

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. The TV station may air a fully informative tune-in during the first program. The cost of the tune-in is the forgone advertising revenue. Under mild conditions, there exists a unique perfect Bayesian equilibrium in which some viewers watch the first program just to see if there is a tune-in or not, and the TV station airs a tune-in unless the two programs are too dissimilar. In the absence of a tune-in, no viewer within the first-period audience keeps watching TV. Full information disclosure never arises. The market outcome is suboptimal; a social planner would air a tune-in for a wider range of programs.

Abstrakt

Tento článek analyzuje volby jedné televizní stanice pro vysílání upoutávek (tzv. "tune-ins"). Uvažuje dva pořady vysílané po sobě. Potencionální diváci znají předchozí pořady, ale nejsou si jistí o těch nastávajících. Televizní stanice může vysílat úplně informativní upoutávky během prvního pořadu. Cena vysílání upoutávek je ušlý zisk z reklam. Při jistých středních podmínkách existuje jediný perfektní Bayesovský rovnovážný bod, ve kterém některí diváci sledují první pořad jen kvůli možným upoutávkám a kde televizní stanice vysílá upoutávky nehledě na to, jak jsou tyto dva pořady rozdílné. V nepřítomnosti upoutávek nebude žádný divák během prvního pořadu sledovat televizi později. Úplné informativní uzavření nikdy nenastane. Výstup trhu není optimální, protože sociální plánovač by vysílal upoutávky pro širší třídu pořadů.

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

JEL Classification: L82, M37.

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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. If, however, 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 also be informative. If they also 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 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 in the absence of 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.

The TV market serves as a two-sided market. On one side of the market, there are companies that are willing to purchase commercial spots in order reach potential consumers. On the other side, there are viewers who generally dislike watching commercials. The main role of a TV station is to find the right balance of delivering viewers to advertisers. Anderson and Coate (2005) was the first formal study to acknowledge the two-sided role of the TV market. They analyze the welfare properties of TV advertising and find that the market may fail to provide optimal advertising levels. Overprovision of advertising may occur when viewers' nuisance from an additional commercial exceeds advertisers' expected benefits from reaching a marginal viewer. Alternatively, underprovision may occur when the market is served by a single TV station and viewer nuisance cost is close to zero, or when programs are close substitutes.⁴

¹For examples, see Grossman and Shapiro (1984) and Christou and Vettas (2008).

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

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

⁴For a more comprehensive review of the literature on advertising in two-sided markets, see Anderson and

TV stations forgo about 20% of their advertising revenues to air tune-ins for their upcoming programs (Anand and Shachar (1998)).⁵ 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 already been fully informed about the upcoming programs, there would be no need for tune-ins.

Tune-ins often provide direct information about program characteristics.⁶ The level 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 all 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.

In my model, there is a single TV station airing two consecutive programs. The TV station's revenue comes from the commercials placed in the 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. They hold common priors about it. They 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.

The TV station may place a tune-in for the second program during the first one. Therefore, in making their viewing decisions in the first period, viewers consider the utility of the program

Gabszewicz (2006).

⁵Anand and Shachar (1998) report that in 1995, three major network stations in the U.S. devoted 2 of 12 minutes of non-programming 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%.

⁶It is necessary to distinguish between tune-ins for regular programs, such as weekly sitcoms, and 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.

itself and any informational benefits that may result from exposure to tune-ins. Because of these informational benefits, some viewers watch TV in the first period who would otherwise choose not to watch. This has important implications for the behavior of the TV station. On the one hand, the TV station has the chance of delivering the tune-in to a higher number of viewers and thus the commercial revenue from the second program is higher. On the other hand, the (opportunity) cost of a tune-in is now higher. Furthermore, in the absence of a tune-in, all of these extra viewers switch off their TVs. Hence, the tune-in strategy of the TV station is determined by a careful cost-benefit analysis.

I characterize the perfect Bayesian equilibria (PBE) for different values of the maximal utility a viewer can enjoy watching a program. If this value is not too high, then there exists a PBE in which the TV station airs a tune-in whenever the two programs are similar enough.⁷ There are some viewers who watch the first program just to observe the tune-in decision of the TV station. In the absence of a tune-in, no viewer within the first-period audience keeps watching TV. This PBE is unique if viewers' priors are not skewed to the right very much. I also find that there are no PBEs in which the TV station airs a tune-in for all program locations. I then analyze a social planner's problem who cares for viewer well-being as well. I find that the market performs suboptimally in the sense that there always exists an equilibrium in which the social planner airs a tune-in for a wider range of programs.

Although the model is developed within the context of a TV market, the general setup is applicable to other principal-agent frameworks with costly information disclosure. Consider a labor market with a potential executive manager seeking a job and many firms each seeking to employ an executive manager with different qualifications. Suppose the manager uploads his resume on a website. All potential employers receive a notice without any further detail that there is a new potential manager. An employer needs to pay a certain amount and subscribe to the web site in order to receive further information. Suppose certain employers are already subscribed to the web site. Then, depending on the correlation between the manager's and the already subscribed employers' desired qualifications, the manager chooses the level of information to disclose in his resume. The model presented in this paper allows for an analysis of the equilibrium level of information disclosure in the described labor market.

⁷This 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-VOs).

The paper is organized as follows. The next section reviews the related literature. Section 3 introduces the main model, characterizes the market equilibria and then compares it to the socially optimal outcome. Section 4 discusses the findings and concludes.

