Monopoly Provision of Tune-ins*

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Abstract

This paper analyzes a single television station's choice of airing tune-ins (preview advertisements). I consider two consecutive programs located along a unit line. Potential viewers know the earlier program but are uncertain about the later one. They may learn its location through a tune-in if they watch the earlier program and the television station chose to air a tune-in, or by sampling it for a few minutes. If the sampling cost is sufficiently low, the unique perfect Bayesian equilibrium (PBE) exhibits no tune-ins. If it is sufficiently high, the unique PBE involves a tune-in whenever the two programs are similar enough. For all other values of the sampling cost, either PBE may arise. When the programs are also quality-differentiated, the willingness to air a tune-in, and thus to disclose location information, may be sufficient to signal high quality without any dissipative advertising.

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

Most studies of informative advertising in differentiated-products markets postulate consumers as initially being unaware of the market's existence.[1] Thus, advertisements (henceforth, ads) inform them about product existence along with several other product characteristics. Since consumers are ex-ante unaware of the market structure, they do not make any inferences for the products about which they have not been informed through ads. Introducing consumer search into this context is problematic since one has to define a broad set of prior beliefs that consumers possess regarding the market structure. Therefore, most authors assume search costs are prohibitively high so that consumers never engage in search.

Many differentiated-products markets do not fit these specifications. Product existence is common knowledge and/or consumers actively search for product information in several markets. If, for instance, consumers are aware of a product's existence but are not very well informed about its characteristics, then a firm's unwillingness to advertise may be informative. If they know the available number of products in a market, then a firm's willingness to advertise may reveal further information regarding the other products.[2] In markets that consumers are initially unaware of, on the other hand, information comes only from the content of the received ads, if any. However, the assumption of high search costs in these markets restricts consumers from acquiring further information, and thus causes overprovision of advertising.

In this paper, I analyze the provision of tune-ins in the market for television (henceforth, TV) broadcasting.[3] A key feature of the TV market is that the existence of TV programs is common knowledge to everyone beforehand. Therefore, a TV station's decision to advertise its upcoming programs must account for the possible inferences its current viewers may draw upon not seeing a tune-in. In other words, information about the attributes of an upcoming program comes from both the content of the ad and the decision of a TV station to advertise. Another feature of the TV market is that viewers often switch between different TV stations. This behavior is primarily driven by the motive to learn the programs at other stations.

TV stations forgo about 20% of their advertising revenues to air tune-ins for their upcoming programs (Shachar and Anand (1998)).[4] This fact, on its own, suggests the importance of the incomplete information structure in the TV market, yet most of the related literature assumes that viewers possess full information about program characteristics. 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 uninformed due to the costs associated with gaining information. Furthermore, individuals have limited memories. Therefore, TV stations use tune-ins to communicate with their viewers. Had viewers been fully informed about the upcoming programs, there would be no need for tune-ins.

Tune-ins often provide direct information about program characteristics.[5] The level

[1] For example, see Grossman and Shapiro (1984).

[2] This requires that firms have common knowledge about all products, and consumers know that firms have this information.

[3] Tune-ins are preview ads for broadcasters' upcoming programs.

[4] Shachar and Anand (1998) report that in 1995, three major network stations in the U.S. devoted 2 of 12 minutes of nonprogramming time to tune-ins. Since advertising revenues represent almost all of the revenues of a network, the share of revenues spent on tune-ins is proxied as 20%.

[5] It is necessary to distinguish between tune-ins for regular programs, such as everyweek sitcoms, and

of information they provide is quite high. Based on a detailed panel dataset on viewer choices, Emerson and Shachar (2000) report that about 65% of viewers continue to watch the same network broadcaster (including the times when a tune-in has not been aired). This observation demonstrates that tune-ins achieve their main goal: raising the audience sizes of the promoted programs. Tune-ins also depend on the revenues of the programs during which they are aired. Their opportunity costs are higher during programs whose audience sizes are higher. So, the equilibrium provision of tune-ins depends on a careful cost-benefit analysis.

Certain programs are advertised several times during an ongoing program. This, however, is not completely due to high revenues that TV stations expect to generate from the advertised programs. Although about 80% of the network commercial time is sold in the up-front market during May for the upcoming season and the price paid by advertisers depends on the expected audience size, TV stations are bound to make up for the difference between the expected and the actual audience sizes should the former exceed the latter. Therefore, TV stations' intention for airing several tune-ins for a program may be to signal the quality of that program. I analyze this possibility as an extension of the main model which I describe next.

I first lay out a benchmark model that has a single TV station airing two consecutive programs. Potential viewers differ in their preferred program characteristics. Programs and viewer preferences are represented by locations along a unit interval a lá Hotelling. I assume that viewers know the location of the program to be aired in the first period, but are uncertain about the location of the program to be aired in the second period. The TV station has the option of placing a tune-in for the second program during the first one, and chooses to do so when the marginal advertising revenue resulting from the increase in the second-period audience size exceeds the opportunity cost of airing a tune-in. People may choose to watch or not to watch TV in each period. Once they choose to watch a program, they can do no better than watching it until the end even if it turns out a bad match. In making their viewing decisions in the first period, viewers consider the direct utility of the program itself and any informational benefits that may result from exposure to tune-ins. As a result of these informational benefits, some viewers watch TV in the first period who would otherwise choose not to watch.

The benchmark model produces a unique perfect Bayesian equilibrium (PBE) in which the TV station airs a tune-in as long as the advertising revenue generated by the viewers continuing to watch offsets or exceeds the cost of airing it. In other words, the TV station airs a tune-in whenever the two programs are not too dissimilar.[6] In the absence of a tune-in, no viewer from the first-period audience keeps watching TV in this unique PBE.

I then introduce the possibility of program sampling. Hence, viewers have the option of sampling a few minutes of the second program and switching off if they do not like it. However, sampling is costly; a viewer incurs a utility loss if she switches off after sampling a program. The equilibrium now depends on the value of the sampling cost. For sufficiently small values of the sampling cost, the unique PBE involves no tune-ins. For high values of the sampling cost, the PBE in the benchmark case, that is advertise whenever the two programs are not too dissimilar, constitutes the unique PBE. For moderate values of the sampling cost, both PBEs may arise.

those for special programs, such as movies. The latter are expected to be more effective on ratings in the sense that people may possess little or no information about the timing and attributes of such programs.

[6] This finding offers a natural explanation for targeting of audiences which has recently been a popular topic in the press (especially with the invention of Ti-Vo's).

In order to analyze the quality-signaling role of advertising, I extend the model by allowing TV programs to be differentiated along two dimensions; one horizontal, one vertical. The vertical dimension is interpreted as the quality of a program which, I assume, is either high or low. If the upcoming program is one of low quality, the TV station may try to mislead viewers so as to attract more viewers. However, some of these viewers will switch off after sampling a few minutes of the program while some will get stuck watching it until the end. There are both separating and pooling equilibria depending on the location of the second program. Most importantly, for certain program locations, there exists a separating equilibrium in which airing the quality-certainty optimal number of tune-ins is sufficient to signal high quality. These are the programs for which only a TV station with a high-quality program can afford to air a tune-in; that is these programs do not generate enough audiences to meet the cost of the tune-in when the upcoming program has a low quality.

Directly informative advertising has been the topic of several previous studies. Butters (1977) was the first to model the informative role of advertising. In his paper, products are homogenous. Advertising is the mechanism through which firms inform potential consumers about the price of their products. Because consumers have no knowledge of product existence prior to receiving an ad, the ad informs them of this as well. Grossman and Shapiro (1984) extended Butters' model by introducing differentiated product and heterogeneous consumers. Advertising informs consumers not only about the existence but also about the characteristics of the products. Common to both Butters (1977) and Grossman and Shapiro (1984) is the assumption that the advertising technology is exogenous. So, people cannot change their likelihood of receiving ads.

