] \\ &= \left(\frac{1}{2} - 3c\right) c. \end{aligned}$$

The remaining four cases are symmetric with the first four cases, and therefore are omitted. Finally, taking the average over all nine possible (y, z) cases, we get the following:

$$\begin{aligned} E\left[U^{NR} - U^{NT}\right] &= \frac{1}{9}\left(\frac{15}{2} - 10c - 6v\right) c, \\ E\left[U^{PR} - U^{NT}\right] &= \left(\frac{1}{3} - c\right) c. \end{aligned}$$

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