2 Related Literature

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 homogeneous. 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. 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.⁸

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

⁸Previous work on advertising assumes that people cannot change their likelihood of receiving ads. However, in most 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 a "Do Not Call List" to avoid calls by telemarketers. Although this paper 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.

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 known probability distribution which is common 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 advertising the match information is uninformative for her. In the model presented in this paper, however, viewers' preferences for the upcoming program are ex-ante known to the TV station. Therefore, it is informative for viewers if the TV station chooses not to air a tune-in.

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. They 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.

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 affects 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. The authors 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 important 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 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.

Finally, this paper is related to a growing literature on games of information disclosure in vertically-differentiated markets, the so-called "persuasion games". Milgrom (1981), Grossman (1981) and Jovanovic (1982) establish in their early (independent) papers that full disclosure of a vertical characteristic, such as quality, is the unique outcome if a single seller can credibly and costlessly disclose it. This is quite intuitive: when information is withheld, a potential consumer rationally infers that the good must be of an inferior or lower quality. However, the seller of an intermediate-quality good would not want to be perceived as selling a low-quality good. Therefore, he discloses his product information. The same occurs for all other types of sellers as well. So, full disclosure arises as the unique equilibrium outcome. In a related paper, Sun (2007) finds that full disclosure may fail when both horizontal and vertical differentiation are present. In this case, the seller of a not-so-popular brand may conceal information in order to be pooled with the sellers of other not-so-popular brands on the other side of the product space.

3 The Model

There is a single TV station who airs two consecutive programs x_1 and x_2 , where x_t represents the location of the program in period t over the unit interval. The locations of both programs are known to the TV station. 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 time slots to be allocated to non-program content during each program, where A is taken as exogenous.⁹ I will henceforth refer to these as ads. Thus, the

⁹While U.S. broadcasters are free to choose the amount of their non-program minutes, advertising ceilings are imposed on broadcasters in most European countries. Therefore, in most cases, especially in the prime-time, the amount of non-program minutes that maximizes 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 people would rationally form priors 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.

game in this paper may be thought of as a subgame of a larger game in which the choices of program locations and the amount of non-program minutes are already made.

There is a large number of advertisers, each willing to pay up to $\$p$ per viewer reached for placing a commercial during a program. Each commercial is one time-slot long. Alternatively, the TV station may choose to air a tune-in (or tune-ins) during the first program for the purpose of promoting the next program. Production of a tune-in does not entail any costs. I assume that a tune-in has the same length as a commercial. The TV station splits the available A ads during the first program between commercials and tune-ins (so, an ad may be in the form of a commercial or a tune-in). Hence, the TV station incurs an opportunity cost for placing tune-ins. I assume that the TV station cannot lie in a tune-in; i.e. the TV station is legally bound to advertise 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 its total advertising revenue which is generated by payments received from advertisers for placing commercials.

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 ideal. A viewer who is located at λ obtains a net utility $u(\lambda, x) = v - |\lambda - x|$ from watching a program located at x .^{10,11} Viewers' locations stay the same across the two periods. Not watching TV yields zero benefit.¹²

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; i.e. they know x_1 with certainty while they hold prior beliefs for x_2 .¹³ They know that the TV station is privately informed about x_2 . When making their viewing decisions in the first period, viewers

Doing so is an excellent area for future research.

¹⁰The gross utility v can capture how interruptions during a program affect a viewer. Specifically, the effect of an increase (a decrease) in the nuisance cost of a commercial on a viewer's utility can be captured by lowering (raising) the gross utility. Note that, in this formulation, tune-ins also create a nuisance.

¹¹Alternatively, v can be interpreted as the quality of a program which enters into everyone's utility in the same way.

¹²A constant, t , can be put in front of $|\lambda - x|$ 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 $r - |\lambda - x|$, where $r = \frac{v}{t}$.

¹³The fact that viewers know the location of the first program is without loss of generality since there are no tune-ins for it. It can practically be thought as the evening news program which everybody knows.

consider not only their current utilities but also the expected informational benefits they may obtain by seeing a tune-in for the second program. They have identical priors for the location of the second program. Their priors for x_2 are summarized by a density function $f(\cdot)$ defined over $[0, 1]$, with a corresponding cumulative distribution function $F(\cdot)$. I assume for analytical convenience that $f(\cdot)$ is strictly positive and bounded everywhere on $[0, 1]$.¹⁴

Under complete information, the utility of watching the first program for a viewer located at λ is $u(\lambda, x_1) = v - |\lambda - x_1|$. This is non-negative when λ lies within v units of distance around x_1 . Thus, when $v < x_1 < 1 - v$, viewers with ideal program locations between $x_1 - v$ and $x_1 + v$ watch the first program with certainty. Likewise, when $x_1 \leq v$, viewers with locations $\lambda \leq x_1 + v$ watch it with certainty. There are also expected informational benefits associated with watching the first program and seeing (or not) a tune-in for the second program. Depending on the magnitude of these informational benefits, viewers located farther away from x_1 may also watch the first program – despite a direct utility loss. However, because of the general form for the prior beliefs, these viewers' locations will not be symmetric around x_1 . This makes the analysis complicated without adding much to the results. Assuming $x_1 \leq v$ greatly simplifies the analysis since I can focus solely on the behavior of the viewers located to the right of the first program. Therefore, for the remainder of the analysis, I maintain the assumption that $x_1 = 0$.¹⁵ Thus, viewers with ideal programs that lie on the left of v watch the first program with certainty.