My model is similar to the one used in Grossman and Shapiro (1984) in that programs and viewer preferences are represented in a spatial framework. I depart from their work by introducing a two-period model and by assuming that program existence is common knowledge. Viewers also have the option of not watching TV, and sampling a program and switching off if they wish. Another important departure of my model is that people are not necessarily passive in receiving ads. More precisely, since tune-ins are always bundled with TV programs, a person receives a tune-in if and only if she chooses to watch the first program.[7]

A related recent paper is by Anderson and Renault (2006) who analyze a monopolist's choice of how much information to disclose in its ad. There is a single consumer who is uncertain about her match value with the monopolist's product. She can learn her match value and the price by conducting a costly search. The monopolist is also uncertain about the consumer's match value. The authors find that the monopolist may advertise only price, only match, or both price and match information depending on the search costs that consumers face. Furthermore, their results show that the monopolist prefers to convey only limited product information. Anderson and Renault use a random-utility model. The consumer's match value is a random draw from a probability distribution which is known to both the monopolist and the consumer. Therefore, although product existence is a priori known to the consumer in their model, the monopolist's choice of not

[7]Previous work on advertising assumes that people cannot change their likelihood of receiving ads. However, in various real life situations, people can, and actually do, change their likelihood of receiving ads. Take the example of low fare alerts that one can receive in an email from Travelocity. Other examples are using a DVR to skip ads while watching TV, or subscribing to "Do Not Call List" to avoid calls by telemarketers. Although this peper does not specifically model how people change their likelihood of receiving ads, it allows them to watch the first program even when it yields a negative utility.

advertising the match information is uninformative for her. In the model presented in this paper, however, the broadcaster knows how its upcoming program matches each viewer's preference. Therefore, the broadcaster's choice of not airing a tune-in is informative for viewers.

To the best of my knowledge, there are no theoretical papers that analyze the role of 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 of tune-ins on viewing decisions for regular and special shows. They use a novel dataset in their estimation which includes micro-level panel data on the TV viewing choices of a large sample of people and data on program attributes and the frequency of tune-ins. They find that a viewer's utility from a regular show is a positive concave function of the number of times she is exposed to its tune-ins. This indicates that tune-ins are effective but have diminishing returns. The authors also find a significant difference between the effectiveness of regular and special tune-ins, with special ones being less effective when there are few tune-ins and more effective when there are many. They also find the optimal number of tune-ins for a TV network using a very simple model.

In Anand and Shachar (2005), the content of tune-ins is modeled as a noisy signal of program attributes. Consumers are a priori uncertain about program attributes and exposure to tune-ins affect their information sets. Consumers have additional sources of information other than tune-ins, such as word-of-mouth and media coverage. Before each period starts, they update their beliefs based on the tune-ins they have been exposed to and the other information they have received, and then choose the program that maximizes their utility. They find that while exposure to advertising improves the matching of viewers and programs, in some cases it decreases a viewer's tendency to watch a program.

There are main differences between the model in this paper and the two papers by Anand and Shachar. I improve upon their models by assuming forward-looking viewers rather than myopic. Therefore, viewers correctly anticipate the tune-in strategy of the TV station. Most importantly, they infer that unadvertised programs are not likely to offer a good match. Anand and Shachar only analyze the viewer behavior thereby ignoring the optimal tune-in choices of TV stations. However, tune-in choices of TV stations depend on the viewing decisions of people. By explicitly modeling the optimal TV station behavior, I offer a more thorough analysis of tune-ins and their effects on people's viewing choices.

The paper is organized as follows. The next section introduces the benchmark model. Section 3 extends the benchmark model by allowing viewers to turn off their TVs after sampling a program. Section 4 discusses the implications of vertical differentitation. Finally, section 5 concludes.

2 Benchmark Model

In this section, I present a simple model with a single TV station and no possibility of program sampling. The analysis provides a benchmark that I build upon for the extensions. The TV station airs two consecutive programs (x_1, x_2), where x_t represents the location of the program in period t over the unit interval. The programs are of the same length. The production costs are assumed to be sunk and the same for both programs, and are set to zero for simplicity. There is a discrete number $A > 1$ of non-program breaks during each program, where A is taken as exogenous.[8] There is a large number of advertisers, each willing to pay up to $\$p$ per viewer reached for placing a commercial during a program. The TV station may choose to devote one of the non-program breaks in the first period to a tune-in for the purpose of promoting the next program. Production of a tune-in does not entail any costs. I assume that the TV station cannot lie in a tune-in, i.e. the TV station is legally bound to air a preview of the actual program in the tune-in, and that the tune-in is fully informative. Finally, the objective of the TV station is to maximize the total commercial revenue.

On the other side of the market, there is a continuum of N potential viewers who are uniformly distributed along the unit interval with respect to their ideal programs. To each possible program location, there corresponds a viewer for whom that program is the ideal one. An individual derives v units of utility from watching her ideal program that carries A non-program breaks.[9] Formally, a viewer who is located at λ obtains a net viewing benefit $u(\lambda, x) = v - |\lambda - x|$ from watching a program that is located at x. Not watching TV yields zero benefits.[10] I will refer to a particular viewer as "she" when it is convenient.

In each period, viewers choose between watching or not watching TV. An individual's objective is to make the decision at each time that maximizes her total utility. Viewers are assumed to be uncertain only about the location of the program in the second period. When making their viewing decisions in the first period, viewers consider not only their current utilities, but also the expected informational benefits that they may obtain by seeing a tune-in for the second program. They base their decisions on their prior beliefs about the location of the second program and the equilibrium tune-in strategy of the TV station, which they rationally anticipate. Their unconditional prior belief for the location of the second program is summarized by a uniform density function over $[0, 1]$. Because of possible informational gains associated with watching the first program, some viewers may watch the first program despite a negative first-period utility.

To simplify the analysis, I assume that the first program is located at 0, and that viewers possess this information.[11] This assumption implies that viewers with ideal program locations to the left of v watch the first program even if there were no tune-ins.

Assumption 1 *The first program is located at zero, i.e.* $x_1 = 0$.

I also assume that $\frac{1}{4} < v < \frac{1}{2}$. This assumption places a restriction on the behavior

[8] The assumption that the number of non-program breaks is fixed is certainly restrictive. However, while U.S. broadcasters are free to choose the number of their non-program breaks, advertising ceilings are imposed on broadcasters in most European countries. Therefore, in most cases, especially in the prime-time, the number of non-program breaks 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 number of non-program breaks, then people would rationally form priors about it. Second, and most importantly, the number of non-program breaks 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 informative advertising. Doing so is an excellent area for future research.

[9] The base utility v also captures how interruptions during a program affect the utility of a viewer. Specifically, the effect of an increase (a decrease) in the nuisance cost of a non-program break on a viewer's utility can be captured by lowering (raising) the base utility.

[10] A constant, t, can be put in front of d that measures the disutility associated with one unit of distance from the ideal program location. However, since the value of not watching TV is zero, utility can easily be expressed as $r - d$, where $r = \frac{v}{t}$.

[11] This assumption does not change any of the main results.

of the viewers who do not watch the first program. To be more specific, when $v < \frac{1}{4}$, none of these viewers watch the second program, and when $v \geq \frac{1}{2}$, all of them do. Futhermore, when v is too large, viewers always expect the TV station to air a tune-in in equilibrium and it is difficult to specify their off-the-equilibrium path beliefs when there are no tune-ins.

Assumption 2 $\frac{1}{4} < v < \frac{1}{2}$.

The timing of the game is as follows. First, viewers make their first-period decisions that maximize their expected two-period utilities. The first program starts, and during its progress, the TV station makes its tune-in decision. After the first program ends, if the TV station aired a tune-in, the first-period viewers learn the exact location of the second program. If the TV station did not air a tune-in, they only rationally update their beliefs. Finally, viewers make their second-period optimal decisions and payoffs are realized. As a tie breaking rule, I assume that the TV station airs a tune-in whenever it is indifferent between airing and not airing one, and that people watch TV whenever they are indifferent between watching and not watching.

The equilibrium concept used is perfect Bayesian equilibrium (PBE). That is, we require the TV station to make an optimal tune-in decision taking into account the inferences viewers make in the absence of a tune-in, and in turn, people to make optimal decisions (correctly) anticipating the TV station's strategy. In particular, people's inferences (or posterior beliefs) about the location of the second program following no tune-ins during the first program must be correct.

As a result of the tie-breaking rule, the TV station's optimal tune-in strategy is airing a tune-in with certainty if the resulting advertising revenue is at least as high as the revenue that it would earn without airing any tune-ins. Because a tune-in is assumed to be fully informative, and viewers watch a program until the end, the TV station only airs one tune-in. Since the location of the second program is unknown to viewers prior to their first period decisions, they form beliefs about when the TV station would air a tune-in. These beliefs will be described by a set of points Ω such that viewers ex-ante anticipate to see a tune-in for the second program whenever $x_2 \in \Omega$.