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

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 update their beliefs accordingly. 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

¹⁴Main results extend to any prior density function that is strictly positive at least at two points over $[0, 1]$. However, calculations get more cumbersome because of potential corner solutions.

¹⁵This is without loss of generality since the results are qualitatively the same for any $x_1 \leq v$.

that people do watch TV whenever they are indifferent between watching and not watching.¹⁶

The equilibrium concept used is perfect Bayesian equilibrium (PBE). That is, the TV station makes an optimal tune-in decision taking into account the inferences viewers make in the absence of a tune-in, and in turn, people 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.

3.1 Market Equilibrium

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 exceeds the revenue that it would earn without airing any tune-ins. Since a tune-in is assumed to be fully informative, and viewers watch a program until the end, the TV station airs only one tune-in. Viewers 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 ideal program. So, her ex-ante expected utility in this case is given by $\int_{\lambda-v}^{\lambda+v} u(\lambda, x) \mathbf{1}_{x \in \Omega} dF(x)$ where $\mathbf{1}_{x \in \Omega}$ 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 non-negative. So, her ex-ante expected utility in this case is $\max\{0, \int_0^1 u(\lambda, x) \mathbf{1}_{x \notin \Omega} dF(x)\}$. Finally, in case she does not watch the first program, she would base her decision on her prior belief and will choose to watch the second program if $\int_0^1 u(\lambda, x) dF(x) \geq 0$.¹⁷ Hence, the benefit of watching

¹⁶Tie-breaking rules are imposed in order to rule out mixed strategy equilibria at the states of indifference. The specifics of the tie-breaking rule are without loss of generality since the distribution of program locations as well as of people's ideal programs are both continuous.

¹⁷Note that if $\int_0^1 (v - |\lambda - x|) f(x) dx > 0$ for some λ , then it must be that $\int_0^1 (v - |\lambda - x|) f(x) dx \geq 0$ for a closed set of viewers.

the first program for this viewer, which I will denote with $B(\lambda)$, can be expressed as

$$\begin{aligned} B(\lambda) &= \int_{\lambda-v}^{\lambda+v} u(\lambda, x) \mathbf{1}_{x \in \Omega} dF(x) + \max\{0, \int_0^1 u(\lambda, x) \mathbf{1}_{x \notin \Omega} dF(x)\} \\ &\quad - \max\{0, \int_0^1 u(\lambda, x) dF(x)\}. \end{aligned} \quad (1)$$

Without any potential information gains, this viewer would not watch the first program since her direct utility from watching it, $(v - \lambda)$, 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. 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. The marginal benefit of airing a tune-in is the marginal second-period advertising revenue as a result of a higher audience size. The only source of revenue for the TV station is the payments received from the advertisers. Thus the marginal revenue due to a tune-in can be expressed as $A p N [s_2(x_2 | q = 1) - s_2(x_2 | q = 0)]$ where $s_2(x_2 | q)$ is the fraction of viewers watching a program located at x_2 in the second period conditional on the realization of q . The cost is the forgone revenue that the TV station could have earned in the first period by selling the time used for the tune-in to an advertiser. So, it is given by $p N s_1$ where s_1 is the fraction of viewers watching the first program. Hence, from the viewers' point of view, the optimal tune-in strategy of the TV station as a function of x_2 is

$$q(x_2) = \begin{cases} 1, & s_2(x_2 | q = 1) - s_2(x_2 | q = 0) \geq \frac{s_1}{A} \\ 0, & \text{otherwise} \end{cases}. \quad (2)$$

Note that, unless v is very large or the priors are extremely skewed to the right, there are viewers who only watch the second program. These viewers expect to have a non-negative utility if they watch the second program without any further information. They do not watch the first program since it is simply too costly for them. Thus, their decisions do not depend on the actual tune-in decision of the TV station. Similarly, when making its tune-in strategy, the TV station does not consider these viewers. Therefore, I will suppress these viewers for the remaining part of the paper unless I state otherwise.

The following lemma establishes that there cannot be any discontinuities in viewers' beliefs as to the tune-in strategy of the TV station. This result proves very useful for the rest of the analysis.

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

The proof of Lemma 1 (as well as all the remaining proofs except for obvious ones) can be found in the Appendix. It argues that if viewers anticipate seeing 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 seeing a tune-in for an interval of programs. Note that if $\Omega \neq \emptyset$ and $0 < x_L < x_H < 1$, then the inequality given in equation (2) must be satisfied with equality when $x_2 = x_L, x_H$, and must be strict when $x_2 \in (x_L, x_H)$. Also note that, if $\Omega \neq \emptyset$, then $v \in \Omega$. This is simply because when $x_2 = v$, all first-period viewers continue watching TV if they see a tune-in. Two possible PBEs are graphically depicted in Figure 1.

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

$$B(\lambda) = \int_{\max\{x_L, \lambda-v\}}^{\min\{x_H, \lambda+v\}} u(\lambda, x) dF(x) + \max\left\{0, \int_0^{x_L} u(\lambda, x) dF(x) + \int_{x_H}^1 u(\lambda, x) dF(x)\right\} - \max\left\{0, \int_0^1 u(\lambda, x) dF(x)\right\}.$$

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 be monotonically decreasing in λ . 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 $B(v) > 0$, 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. With a little abuse of notation, let $\hat{\lambda} = v$ when $B(v) \leq 0$. The next lemma summarizes

some properties of Ω depending on $\hat{\lambda}$. These properties prove useful for later discussion.

Lemma 3 *When $\hat{\lambda} > v$ in equilibrium, (i) if $\Omega \neq \emptyset$, then it must be that $q(x_2) = 1$ for $x_2 \in [\hat{\lambda} - v, v]$, (ii) if $\Omega \neq \emptyset$ and $x_L = 0$, then it must be that $x_H \geq \hat{\lambda}$, and (iii) if $\Omega \neq \emptyset$ and $x_L > 0$, then it must be that $x_L \leq \hat{\lambda} - v$, $v \leq x_H < \hat{\lambda}$ and $x_H = \hat{\lambda} - x_L$. When $\hat{\lambda} = v$ in equilibrium, if $\Omega \neq \emptyset$, then it must be that $x_L = 0$ and $x_H \geq v$.*

When do we get $\hat{\lambda} = v$? This surely happens when $v \geq 1/2$. To see it, note that when $v \geq 1/2$, the second and the third terms in $B(\lambda)$ evaluated at $\lambda = v$ are both positive, and the summation of the first two terms is simply equal to the third term, so $B(v) = 0$. Intuitively, if an individual enjoys watching TV very much (captured by a high v) and she is uncertain about a program, then she would not get involved in any costly ways of information acquisition. Instead, she would simply watch that program.

Lemma 4 *Suppose $\Omega \neq \emptyset$. Then $\hat{\lambda} = v$ if and only if $\int_0^{x_L} x dF(x) + \int_{x_H}^1 (2v - x) dF(x) \geq 0$.*

Note that $\int_0^{x_L} x dF(x) + \int_{x_H}^1 (2v - x) dF(x)$ is the ex-ante expected utility of watching the second program for a viewer located at v , conditional on seeing no tune-ins during the first program. In words, Lemma 4 says that if v is sufficiently large (and/or $f(x)$ is sufficiently skewed to the right) so that the viewer located at v continues to watch TV even in the absence of a tune-in during the first program, then the expected informational gains associated with watching the first program for $\lambda > v$ are too small so that $\hat{\lambda} = v$.

Lemma 4 together with Lemma 3 implies that, if either one of the two arguments in Lemma 4 holds true, then the equilibrium value of x_L must be equal to zero. Hence, the necessary and sufficient condition for $\hat{\lambda} = v$ when $\Omega \neq \emptyset$ can be rephrased as $\int_{x_H}^1 (2v - x) dF(x) \geq 0$.¹⁸ When $\Omega \neq \emptyset$, it is clear that $\hat{\lambda} = v$.

With the current form of prior beliefs, it is possible that the probability density function has spikes for certain ranges of program locations in the domain. If this is the case, viewers may behave in an economically unreasonable way. To be more precise, it is possible that viewers' response to a marginal change in program location is higher in magnitude under incomplete information than under complete information. Suppose $\Omega = [0, x_H]$ where $x_H > v$. Then,

¹⁸Of course, x_H is endogenously determined in the model. Lemma 5 will later provide the necessary condition for $\hat{\lambda} = v$ with respect to the value of v .

the marginal first-period viewer, denoted by $\tilde{\lambda}$, who continues watching TV in the absence of a tune-in is given by the solution to $\int_{x_H}^1 (v + \tilde{\lambda} - x) dF(x) = 0$ (assuming there exists a solution $\tilde{\lambda} \leq v$). Suppose, $\tilde{\lambda} < v$. Then, all viewers with locations $\lambda < \tilde{\lambda}$ will switch off while the ones with $\lambda \geq \tilde{\lambda}$ will continue watching. Using implicit function theorem, one can easily find that

$$\frac{d\tilde{\lambda}}{dx_H} = \frac{(v + \tilde{\lambda} - x_H)f(x_H)}{1 - F(x_H)}$$

As will be stated in Proposition 2, $v + \tilde{\lambda} - x_H$ is equal to $\frac{v}{A}$ in equilibrium. However, if the hazard rate at x_H is sufficiently high, then it may be the case that $\frac{d\tilde{\lambda}}{dx_H} > 1$. Under complete information, the marginal viewer would simply be located at $x_H - v$, and thus $\frac{d\tilde{\lambda}}{dx_H} = 1$. I find this economically unreasonable. Therefore, I make the following assumption which ensures that such situations do not arise.

Assumption 2 *The hazard rate $\frac{f(x)}{1-F(x)}$ is bounded above by $\frac{A}{s_1}$ for all $x < k$, where $k < 1$.*

Above, s_1 is the first-period audience share. The positive number k is strictly less than 1 since Assumption 2 is unlikely to hold for values of x that are very close to 1. As it turns out, I do not need the hazard rate to be bounded for sufficiently large x because the equilibrium value of x_H is always less than 1.