To describe the optimal viewer decision in the first period, it is useful to consider an individual whose ideal program location, λ, is to the right of v, i.e. $\lambda > v$. If she watches the first program and sees a tune-in for the second program, she would watch the second program as well provided that its location is at most v units apart from her location. So, her ex-ante expected utility in this case is given by $\int\limits_{\lambda-v}^{\lambda+v} u(\lambda, x)\,\mathbf{1}[x \in \Omega]\,dx$ where $\mathbf{1}[\cdot]$ is an indicator function that equals one when $x \in \Omega$. If she watches the first program and does not see a tune-in, she would keep watching TV provided that her updated expected utility is nonnegative. So, her ex-ante expected utility in this case is $\max\left\{0, \int\limits_0^1 u(\lambda, x)\,\mathbf{1}[x \notin \Omega]\,dx\right\}$. Finally, if she does not watch the first program, she would choose to watch the second program based on her prior belief about its location, that is when $\int\limits_0^1 u(\lambda, x)\,dx \geq 0$.[12] Hence, the benefit of watching the first program for this

[12] Note that $\int\limits_0^1 (v - |\lambda - x|)\,dx \geq 0$ when $\lambda \in \left[\frac{1-\sqrt{4v-1}}{2}, \frac{1+\sqrt{4v-1}}{2}\right]$.

particular viewer, which I will denote with $B(\lambda)$, can be expressed as

$$\begin{aligned} B(\lambda) &= \int_{\lambda-v}^{\lambda+v} u(\lambda,x)\,\mathbf{1}[x\in\Omega]\,dx + \max\left\{0, \int_0^1 u(\lambda,x)\,\mathbf{1}[x\notin\Omega]\,dx\right\} \\ &\quad - \max\left\{0, \int_0^1 u(\lambda,x)\,dx\right\}. \end{aligned} \tag{1}$$

Without any potential information gains, this viewer would not watch the first program since her direct utility, $(v-\lambda)$, is negative. However, $B(\lambda)$ may be positive. So, her optimal first-period decision is to watch TV when $B(\lambda) \geq \lambda - v$.

Ω is determined in equilibrium by viewers' anticipations for the TV station's tune-in strategy corresponding to every possible program location. The marginal benefit of airing a tune-in for the TV station is the marginal second-period advertising revenue as a result of a higher audience size. The cost is the forgone revenue of an additional commercial that the TV station would have earned in the first period without a tune-in. Let the binary variable $q \in \{0,1\}$ represent the TV station's tune-in decision, where $q=0$ when it does not air a tune-in, and $q=1$ when it does. So, from viewers' point of view, the optimal tune-in strategy of the TV station as a function of x_2 is

$$q = \begin{cases} 1, & ApN\left[s_2(x_2 \mid q=1) - s_2(x_2 \mid q=0)\right] \geq pNs_1 \\ 0, & \text{otherwise} \end{cases},$$

where s_1 is the fraction of viewers watching the first program, and $s_2(x_2 \mid q)$ is the fraction of viewers watching the second program conditional on the realization of q. The advertising revenue that the TV station forgoes by airing a tune-in is pNs_1 which is on the right-hand side of the inequality above. The left-hand side is the increase in the advertising revenue when the TV station airs a tune-in.

The following lemma establishes that there cannot be any gaps in the set of program locations for which viewers anticipate to see a tune-in. This result proves very useful for the remaining of the analysis.

Lemma 1 *Viewers' beliefs for when the TV station would air a tune-in must be in the form* $\Omega = [x_L, x_H]$, *where* $0 \leq x_L < x_H \leq 1$, *or* $\Omega = \varnothing$.

The proof of Lemma 1 (as well as all the remaining proofs) can be found in the Appendix section of this paper. It argues that if viewers anticipate to see a tune-in for two distinct programs and these programs are advertised in equilibrium, then any program located between these two programs must also be advertised. Therefore, viewers anticipate to see a tune-in for an interval of programs. Note that, if $\Omega \neq \varnothing$, then $v \in \Omega$.

Given Lemma 1, the integrals in equation (1) can be further simplified, and accordingly, the benefit of watching the first program can be expressed as

$$\begin{aligned} B(\lambda) &= \int_{\max\{x_L,\lambda-v\}}^{\min\{x_H,\lambda+v\}} u(\lambda,x)\,dx + \max\left\{0, \int_0^{x_L} u(\lambda,x)\,dx + \int_{x_H}^1 u(\lambda,x)\,dx\right\} \\ &\quad - \max\left\{0, \int_0^1 u(\lambda,x)\,dx\right\}. \end{aligned}$$

Note that all of the three terms in $B(\lambda)$ are continuous functions of λ. Even though $B(\lambda)$ may display kinks, it does not have any discontinuities. Furthermore, $\partial B(\lambda)/\partial\lambda <$

1 for all values of λ (since $\partial u(\lambda, x)/\partial\lambda$ is at most 1). So, $(B(\lambda) - (\lambda - v))$ must have no gaps. Furthermore, it must be decreasing in λ. This is because the increase in $(\lambda - v)$ as λ increases always exceeds the aggregate increase in the other terms. In other words, by marginally changing a viewer's location in the first period, her informational benefits associated with watching the first program may increase or decrease. However, relocation directly affects her first-period utility, too. The latter effect dominates the former one and therefore we have $\partial(B(\lambda) - (\lambda - v))/\partial\lambda < 0$. This observation gives rise to an immediate result.

Lemma 2 *If $B(v) > 0$, then there exists a unique value of $\lambda > v$, denoted by $\hat{\lambda}$, such that $B(\hat{\lambda}) = \hat{\lambda} - v$.*

This critical value of λ also represents the fraction of the population watching TV in the first period (will also be referred to as the first-period audience share). If $B(v) = 0$, then we'll simply have $\hat{\lambda} = v$.

If an individual watched TV in the first period and did not see a tune-in for the second program, she infers that $x_2 \notin \Omega$. In this case, her second-period decision depends on her expected utility conditional on her updated belief. She watches the second program if $E[u(\lambda, x_2 \mid x_2 \notin \Omega)] \geq 0$, where

$$E[u(\lambda, x_2 \mid x_2 \notin \Omega)] = \int_0^{x_L} u(\lambda, x)\frac{dx}{1-(x_H - x_L)} + \int_{x_H}^{1} u(\lambda, x)\frac{dx}{1-(x_H - x_L)}. \tag{2}$$

This function is clearly continuous in λ. Provided that x_H is high enough, the value of λ for which this function equals zero is unique. Using the relationship between $B(\lambda) - (\lambda - v)$ and $E[u(\lambda, x_2 \mid x_2 \notin \Omega)]$ as well as the equilibrium existence conditions, the next lemma shows that for Ω to be consistent with the TV station's optimal tune-in strategy, the equilibrium value of the lower bound of Ω must be zero. Thus, viewers' inferences from observing no tune-ins take a simple form. This is especially useful in characterizing the equilibrium.

Lemma 3 *$x_L = 0$ in equilibrium. That is $\Omega = [0, x_H]$.*

It directly follows from Lemma 2 that $x_H > \hat{\lambda}$. This is because the two programs, $x_2 = 0$ and $x_2 = \hat{\lambda}$, yield equal second-period audience sizes if advertised during the first program, i.e. $s_2(0 \mid q = 1) = s_2(\hat{\lambda} \mid q = 1)$. It is also easy to see that $x_H < \hat{\lambda} + v$.

Lemma 4 *In equilibrium, $\hat{\lambda} < x_H < \hat{\lambda} + v$.*

Now that the form of the PBE has been specified, it is possible to characterize the viewing decisions of individuals. The final step is to determine when $E[u(\lambda, x_2 \mid x_2 \notin \Omega)] \geq 0$. Next lemma establishes this result.

Lemma 5 *If $\hat{\lambda} > v$, then no viewer from the first-period audience keeps watching TV in the absence of a tune-in; i.e., $E[u(\lambda, x_2 \mid x_2 \notin \Omega)] < 0$ for all $\lambda \leq \hat{\lambda}$.*

From earlier discussion, the necessary condition for the existence of a PBE is given by

$$s_2(x_2 \mid q = 1) - s_2(x_2 \mid q = 0) \geq \frac{\hat{\lambda}}{A} \text{ for } \forall x_2 \in [0, x_H], \tag{3}$$

where $\hat{\lambda}$ is given by the solution to $B(\hat{\lambda}) = \hat{\lambda} - v$. By continuity, the inequality is strict at $x_2 = x_H$. By Lemma 5, if $\hat{\lambda} > v$, then $s_2(x_2 \mid q = 0) = 0$. It is easy to see that $s_2(x_H \mid q = 1) = \hat{\lambda} - (x_H - v)$. So, the equilibrium condition for the TV station for a given value of $\hat{\lambda}$ is simply

$$x_H = v + (1 - \frac{1}{A})\hat{\lambda}. \tag{3'}$$

For a given $\Omega = [0, x_H]$, and by Lemma 5, $\hat{\lambda}$ is simply determined by

$$\int_{\hat{\lambda}-v}^{x_H} (v - |\hat{\lambda} - x|)dx - \max\left\{0, \int_0^1 (v - |\hat{\lambda} - x|)dx\right\} = \hat{\lambda} - v. \tag{4}$$