Proposition 1 *Let \bar{v} be the solution to $\int_v^1 (v + \frac{v}{A} - x) dF(x) = 0$. If $v \geq \bar{v}$, the unique PBE is described by $\Omega = \emptyset$ and $\hat{\lambda} = v$.*

The finding in Proposition 1 is quite intuitive. When v is sufficiently large, some (or all) first-period viewers watch the second program even in the absence of a tune-in since they simply enjoy watching TV very much. Suppose the TV station airs a tune-in for all $x_2 \leq v$. When $v = \bar{v}$, the marginal viewer who is indifferent between continuing watching or not is located at $\lambda = \frac{v}{A}$. In the absence of a tune-in, all viewers with locations less than $\frac{v}{A}$ switch off their TVs. However, the cost of a tune-in is exactly equal to the marginal advertising revenue that would result if these viewers watched the second program. Therefore, the TV station does not air any tune-ins. Assumption 2 ensures that $\int_v^1 (v + \frac{v}{A} - x) dF(x)$ is monotonically increasing in v so that the solution to \bar{v} is unique. Note that Assumption 2 is required for values of v up to $v + \frac{v}{A} = 1$, i.e. $v = \frac{A}{A+1}$. If $v > \frac{A}{A+1}$, then the person located at $\frac{v}{A}$ surely continues

watching TV in the absence of a tune-in. So $\frac{f(v)}{1-F(v)}$ does not need to be bounded above for $v > \frac{A}{A+1}$.

A high v can alternatively be interpreted as high quality. If people know that it is going to be a sufficiently high-quality program, then they will be willing to watch it in the absence of a tune-in.¹⁹

Proposition 2 *Let y be the solution to $\int_{(2-1/A)v}^1 (2v - x)dF(x) = 0$.²⁰ If $y \leq v < \bar{v}$, the unique PBE is described by $\hat{\lambda} = v$ and $\Omega = [0, x_H]$, and there exists a unique $\tilde{\lambda} \in (0, v]$ such that all first-period viewers with $\lambda \in [\tilde{\lambda}, v]$ continue to watch TV in the absence of a tune-in, while all others switch off. The equilibrium value of $\tilde{\lambda}$ and x_H are uniquely determined by the following two equations:*

$$\int_{x_H}^1 (v + \tilde{\lambda} - x)dF(x) = 0, \quad (3)$$

$$x_H = \tilde{\lambda} + (1 - \frac{1}{A})v. \quad (4)$$

Equations (3) and (4) are graphically depicted in Figure 2. The equilibrium values of $\tilde{\lambda}$ and x_H are determined at the intersection point of these two equations. When v lies in the range described in Proposition 2, some first-period viewers still watch the second program in the absence of a tune-in. However, now, a non-negligible fraction of the first-period viewers switch off. Suppose the second program is actually located at v . If the TV station aired a tune-in, it could have kept all of the first-period viewers tuned in. The marginal revenue in this case exceeds the cost of the tune-in and therefore the TV station chooses to air a tune-in for $x_2 = v$. But if this is profitable, then airing a tune-in for any program $x_2 < v$ must also be profitable. So, the TV station ends up airing a tune-in for all programs with locations up to a certain threshold. Viewers' inferences in the absence of a tune-in are now more negative which implies that the location of the marginal viewer will be closer to v . Therefore, the equilibrium value of $\tilde{\lambda}$ will be higher than $\frac{v}{A}$ which was the location of the marginal viewer when $v = \bar{v}$. As v goes down, more and more people will switch off in the absence of a tune-in. When $v = y$, it is exactly the viewer located at v who is indifferent between watching or not. For lower values of v , there will be viewers with locations $\lambda > v$ watching the first program just to see the

¹⁹For instance, certain TV stations are known to air a Hollywood-quality movie every week at the same day/time slot.

²⁰This solution is unique by Assumption 2.

tune-in decision of the TV station. This gives rise to Lemma 5 which is simply a better-refined version of Lemma 4.

Lemma 5 $\hat{\lambda} > v$ if and only if $v < \underline{y}$.

When $\hat{\lambda} > v$, there are two possibilities: it could either be $x_L = 0$ or otherwise $x_L > 0$. The next lemma establishes an important property of the equilibrium when $x_L = 0$. It is crucial in the construction of Proposition 3 which characterizes a PBE when $v < \bar{v}$.

Lemma 6 If $x_L = 0$ and $\hat{\lambda} > v$ in equilibrium, then no viewer from the first-period audience keeps watching TV in the absence of a tune-in; i.e., $\int_{x_H}^1 (v - \lambda + x) dF(x) < 0$ for all $\lambda \leq \hat{\lambda}$.

If there exists a PBE in which $x_L = 0$, then Lemma 6 implies that the indifference condition for the TV station for airing a tune-in given by equation (2) reduces to a linear relationship between x_H and $\hat{\lambda}$. Now, we are ready to present Proposition 3.

Proposition 3 If $v < \underline{y}$, there exists a PBE described by $\hat{\lambda} \in (v, \underline{y})$ and $\Omega = [0, x_H]$, $x_H > v$, where $\hat{\lambda}$ and x_H are uniquely determined by the following two equations:

$$x_H = v + \left(1 - \frac{1}{A}\right) \hat{\lambda}, \quad (5)$$

$$\hat{\lambda} = v + \int_{\hat{\lambda}-v}^{x_H} (v - |\hat{\lambda} - x|) dF(x) - \max \left\{ 0, \int_0^1 (v - |\hat{\lambda} - x|) dF(x) \right\}. \quad (6)$$

This PBE is unique if $F(\hat{\lambda}) + F(\hat{\lambda} - v) \leq 1$.