Note that if v is sufficiently large so that x_H is very close to 1, then there is not much to gain from watching the first program for an individual with location $\lambda > v$. Therefore, we get $\hat{\lambda} = v$ for sufficiently high values of v. To be more precise, we get $\hat{\lambda} = v$ when $E[u(v, x_2 \mid x_2 \notin \Omega)] \geq 0$. In this case, it can easily be shown that the equilibrium value of x_H is less than $2v$, and therefore $B(v) = 0$. When $E[u(v, x_2 \mid x_2 \notin \Omega)] = 0$, no one except for the viewer at v continues to watch TV in the absence of a tune-in. When $E[u(v, x_2 \mid x_2 \notin \Omega)] > 0$, we'll have an interval of viewers just to the left v who continue to watch TV in the absence of a tune-in. Denote the cutoff viewer by$\tilde{\lambda} < v$. Now, $s_2(x_H \mid q = 1) = v - (x_H - v)$ and $s_2(x_2 \mid q = 0) = v - \tilde{\lambda}$. Its value is given by the solution to $\int_{x_H}^{1} (v - \tilde{\lambda} + x)dx = 0$. So, the PBE is determined by the following set of equations:

$$x_H = \tilde{\lambda} + (1 - \frac{1}{A})v, \tag{5}$$

and

$$\int_{x_H}^{1} (v + \tilde{\lambda} - x)dx = 0. \tag{6}$$

The following proposition, which is the main result of this section, summarizes all the possibilities.

Proposition 1 *Suppose that program sampling is sufficiently costly, so that people stay tuned until a program ends if they chose to watch it. Then, depending on the value of v, the following constitute a PBE:*

(i) When $v < \dfrac{1}{2 + \frac{1}{A}}$, there exists a unique $\hat{\lambda} > v$ given by

$$\hat{\lambda} = \begin{cases} \left(\sqrt{A^2 + 2v(1+v)} - A\right)A & , v < \hat{v} \\ \dfrac{1 - \sqrt{1 - \left(v^2 + \frac{1}{2}\right)\left(1 - \frac{1}{2A^2}\right)}}{\left(1 - \frac{1}{2A^2}\right)} & , \hat{v} \leq v < \dfrac{1}{2 - \frac{1}{A}} \end{cases}. \tag{7}$$

where $\hat{v}$ is the value of v that solves $\left(\sqrt{A^2 + 2v(1+v)} - A\right)A = \frac{1-\sqrt{4v-1}}{2}$. The TV station airs a tune-in for all $x_2 \leq x_H^*$, where $x_H^* = v + \left(1 - \frac{1}{A}\right)\hat{\lambda}$. In the absence of a tune-in, none of the first-period viewers watch the second program.

(ii) When $v \geq \dfrac{1}{2+\frac{1}{A}}$*,* $\hat{\lambda} = v$*. The TV station airs a tune-in for all* $x_2 \leq x_H^*$*, where* $x_H^* = 1 - \frac{2v}{A}$*. In the absence of a tune-in,* $\lambda \in \left[1 - v\left(1+\frac{1}{A}\right), v\right]$ *from the first-period viewers watch the second program.*

The equilibria in all cases are unique.

The equilibrium value of $\hat{\lambda}$ in Proposition 1*(i)* is characterized by a fixed point which is the intersection point of the two equilibrium conditions given by equations (3') and (4). At this fixed point, the TV station's tune-in strategy is correctly incorporated in the decision making of viewers, and the optimal viewing decisions of viewers are correctly incorporated in the decision making of the TV station. Uniqueness of the fixed point is proved in the Appendix using a graphical approach. This is depicted in the following figure.

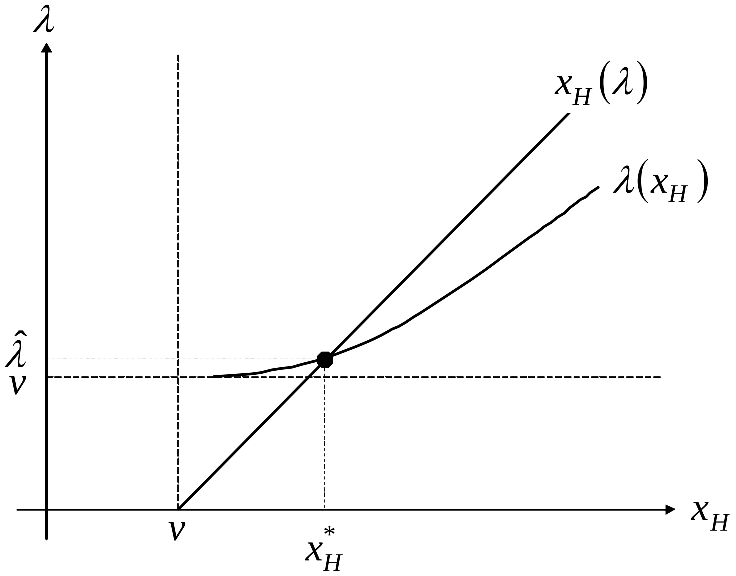

Figure 1 Determination of the PBE when $v < \frac{1}{2-1/A}$.

The unique PBE of the model is described by a binary tune-in strategy (air a tune-in or not) by the TV station that can be summarized by a unique threshold program location x_H^*. The TV station airs a tune-in whenever the location of the second program is not too far from the location of the first one (which is taken to be zero). Before deciding to watch TV in the first period, viewers consider both their first period utilities and the associated informational benefits. In case there are no tune-ins during the first program, viewers who watched it correctly infer where the second program could possibly lie in and make their decisions accordingly. Knowing that viewers will correctly anticipate the resulting tune-in scheme, it never pays off for the TV station to deviate from this equilibrium decision rule. These results are valid for all values of v as specified in Assumption 2 and for all $A > 1$.

3 Program Sampling

In this section, I introduce program sampling whereby people can sample the first few minutes of the second program, if they wish, before they make their final second period decisions. While this process fully reveals the true location of the program, it entails some cost, denoted by $c > 0$ and referred to as the "sampling cost". This cost is incurred only if an individual opts out after sampling the program, thus enjoying the remaining part of the outside option. It should be interpreted as the amount of the forgone utility that an individual would have enjoyed had she chosen the outside option as the first thing, rather than sampling the program. Therefore, if an individual chooses to turn her TV off after sampling the second program, her net second period benefit would be $-c$.

The model is now slightly more complicated than the benchmark case because the viewers have more options. Given anticipations Ω for the optimal tune-in decision of the TV station, an individual with $\lambda > v$ makes a cost-benefit analysis to find her optimal first period decision. Take an individual whose ideal program location is between v and $v + c$. If she watches the first program and sees a tune-in, she would watch the second program as well provided that the advertised program is at most v units apart from her location. If she watches the first program and does not see a tune-in, she would have to decide whether she should sample the second program or not. She would choose to sample if her expected utility based on her posterior beliefs is nonnegative. If she chose to sample it, she continues to watch it until the end unless the program location turns out to be more than $v + c$ units apart from her location. If she does not watch the first program, she would base her decision to whether sample the second program or not on her prior beliefs. She would choose to sample if the expected benefit of doing so exceeds its cost, and would keep watching unless the program location is more than $v + c$ units apart from her location. So, we can express the benefits of watching the first program for an individual with location $\lambda > v$ as follows:

$$\begin{aligned} B(\lambda) &= \int_{\lambda-v}^{\lambda+v} u(\lambda, x)\,\mathbf{1}[x \in \Omega]\,dx \\ &\quad + \max\left\{0, \int_{0}^{\lambda+v+c} u(\lambda, x)\,\mathbf{1}[x \notin \Omega]\,dx - (1 - (\lambda + v + c))\,c\right\} \\ &\quad - \max\left\{0, \int_{0}^{\lambda+v+c} u(\lambda, x)\,dx - (1 - (\lambda + v + c))\,c\right\}. \end{aligned} \tag{8}$$

Each term in $B(\lambda)$ is analogous to the terms given in equation (1). The only difference now is that we have additional terms accounting for program sampling. For instance, if this viewer watches the first program and does not see a tune-in, then she may choose to sample the second program. But the program may turn out to be more than $v + c$ units apart from her location in which case she would simply turn off and incur the sampling cost. This is captured by the term $(1 - (\lambda + v + c))\,c$.