The PBE described in Proposition 3 is graphically depicted in Figure 3. When v is not too large (i.e. when $v < \underline{y}$), under a mild regularity condition, there exists a unique PBE described by a binary tune-in strategy (air a tune-in or not) by the TV station. The TV station airs a tune-in whenever the location of the second program exceeds a certain threshold. In other words, the TV station airs a tune-in whenever the two programs are not too dissimilar. 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, the viewers correctly infer where the second program could possibly lie and accordingly all of them switch their TVs off. 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.

The necessary condition for uniqueness of the PBE in Proposition 3 is satisfied for all density functions that have a median equal to or above y . This is so because $\hat{\lambda}$ is bounded above by y (when a $\hat{\lambda} > v$ exists). When the density function is sufficiently skewed to the right, on the other hand, there is a multiplicity problem. There exists another PBE in which $\Omega = [x_L, x_H]$, $x_L > 0$. If, for instance, there is a high chance that the second program is going to be located at 0, then in this PBE, viewers with locations close to 0 should watch the second program even in the absence of a tune-in. However, there is some chance that these viewers will end up with a high disutility if the program turns out to be far away. With risk neutrality, this risk may be worth taking. Therefore, such a PBE exists.

I have not explored the properties of this PBE. The reason is twofold. First, I believe that this PBE does not make much sense when a PBE described in Proposition 3 exists. Viewers will be better informed and will achieve a higher utility on average if they play the PBE in Proposition 3. This will be ascertained if a bit of pessimism is introduced. If viewers approach the absence of a tune-in pessimistically, then they will not think that it may still be an appealing program even though the TV station did not advertise it. Second, people are typically risk averse. Introduction of risk aversion into the model will make it less likely that such a PBE exists. I have not pursued this approach since introducing risk aversion unnecessarily complicates the analysis.

An important outcome comes out of the first three propositions. An equilibrium in which the TV station airs a tune-in for all possible program locations does not exist. Formally,

Definition 1 *A PBE is fully revealing if $\Omega = [0, 1]$.*

Proposition 4 *A fully-revealing PBE does not exist.*

This outcome may sound quite natural since it is costly for the TV station to air a tune-in and the literature on information disclosure in vertically-differentiated markets establishes that full disclosure does not arise unless disclosure is costless. However, there are PBE in this model in which full disclosure does not arise even if advertising was assumed costless (this happens when v is small). Furthermore, Proposition 4 is valid for any value of v . Suppose that $v \geq 1$. If we relax the tie-breaking rule in favor of not airing a tune-in in case of indifference, then the unique PBE of this model will be the one in which the TV station does not air any

tune-ins even if a tune-in was costless. So, in contrast with persuasion games, in horizontally-differentiated markets, full disclosure does not necessarily arise when advertising is costless.

I have taken the approach of presenting the results taking v as the control variable. One can alternatively present them based on the properties of the prior beliefs. However, since I have kept the density function in a quite general form, this approach is not very tractable.

3.2 Social Planner's Problem

Since the focus in this paper has been on the role of information disclosure, I assumed that there is a fixed number of commercials at a constant price. Without an explicit modeling of the market for commercials, it is difficult to make a thorough welfare analysis. However, it is interesting to analyze how the tune-in strategy of a single TV station would change if a social planner set it. In this case, the social planner would be interested in maximizing not only the commercial revenue, but also the well-being of the viewers. Specifically, airing a tune-in would be optimal as long as the marginal change in advertising revenue plus the marginal change in aggregate viewer surplus (or loss) exceeds the cost of the tune-in. Let $CS(x_2 | q = 1) - CS(x_2 | q = 0) = K$, where $CS(x_2 | q)$ is the aggregate viewer utility conditional on the realization of q . Then the social planner's problem can be expressed as

$$q(x_2) = \begin{cases} 1, & s_2(x_2 | q = 1) - s_2(x_2 | q = 0)] + \frac{K}{NpA} \geq \frac{s_1}{A} \\ 0, & \text{otherwise} \end{cases}. \quad (7)$$

Let the equilibrium set of programs that the social planner chooses to air a tune-in be denoted by $\Omega^S = [x_L^S, x_H^S]$. Suppose $K > 0$ and take some market equilibrium $\Omega^* \neq \emptyset$. Then, for given Ω^* , the social planner will have an incentive to air a tune-in for a strictly larger set of programs. However, since viewers anticipate this beforehand, their viewing decisions may change. If indeed $\Omega^* \subset \Omega^S$, then, compared to the market equilibrium, both $s_2(x_2 | q = 1)$ and $s_2(x_2 | q = 0)]$ will be lower at $x_2 = x_L^S, x_H^S$. So, $s_2(x_2 | q = 1) - s_2(x_2 | q = 0)]$ may assume a sufficiently low value that offsets or even exceeds the extra positive term due to viewer surplus. Furthermore, if $\Omega^* \subset \Omega^S$ actually holds true, then, for lower values of v , there will be a higher number of viewers with locations $\lambda > v$ watching the first program. The social planner must take into account the negative first-period utility these viewers get. Therefore, it is a priori not clear if $\Omega^* \subset \Omega^S$ holds true. However, as Proposition 5 establishes, it is indeed true that there exists a $\Omega^* \subset \Omega^S$ unless v is too large.

Proposition 5 *There exists a solution to the social planner's problem Ω^S such that $\Omega^* \subset \Omega^S$ for all $v < v^S$, and $\Omega^* \equiv \Omega^S$ for $v \geq v^S$, where $v^S > \bar{v}$.*

A result that directly follows from Proposition 5 is that $\Omega^S \rightarrow \Omega^*$ only when $p \rightarrow \infty$. The intuition for why the social planner has an incentive to air tune-ins for a wider range of programs is that she considers the well-being of all viewers as well as the informational benefits accruing to all people who are exposed to tune-ins, including people who would always watch the first program regardless of tune-ins. This concern is not present for a monopolist. As a result, market equilibrium is generally suboptimal.

It is worth noting that it does not necessarily mean that all viewers enjoy a higher utility under the social planner's solution. As mentioned earlier, if $\Omega^* \subset \Omega^S$, then we will have a higher number of viewers with locations $\lambda > v$ watching the first program. Suppose v is very small so that the ex-ante expected utility of watching the second program based on prior beliefs is negative. If, for instance, $x_2 = 0$, then these extra viewers will end up with a lower total utility under the social planner's solution.

4 Conclusion

In this paper, I have presented a model that analyzes the incentives of a firm to provide information about its product. Rationality of people plays a crucial role in the derivation of the equilibria. It implies that the decision of a firm not to advertise actually reveals useful information to people. This point has largely been ignored in the previous literature on informative advertising. Therefore, the findings in this paper 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.

It was 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, are the ones that are unappealing to a majority of the recipients of that ad.

The model presented in this paper could be extended to include multiple periods. In this case a commonly observed phenomenon, endogenous targeting, would arise; the TV station strictly prefers airing a tune-in for a program during the ones that are most similar to it. Another direction that could be taken is analyzing the role of tune-ins when the quality of the upcoming program is also unknown to viewers beforehand. In this scenario, tune-ins do not only carry hard information, but also might signal the quality of the upcoming program. A high-quality monopolist may choose to air more than one tune-in for the same program to signal its quality, even though the tune-in is fully informative. It may also be the case that for certain program locations, there is no need for dissipative advertising to signal quality. These questions are answered in Çelik (2008a).

The form of the utility function can also be varied easily. Since there is no price (nor a choice of the number of commercials) in the model, one can easily include a more general distance function rather than a linear one. As long as the distance function is continuous and strictly increasing, the main findings remain valid.

Analyzing the role of tune-ins in an oligopolistic TV market requires modeling of people's switching behavior during a program. It is common to assume that people do not engage in multihoming; i.e. they consume only one product in every period. Furthermore, empirical data and research support that the 'lead-in' effect is significant and is more than 60%. Therefore, under the assumption that people cannot watch more than one program in a given period, each TV station actually acts like a monopolist to its current viewers. The only difference is that there will be switching viewers from one period to another. If the TV stations do not know each others' program locations when making their tune-in decisions, then their equilibrium tune-in strategies will be similar to the findings in this paper. If they do, on the other hand, the analysis gets complicated. Each station's tune-in decision may now indirectly disclose information about other stations' programs. This is what I study in Çelik (2008b) for a duopoly market.

5 Appendix

Proof of Lemma 1 In a PBE, it must be true that $x_2 \in \Omega$ whenever $q = 1$. Suppose $q = 1$. Since viewers make their first-period decisions without seeing a tune-in, the first-period audience size does not depend on the actual value of x_2 . This is true also for the second-period audience size conditional on no tune-ins during the first program; i.e. $s_2(x_2 | q = 0)$ depends only on the updated beliefs for the second program. Therefore, $s_2(x_2 | q = 0) + \frac{s_1}{A}$ is independent of the actual value of x_2 .

$s_2(x_2 | q = 1)$ can be found as follows. Let $\Delta = \{\lambda > v \mid B(\lambda) \geq \lambda - v\}$ describe the set of viewers watching the first program who would not do so if there were no informational benefits. Note that $\max(\Delta) \leq 2v$ since expected gains can never exceed v . Δ is determined by Ω in equilibrium. When $x_2 = 0$, only $\lambda \leq v$ from the first period audience watch the second program. When $0 < x_2 < \max(\Delta) - v$, all $\lambda \leq v$ plus some viewers belonging to Δ watch it. When $\max(\Delta) - v \leq x_2 \leq v$, all of the first-period audience watch the second program. As x_2 gets larger than v , some viewers start dropping out, and eventually when $x_2 > \max(\Delta) + v$, no one from the first-period audience watches the second program.

So, $s_2(x_2 | q = 1)$ is an increasing function of x_2 for $0 \leq x_2 \leq \max(\Delta) - v$. It attains its maximum for $x_2 \in [(\max(\Delta) - v), v]$, and starts monotonically decreasing at $x_2 = v$. Note that the second-period audience also comprises people who did not watch the first program. However, these people base their decisions on their prior beliefs, and therefore their size is independent of the actual value of x_2 .