Lemma 6 *Suppose for $\lambda \geq v$*

$$\int_{0}^{\lambda+v+c} u(\lambda, x)\,\mathbf{1}[x \notin \Omega]\,dx - (1 - (\lambda + v + c))\,c > 0. \tag{9}$$

Then, no viewer with an ideal program location $\lambda > v$ watches TV in the first period; i.e. $\hat{\lambda} = v$.

Lemma 6 says that if the sampling cost is so small (or v is large) that a viewer located at $\lambda > v$ would still sample the second program even after watching the first program and seeing no tune-ins, then she would simply not watch the first program. So, for sufficiently low values of the sampling cost, absence of a tune-in does not anymore substitute for program sampling for some viewers.

It is possible that no tune-ins prevail in equilibrium if the sampling cost is sufficiently low. As discussed earlier, if the beliefs are such that Ω is nonempty, then it must be true that $v \in \Omega$. This directly follows from the specification of the model; $x_2 = v$ provides the TV station with the highest possible audience size. By Lemma 6, if some viewers with $\lambda > v$ watch the first program, then it must be true that

$$\int_0^{\lambda+v+c} u(\lambda, x)\, \mathbf{1}[x \notin \Omega]\, dx - (1 - (\lambda + v + c))\, c < 0.$$

This means that no one from the first period audience watches the second program unless they see a tune-in.

No viewer with $\lambda > v$ watch TV in the first period if the equilibrium does not involve a tune-in for any program type. Intuitively, this is because an equilibrium involving a tune-in for some program types must involve a tune in for $x_2 = v$, and if such an equilibrium existed, all of the first period audience would watch the second program.

To characterize the no tune-in equilibrium, suppose beliefs of people are given by $\Omega = (0, v)$. The second-period decisions of the first period audience conditional on no tune-ins is determined by the sign of

$$\int_v^{\lambda+v+c} (v - (x - \lambda))\, dx - (1 - (\lambda + v + c))\, c. \tag{10}$$

Those for whom expression (10) is nonnegative watch the second program. It is easy to show that this condition is satisfied when $\lambda + c > \sqrt{2(1-v)c}$. So, conditional on $q = 0$, the total mass of viewers from the first-period audience who keep watching TV is given by $\max\left\{0, v + c - \sqrt{2(1-v)c}\right\}$.

If $x_2 \in [0, v]$ and the TV station aired a tune-in, then all of the first-period audience would watch the second program. If $s_2(x_2 \mid q = 1) - s_2(x_2 \mid q = 0) < \frac{s_1}{A}$ for every $x_2 \in [0, v]$, there is no reason for people to believe that Ω is nonempty. This inequality is satisfied for every $x_2 \in [0, v]$ when c is such that $\sqrt{2(1-v)c} - c < \dfrac{v}{A}$. The left hand side, $\sqrt{2(1-v)c} - c$, is increasing in c for $c < \dfrac{1-v}{2}$. So, there is a cutoff value of c, denoted by c_1, such that there exists a unique PBE that is described by $q = 0$ for all $x_2 \in [0, 1]$, and $\Omega = \varnothing$, when $c < c_1$. Intuitively, when the sampling cost is sufficiently low, the TV station has no incentive to advertise its program since everyone will find it out anyhow.

Now suppose that $c \geq c_1$, and $\Omega = \varnothing$. The TV station would confirm this belief if condition (3) is not satisfied. Since $\Omega = \varnothing$, there are no possible informational gains associated with watching the first program. Hence, only the viewers with locations $\lambda \leq v$ watch it. What happens if they receive a tune-in for $x_2 = v$? They would simply keep watching although they would think that the TV station aired a tune-in by mistake. If they do not receive a tune-in, on the other hand, only those with ideal program locations satisfying the following condition would watch the second program

$$\int_0^{\lambda+v+c} (v - |\lambda - x|)\, dx - (1 - (\lambda + v + c))\, c \geq 0.$$

This follows from the assertion that $\Omega = \varnothing$. This condition is satisfied when $\lambda \geq v+c-\sqrt{2\left((v+c)^2-c\right)}$. So, the beliefs are confirmed when $v+c-\sqrt{2\left((v+c)^2-c\right)} < \frac{v}{A}$, where the left-hand side is $s_2(x_2 \mid q=1) - s_2(x_2 \mid q=0)$, and the right-hand side is $\frac{s_1}{A}$. For values of $c \geq c_1$ that satisfy this inequality, $q = 0$ for all $x_2 \in [0,1]$, and $\Omega = \varnothing$ constitute an equilibrium.

For some values of $c \geq c_1$, there exists another self-fulfilling equilibrium in which the TV station airs a tune-in for all $x_2 \leq x_H$, where $x_H > v$. Formally, watching the first program is more costly than just sampling the second program when $c_1 < c < c_2$, where c_2 is given by[13]

$$c_2 = 1 - \sqrt{(1-2v)^2 - \left(\frac{v}{A}\right)^2} - 2v. \tag{11}$$

Therefore, no one with $\lambda > v$ watch the first program. However, some viewers choose to sample the second program in the absence of a tune-in. When $c \geq c_2$, on the other hand, the cost of sampling the second program conditional on not watching the first program exceeds the cost of watching the first program.

All of the discussion above is summarized in the following proposition. Its proof has been omitted since it is analogous to the derivation of Proposition 1.

Proposition 2 *Suppose that sampling a program is possible, but has a cost of c if an individual does not continue watching. Then, depending on the value of the sampling cost, the following constitute a PBE:*

(i) When $c < c_1$, no viewer with location $\lambda > v$ watches the first program, and no tune-in for the second program takes place. All viewers sample the second program.
(ii) When $c_1 \leq c < c_2$, no viewer with location $\lambda > v$ watches the first program. The TV station airs a tune-in for all $x_2 \leq x_H^*$, where $x_H^* = 1 - \frac{\left(c+\frac{v}{A}\right)^2}{2c}$. Some, not all, of the first-period viewers continues to watch the second program in the absence of a tune-in.
(iii) When $c_2 \leq c < c_3$, viewers with locations $\lambda < \hat{\lambda}$ watch the first program, where $\hat{\lambda} > v$ solves the equation

$$\left(1-\frac{1}{A^2}\right)\lambda^2 - 2(1+v+c)\lambda + \left(v^2+2v+(2-2v-c)c\right) = 0.$$

The TV station airs a tune-in for all $x_2 \leq x_H^*$, where $x_H^* = v + \left(1-\frac{1}{A}\right)\hat{\lambda}$. No viewer from the first-period audience continues to watch the second program in the absence of a tune-in.
(iv) When $c \geq c_3$, the equilibrium described in Proposition 1 prevails.

The equilibria in all cases, except for case (ii), are unique.

The cutoff value of the sampling cost that brings us back to the benchmark model can be found by setting the equilibrium value of $\hat{\lambda}$ in case (iii) equal to that stated in

[13] c_2 can be found by locating the marginal viewer from the first-period audience who keeps watching TV when there is no tune-in given that $\Omega = [0, x_H]$, and then imposing the condition that this value cannot be greater than v.

Proposition 1. Figure 2 below shows how the location of the marginal viewer in the first period and the equilibrium value of x_H^* evolve as a function of the sampling cost.

To summarize, in this extended model, two different equilibria may arise depending on the value of the sampling cost. If the sampling cost is sufficiently low, then the unique PBE exhibits no tune-ins. If it is sufficiently high, then the unique PBE involves a tune-in for the upcoming program unless the two programs are too dissimilar. An important implication in this case is that viewers rationally anticipate the range of programs for which the TV station would air a tune-in. Therefore, no one from the first period audience keeps watching TV unless she was exposed to a tune-in for the second program. For all other values of sampling cost, there are beliefs that support both of the equilibria.

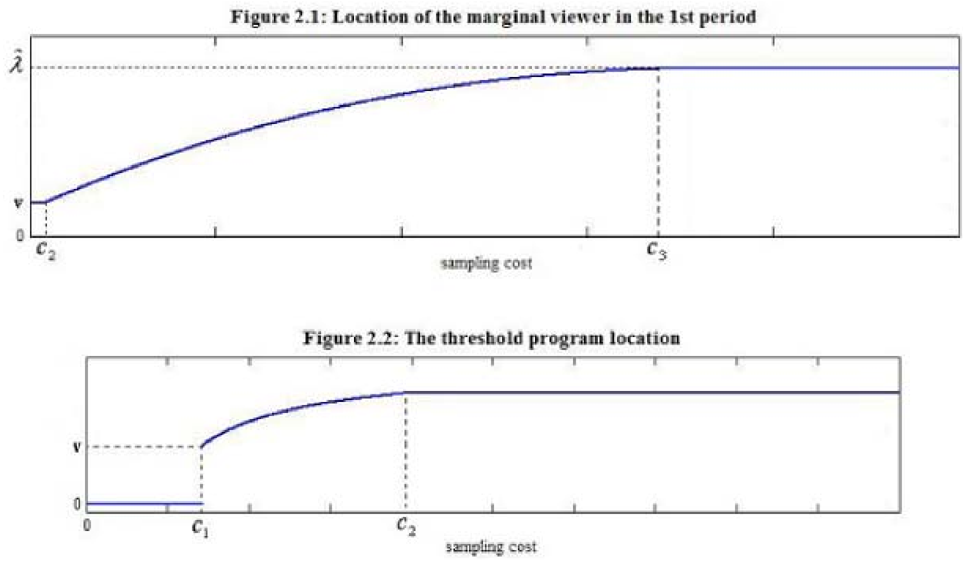

Figure 2 Evolution of $\hat{\lambda}$ and x_H^* as a function of c.

Comparing the results with the benchmark model, we see that the fear that an individual may end up watching a bad program until the end leads some people to gather early information by watching the first program. However, this is not necessarily good news for the TV station. Unless these viewers receive a tune-in, they will not keep watching TV. When it is possible to sample a program for a while, however, viewers are not as constrained because they do not have to watch a bad program until the end. Therefore, not as many viewers watch the first program just to alleviate their informational constraints.

4 Vertical Differentiation

The model with program sampling can be extended to include a second dimension of differentiation. Below, I sketch the main implications of adding a quality dimension about which viewers are uncertain beforehand. I assume that any direct information the TV station may provide about quality in a tune-in is not reliable. This is a common assumption in the literature. For simplicity, suppose that there are only two quality levels, high or low, and that viewers's utility function is given by $u(\lambda, x) = v_j - |\lambda - x|$, $j = H, L$, where $v_H > v_L$. Also suppose that the first program is of low quality. For ease of exposition, the TV station is referred as the "high-quality station" when its second program is of high quality, and as the "low-quality station" when it is of low quality.

The main findings of the previous section extend to this case, too. Namely, for values of c that are not very small – an assumption I maintain in this section – there exists a unique viewer for whom watching and not watching the first program yields the same expected utility. Let this viewer's location be denoted, as before, by $\hat{\lambda}$. Since the first program is assumed to be of low quality, the first-period audience comprises viewers with locations $\lambda < \hat{\lambda}$. Note that it is still true that $\hat{\lambda} - v_L < c$.

As before, it is optimal for the TV station to air a tune-in for the second program as long as it is similar enough with the first one. This only requires that the sampling cost is not too low. In the absence of a tune-in, no one from the first-period audience watch the second program, regardless of its quality. Therefore, there exists a unique program location x_L^* such that the low-quality station advertises its upcoming program when $x_2 \in [0, x_L^*]$. Similarly, there exists a unique program location $x_H^* > x_L^*$ such that the high-quality station advertises its upcoming program when $x_2 \in [0, x_H^*]$.

In a separating equilibrium, we need the low-quality station to behave the same as it would behave if viewers knew with certainty that the second program had a low quality. Therefore, it must be true in a separating equilibrium that $x_L^* = v_L + \left(1 - \dfrac{1}{A}\right)\hat{\lambda}$.

The incentive for the low-quality station to act as if its upcoming program was of high quality comes from the fact that program sampling is costly. Suppose the low-quality station claims in its tune-in that the upcoming program has a high quality, and the viewers believe this statement. Those for whom watching a high-quality program yields nonnegative utility start to watch the second program. After a few minutes, the viewers realize that the TV station actually lied in the tune-in; the program was one of low quality. While some of these viewers switch off at this point, not all do the same. Viewers whose ex-post utilities are at least as high as $-c$ would keep watching since the cost of sampling has already been sunk. So, when the low-quality station lies in a separating equilibrium, the increase in its second-period audience size is at least c.

An important result follows from the discussion above; in a separating equilibrium, only one tune-in for a program located at $x_2 \in (x_L^* + c, x_H^*]$ suffices to signal high quality. Given that the low-quality station does not air any tune-ins for $x_2 > x_L^*$ in a separating equilibrium, it must not have any incentive to falsify viewers by airing a tune-in for $x_2 > x_L^* + c$. Therefore, separation occurs with no distortion in the tune-in strategy. This result is in contrast with the existing literature on quality signaling. A high-quality firm is generally required to engage in dissipative advertising – also referred to as "money burning" – in order to correctly signal its quality. In the current setup, however, it is possible to signal high quality with no distortion in the advertising strategy by simply providing the location of the product. When this information deters a sufficient number of viewers from continuing to watch, it is correctly understood that the program must have a high-quality.

For $x_2 \leq x_L^* + c$, we must have in a separating equilibrium that the high-quality station airs more than one tune-in, and that it is not optimal for the low-quality station to mimic this strategy. The high-quality station would be willing to separate itself as long as the cost of airing the extra tune-in(s) does not exceed the extra revenue it would enjoy by separation. Hence, the high-quality station would do so if the extra audience size generated by separation is at least as high as $k\dfrac{\hat{\lambda}}{A}$, where k is the number of extra tune-ins required for separation. If $c < \frac{\hat{\lambda}}{A}$, one extra tune-in would be sufficient for separation. If $\frac{\hat{\lambda}}{A} < c < 2\frac{\hat{\lambda}}{A}$, then two more tune-ins are required for separation. I will make the following assumption for the rest of the analysis.

Assumption 3 $v_H - v_L > \frac{\hat{\lambda}}{A} > c.$

Separation is not possible when the location of the second program is close to 0, i.e. when the two programs are more similar. This is because such a program would appeal to all of the first-period viewers regardless of its quality. Suppose the second program is also located at 0. In a separating equilibrium, no viewer with $v_L < \lambda \leq \hat{\lambda}$ would sample the second program if they inferred that it has a low quality. If, on the other hand, they inferred that the second program has a high quality, then all of them would continue to watch. However, the high-quality station has to be willing to air an additional tune-in in the first period to separate itself. By separation, it gains an extra audience size of at most $\hat{\lambda} - v_L$. Since $\hat{\lambda} - v_L < c$, the gain by separation falls short of its cost, and therefore, the high-quality station would choose to pool. This argument is valid for all $x_2 < v_L + \frac{\hat{\lambda}}{A}$.

To summarize, when the first program has low quality, we have the following results:

Proposition 3 *Under Assumption 3, the following constitutes a PBE:*

(i) When $x_2 \leq v_L + \frac{\hat{\lambda}}{A}$*, there is no separating equilibrium in quality. Each type airs 'one' tune-in.*
(ii) When $v_L + \frac{\hat{\lambda}}{A} < x_2 \leq \left(1 - \frac{1}{A}\right)\hat{\lambda} + (v_L + c)$*, the high-quality station airs two tune-ins to signal high quality. The low-quality station airs one tune-in for* $v_L + \frac{\hat{\lambda}}{A} < x_2 \leq \left(1 - \frac{1}{A}\right)\hat{\lambda} + v_L$ *and airs none for* $x_2 > \left(1 - \frac{1}{A}\right)\hat{\lambda} + v_L$*.*
(iii) When $\left(1 - \frac{1}{A}\right)\hat{\lambda} + (v_L + c) < x_2 \leq \left(1 - \frac{1}{A}\right)\hat{\lambda} + v_H$*, only the high-quality station airs one tune-in amd this is sufficient to signal high quality.*
(iv) When $x_2 > \left(1 - \frac{1}{A}\right)\hat{\lambda} + v_H$*, no tune-in takes place (so there is no separation).*

The strategies described in Proposition 3 satisfy individual rationality and incentive compatibility constraints for both station types. As mentioned before, the reason for why the high-quality station airs 'two' tune-ins for separation comes from the specification that there is an integer number of tune-ins, and the assumption that $\frac{\hat{\lambda}}{A} > c$. More generally, letting $c = k\frac{\hat{\lambda}}{A} - \varepsilon$, we would need k additional tune-ins by the high-quality station to signal quality. Figure 3 below displays the posssible equilibria.

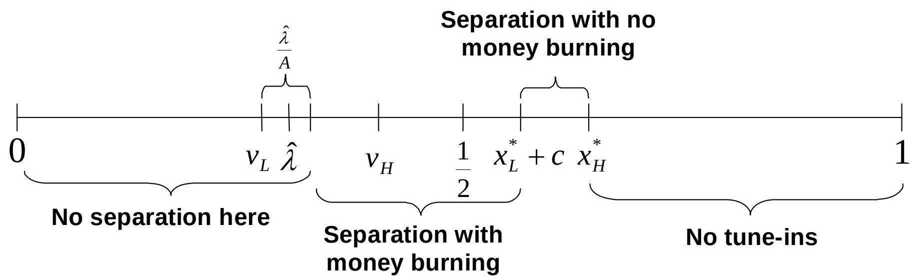

Figure 3 Quality signaling when the first program has low quality.

Similar results obtain when the first program has high quality. The only difference is that separation by airing more tune-ins is now also possible for program locations that are sufficiently close to 0. The reason is that there is now a higher number of viewers watching the first program, and therefore the high-quality station can gain enough by separation when $x_2 < \hat{\lambda} - (v_L + \frac{\hat{\lambda}}{A})$. The possible equilibria are depicted in Figure 4 below.

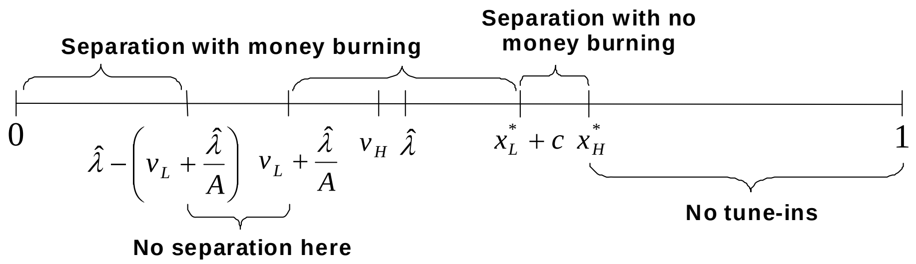

Figure 4 Quality signaling when the first program has high quality.

5 Conclusion

In this paper, I have presented a model to analyze the incentives of a firm to provide information about its product. Rationality of people plays a crucial role in the derivation of the equilibrium. It implies that the decision of a firm not to provide information actually reveals useful information to people. This point has largely been ignored in the previous literature. Therefore, the findings in this chapter constitute an important step towards a more comprehensive understanding of the informative role of advertising. Analyzing the TV industry is especially suitable for such a purpose, since tune-ins directly inform people about program characteristics.

The main findings can be summarized as follows. When there is a single TV station offering two consecutive programs that are horizontally differentiated, two equilibria may arise depending on the value of the sampling cost viewers incur. If it is sufficiently low, the unique PBE exhibits no tune-ins. For higher values of the sampling cost, there exists a PBE in which the TV station airs a tune-in for its upcoming program as long as it is similar enough with the program during which it would air the tune-in. Moreover, this PBE is unique if the sampling cost is sufficiently high.

The benchmark model and its extension with program sampling also enable me to analyze quality signaling when viewers are uncertain about the actual quality of the upcoming program. The most important finding in this extension is that money burning is not always necessary for a TV station to signal high quality. This is because there are programs that only a TV station with a high-quality program can afford to advertise.

Some restrictive assumptions have been made in the analysis. First, viewers' priors for the location of the second program were assumed to be uniform. Even though uniform distribution is particularly relevant for describing priors when viewers are clueless for a program's characteristics, allowing for more general probability distributions serves as a useful extension. I believe, however, that similar results will prevail under continuous (quasi)concave distributions although algebra will get significantly more tedious.

It was also assumed that horizontal attributes of programs can be described by a single location. In reality, it is more probable that TV programs are differentiated along several horizontal dimensions. A useful extension may consider including more than one horizontal attribute and analyzing the incentives of TV stations to provide information on multiple dimensions. Moreover, such an extension would enable an application of the model to other industries, such as the market for real estate. There is usually a certain number of characteristics that may be advertised in real estate magazines. Therefore, the content of a particular ad plays a key role in shaping people's beliefs. If a person knows the population distribution of house preferences, then she can infer that the characteristics that are excluded in an ad, if any, have to be the ones that are unappealing to a majority of the recipients of that ad.

6 Appendix

Proof of Lemma 1 In a PBE, it must be true that $x_2 \in \Omega$ whenever $q = 1$. Suppose $q = 1$. Since people make their first period viewing decisions without seeing a tune-in, the first period audience size does not depend on x_2. This is also true for the audience size in the second period given that the station did not air a tune-in at $t = 1$, i.e. $s_2(\cdot \mid q = 0)$ only depends on the updated beliefs about the second program. Therefore, $s_2(x_2 \mid q = 0) + \frac{s_1}{A}$ is constant for all x_2.

$s_2(x_2 \mid q = 1)$ can be found as follows. First note that the second-period audience comprises people who did not watch the first program. Therefore, these people base their decisions on their prior beliefs. Let $\Delta = \{\lambda > v \mid B(\lambda) \geq \lambda - v\}$ describe the set of people that watch the first program who would not if there were no tune-ins. Note that $\max(\Delta) \leq 2v$ since expected gains can never exceed the utility a person could obtain by watching her ideal program. Δ is determined by Ω in equilibrium. When $x_2 = 0$, only $\lambda \leq v$ from the first period audience watch the second program. Since $0 < x_2 < \max(\Delta) - v$, some people, but not all, from Δ also watch it. All of the first period audience watch the second program when $\max(\Delta) - v \leq x_2 \leq v$. As x_2 gets farther from v, some people will start dropping out, and eventually when $x_2 > \max(\Delta) + v$, no one from the first period audience watches the second program.

So, $s_2(x_2 \mid q = 1)$ is a linear function of x_2 that monotonically rises for the values of x_2 from 0 to $(\max(\Delta) - v)$. It attains its maximum at $x_2 \in [(\max(\Delta) - v), v]$, and starts monotonically decreasing at $x_2 = v$. Hence, conditional on the existence of a PBE, $s_2(x_2 \mid q = 1)$ can intersect $s_2(x_2 \mid q = 0) + \frac{s_1}{A}$ at a maximum of two points Denote these two points x_L and x_H. Then $s_2(x_2 \mid q = 1) \geq s_2(x_2 \mid q = 0) + \frac{s_1}{A}$ for all $x_2 \in [x_L, x_H]$ in a PBE, which implies that $q = 1$ only if $x_2 \in [x_L, x_H]$. Therefore, $\Omega = [x_L, x_H]$. ■

Proof of Lemma 3 Assume on the contrary that $\Omega = \{[x_L, x_H] \mid x_L > 0\}$. Since $x_2 = 0$ does not lie in Ω, it must be true that $\hat{\lambda} \notin \Omega$. This follows from the fact that $s_2(0 \mid q = 1) = s_2(\hat{\lambda} \mid q = 1)$. For $\Omega = \{[x_L, x_H] \mid x_L > 0\}$ to be consistent with TV station's optimal tune-in decision, $[x_L, x_H]$ must satisfy condition (3). Since $s_2(x_2 \mid q = 0)$ and $\frac{\hat{\lambda}}{A}$ do not depend on the actual value of x_2, it must be true that $s_2(x_L \mid q = 1) = s_2(x_H \mid q = 1)$ and $x_H = \hat{\lambda} - x_L$. Also note that $x_L < v < x_H$ since $s_2(x_2 \mid 1)$ attains its maximum for $x_2 \in [\hat{\lambda} - v, v]$. We are now ready to present the formal proof.

Step 1: $E[u(\lambda, x_2 \mid x_2 \notin \Omega)] \geq 0 \Leftrightarrow \int_0^1 u(\lambda, x)\, dx - \int_{x_L}^{x_H} u(\lambda, x)\, dx \geq 0$. We also have

$$\int_{x_L}^{x_H} u(\lambda, x) dx = \int_{x_L}^{x_H} (v - |\lambda - x|) dx = x_H - x_L \left(v - \frac{2\lambda - (x_H + x_L)}{2} \right) \text{ for } \lambda > x_H.$$

Evaluating $E[u(\lambda, x_2 \mid x_2 \notin \Omega)]$ at $\lambda = \hat{\lambda}$, and using $x_H + x_L = \hat{\lambda}$, we have

$$E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)] = \int_0^1 (v - |\hat{\lambda} - x|) dx - (x_H - x_L)(v - \frac{\hat{\lambda}}{2}).$$

The equilibrium value of $\hat{\lambda}$ cannot exceed $2v$, so $(x_H - x_L)(v - \frac{\hat{\lambda}}{2})$ is positive. This implies that if, in equilibrium, $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)] \geq 0$, then $\int_0^1 u(\hat{\lambda}, x) dx$ must be positive, too.

Suppose $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)] \geq 0$. Then

$$B(\hat{\lambda}) - (\hat{\lambda} - v) = \int_{\hat{\lambda}-v}^{x_H} (v - (\hat{\lambda} - x))dx - \int_{x_L}^{x_H} (v - (\hat{\lambda} - x))dx - (\hat{\lambda} - v) = 0.$$

$(\hat{\lambda} - v)$ is always at least as large as x_L, since $x_H + x_L = \hat{\lambda}$ and $x_H \geq v$. Rearranging the above condition, we have

$$\frac{((\hat{\lambda} - v) - x_L)^2}{2} = \hat{\lambda} - v.$$

The solution to this equation is $x_L = (\hat{\lambda} - v) - \sqrt{2(\hat{\lambda} - v)}$. However, $\sqrt{2(\hat{\lambda} - v)}$ is always bigger than $\hat{\lambda} - v$, since $0 < \hat{\lambda} - v < v$. This contradicts with the initial assumption that $\Omega = \{[x_L, x_H] \mid x_L > 0\}$ constitutes an equilibrium which is consistent with the TV station's optimal tune-in decision. Therefore, it must be true that $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)] < 0$.

Step 2: Given that $x_H + x_L = \hat{\lambda}$, it can be shown for $\lambda < \hat{\lambda}$ that

$$\frac{dE\left[u\left(\lambda, x_2 \mid x_2 \notin \Omega\right)\right]}{d\lambda} > 0.$$

It was shown that for $\Omega = \{[x_L, x_H] \mid x_L > 0\}$ to be consistent with TV station's optimal tune-in decision, $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)]$ must be negative. This implies that $E\left[u\left(\lambda, x_2 \mid x_2 \notin \Omega\right)\right] < 0$ for every $\lambda < \hat{\lambda}$, which means that no one from the first-period audience watches the second program unless they were exposed to a tune-in. Depending on how larger $\hat{\lambda}$ is relative to v, $s_2\left(x_2 \mid q = 1\right) - s_2\left(x_2 \mid q = 0\right)$ can range between v and $\hat{\lambda}$. So, from the equilibrium condition $s_2\left(x_2 \mid q = 1\right) - s_2\left(x_2 \mid q = 0\right) \geq \frac{\hat{\lambda}}{A}$, we have $v < \frac{\hat{\lambda}}{A} < \hat{\lambda}$, which cannot be true as long as $A > 1$. Therefore $\Omega = [x_L, x_H]$ cannot be consistent with the TV station's optimal tune-in decision unless $x_L = 0$. ■

Proof of Lemma 5 Suppose, on the contrary, that some people keep watching. Then $\lambda = \hat{\lambda}$ has to be one of these viewers. If $\int_0^1 u(\hat{\lambda}, x)dx > 0$, then the condition $B(\hat{\lambda}) = (\hat{\lambda} - v)$ is expressed as

$$\int_{\hat{\lambda}-v}^{x_H} (v - |\hat{\lambda} - x|)dx - \int_0^{x_H} (v - |\hat{\lambda} - x|)dx = \hat{\lambda} - v.$$

Rearranging the left-hand side, we have

$$-\int_0^{\hat{\lambda}-v} (v - (\hat{\lambda} - x))dx = \hat{\lambda} - v.$$

The value of the integral on the lefthand side is $\frac{(\hat{\lambda}-v)^2}{2}$. But $(\hat{\lambda} - v)$ is always greater than $\frac{(\hat{\lambda}-v)^2}{2}$. So, if $\int_0^1 u(\hat{\lambda}, x)dx > 0$, then $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)]$ cannot be positive. Now, if $\int_0^1 (v - |\hat{\lambda} - x|)dx \leq 0$, then the condition $B(\hat{\lambda}) = (\hat{\lambda} - v)$ becomes

$$\int_{\hat{\lambda}-v}^{1} (v - |\hat{\lambda} - x|)dx = \hat{\lambda} - v.$$

This condition can be rearranged as

$$\int_0^1 (v - |\hat{\lambda} - x|)dx = \int_0^{\hat{\lambda}-v} (v - |\hat{\lambda} - x|)dx + (\hat{\lambda} - v).$$

However, $\int_0^{\hat{\lambda}-v}(v-(\hat{\lambda},x))dx = \frac{-(\hat{\lambda}-v)^2}{2}$, so that $\int_0^{\hat{\lambda}-v}(v-|\hat{\lambda}-x|)dx+(\hat{\lambda}-v) > 0$. This contradicts with $\int_0^1(v-|\hat{\lambda}-x|)dx \leq 0$. So, it has to be true that $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)] < 0$. Since $E[u(\hat{\lambda}, x_2 \mid x_2 \notin \Omega)] < 0$ is increasing in λ for $\lambda \leq \hat{\lambda}$, no one with $\lambda \leq \hat{\lambda}$ keeps watching conditional on exposure to no tune-ins. ■

Proof of Proposition 1 The value of $\hat{\lambda}$ is obtained by simultaneously solving equation (3'), and equation (4). Suppose the equilibrium value of $\hat{\lambda}$ turns out to be less than $\frac{1-\sqrt{4v-1}}{2}$, in which case the second term in equation (4) equals zero. Then, $\hat{\lambda}$ is given by the solution to

$$\int_{\hat{\lambda}-v}^{v+\left(1-\frac{1}{A}\right)\hat{\lambda}}(v-|\hat{\lambda}-x|)dx = \hat{\lambda}-v.$$

The integral on the lefthand side equals $(v^2-\frac{\hat{\lambda}^2}{2A^2})$. Solving the equation for $\hat{\lambda}$, we obtain

$$\hat{\lambda} = \left(\sqrt{A^2+2v\,(1+v)}-A\right)A.$$

This constitutes an equilibrium as long as it is less than $\frac{1-\sqrt{4v-1}}{2}$, which is satisfied when $v < \hat{v}$. Similarly, if the equilibrium value of $\hat{\lambda}$ turns out to be greater than $\frac{1-\sqrt{4v-1}}{2}$, then $\hat{\lambda}$ is obtained by solving

$$\int_{\hat{\lambda}-v}^{v+\left(1-\frac{1}{A}\right)\hat{\lambda}}(v-|\hat{\lambda}-x|)dx - \int_0^1(v-|\hat{\lambda}-x|)dx = \hat{\lambda}-v.$$

Solving this equation for $\hat{\lambda}$,we obtain

$$\hat{\lambda} = \frac{1-\sqrt{1-\left(v^2+\frac{1}{2}\right)\left(1-\frac{1}{2A^2}\right)}}{\left(1-\frac{1}{2A^2}\right)}.$$

This value of $\hat{\lambda}$ constitutes an equilibrium as long as it is greater than $\frac{1-\sqrt{4v-1}}{2}$ which is satisfied when $v \geq \hat{v}$.

Uniqueness: TO BE COMPLETED!

■

Proof of Lemma 6 First observe that

$$\frac{\partial\left[\int_0^{\lambda+v+c}(v-|\lambda-x|)\,dx+(1-(\lambda+v+c))\,(-c)\right]}{\partial\lambda} > 0 \text{ for } v < \lambda \leq v+c.$$

When $\lambda = v$, the value of the integral in the derivative becomes $v^2-\frac{c^2}{2}-(1-(2v+c))\,c$, which can be rearranged as $\frac{1}{2}\left(c^2-2\,(1-2v)\,c+2v^2\right)$. This is positive for every $c < v$ when $v \geq \frac{1}{4}$. Therefore the last term in $B\,(\lambda)$ is positive for $v < \lambda \leq v+c$. Suppose c is small enough as stated in the lemma. Then, $B\,(\lambda) \geq (\lambda - v)$ when

$$\int_0^{\lambda-v}u\,(\lambda,x)\,(\mathbf{1}\,[x\notin\Omega]-1)\,dx+\int_{\lambda+v}^{\lambda+v+c}u\,(\lambda,x)\,(\mathbf{1}\,[x\notin\Omega]-1)\,dx \geq \lambda-v.$$

Suppose there exists $v < \hat{\lambda} \leq v+c$ such that $B(\hat{\lambda}) = (\hat{\lambda}-v)$. Then, $\mathbf{1}\,[x\notin\Omega] = 1$ for $x > \hat{\lambda}+v$ since no one from the first-period audience keeps watching if the TV station advertises $x_2 > \hat{\lambda} + v$. Now, the condition for $B(\lambda) = (\lambda - v)$ becomes

$$\int_0^{\lambda - v} u(\lambda, x)\left(\mathbf{1}\left[x \notin \Omega\right] - 1\right) dx = \lambda - v.$$

However, the left-hand side is at most $\frac{(\lambda-v)^2}{2}$ for any Ω. This is equal to $\lambda - v$ only when $\lambda = v$. So there is no $v < \lambda \leq v + c$ such that $B(\lambda) = (\lambda - v)$. People with $\lambda > v + c$ never watch the first program since their first-period disutility exceeds the sampling cost. ■

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