Hence, $s_2(x_2 | q = 1)$ can intersect $s_2(x_2 | q = 0) + \frac{s_1}{A}$ at a maximum of two points, conditional on the existence of a PBE. Denote these two points x_L and x_H . Then, $s_2(x_2 | q = 1) \geq s_2(x_2 | q = 0) + \frac{s_1}{A}$ 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 2 See the discussion that precedes Lemma 2. ■

Proof of Lemma 3 Suppose $\hat{\lambda} > v$ in equilibrium. In this case, $s_2(x_2 | q = 1)$ attains its maximum for $x_2 \in [\hat{\lambda} - v, v]$ since these program locations appeal to all first-period viewers. Therefore, if $\Omega \neq \emptyset$, we must have $q(x_2) = 1$ for $x_2 \in [\hat{\lambda} - v, v]$. Also note that, by continuity, we must have $s_2(x_L | q = 1) \geq s_2(x_H | q = 1)$ with equality when $x_L > 0$. So,

if in equilibrium $x_L = 0$, then it must be that $x_H \geq \hat{\lambda}$. If, on the other hand, $x_L > 0$ in equilibrium, then we must have $x_L \leq \hat{\lambda} - v$ and $v \leq x_H < \hat{\lambda}$ with the additional property that $x_H = \hat{\lambda} - x_L$. This last property follows from the fact that $s_2(x_L | q = 1) = x_L + v$ and $s_2(x_H | q = 1) = \hat{\lambda} - (x_H - v)$, and these two are equal in equilibrium.

Alternatively, it could be that $\hat{\lambda} = v$ in equilibrium. In this case, since $s_2(x_2 | q = 1)$ attains its maximum for $x_2 \in [0, v]$, the equilibrium Ω is either an empty set or is given by $\Omega = [x_L, x_H]$ with $x_L = 0$ and $x_H \geq v$. ■

Proof of Lemma 4 Suppose $\hat{\lambda} = v$. Then by Lemma 3, it must be that $x_L = 0$ and $v \leq x_H < 2v$. It must also be that $B(v) \leq 0$.

$$\begin{aligned} B(v) &= \int_0^{x_H} (v - |v - x|) dF(x) + \max\{0, \int_{x_H}^1 (2v - x) dF(x)\} \\ &\quad - \max\{0, E[u(v, x_2)]\} \end{aligned}$$

The first term above is clearly positive. Suppose $E[u(v, x_2)] \leq 0$. But then the $\int_{x_H}^1 (2v - x) dF(x)$ must be negative. Thus, $B(v) > 0$ which is a contradiction. Now, suppose that $E[u(v, x_2)] > 0$ and that $\int_{x_H}^1 (2v - x) dF(x) < 0$. But then we will have $B(v) = -\int_{x_H}^1 (2v - x) dF(x) > 0$, which is a contradiction. So, if $\hat{\lambda} = v$, then $\int_{x_H}^1 (2v - x) dF(x) \geq 0$.

Suppose $\int_0^{x_L} x dF(x) + \int_{x_H}^1 (2v - x) dF(x) \geq 0$. Then $E[u(v, x_2)] > 0$ must be satisfied. In this case, $B(v) = 0$, which implies that $\hat{\lambda} = v$. ■

Proof of Proposition 1 When $E[u(v, x_2 | x_2 \notin \Omega)] > 0$, we will have an interval of viewers just to the left of v who continue to watch TV in the absence of a tune-in. Denote the cutoff viewer $\tilde{\lambda} < v$. If $\int_{x_H}^1 (v - x) dF(x) \geq 0$, then we will simply have $\tilde{\lambda} = 0$. Otherwise, the value of $\tilde{\lambda}$ is given by the solution to $\int_{x_H}^1 (v + \tilde{\lambda} - x) dF(x) = 0$. Now, we have $s_2(x_H | q = 1) = v - (x_H - v)$ and $s_2(x_2 | q = 0) = v - \tilde{\lambda}$. So, the indifference condition for the TV station becomes:

$$\begin{aligned} s_2(x_2 | q = 1) - s_2(x_2 | q = 0) &= \frac{v}{A} \\ x_H &= \tilde{\lambda} + (1 - \frac{1}{A})v \end{aligned}$$

It is easy to see that $x_H = v$ when $\tilde{\lambda} = v/A$. If the equilibrium value of $\tilde{\lambda}$ turns out to be equal to or less than v/A for a given value of $x_H \geq v$, then $s_2(x_2 | q = 0) \geq v - \frac{v}{A}$, and thus the TV station is better off not airing any tune-ins at all. This, however, will be rationally expected by viewers. Therefore, $\Omega = \emptyset$ arises as a PBE if $\tilde{\lambda} \leq v/A$ when $x_H = v$. Uniqueness

follows from the fact that $\int_v^1(v + \frac{v}{A} - x)dF(x)$ is monotonic in v due to Assumption 2:

$$\frac{d\int_v^1(v + \frac{v}{A} - x)dF(x)}{dv} = (1 + \frac{1}{A})(1 - F(v)) - \frac{v}{A}f(v).$$

This expression is positive when $\frac{f(v)}{1-F(v)} < \frac{A}{v}(1 + \frac{1}{A})$ which is true by Assumption 2 for any $v < k$. Also note that $\int_v^1(v + \frac{v}{A} - x)dF(x) < 0$ for small values of v (such as $v = 0$), and is positive for large values of v (such as $v = \frac{A}{A+1} + \varepsilon$). So, there can be a unique value of v , denoted by \bar{v} , which satisfies $\int_{\bar{v}}^1(\bar{v} + \frac{\bar{v}}{A} - x)dF(x) = 0$. For all higher values of v , $\int_{\bar{v}}^1(\bar{v} + \frac{\bar{v}}{A} - x)dF(x) > 0$, and hence, $\Omega = \emptyset$ is the unique PBE. ■

Proof of Proposition 2 Firstly, note that when $\int_{(2-\frac{1}{A})v}^1(2v - x)dF(x) = 0$, we have $\tilde{\lambda} = v$ and $x_H = (2 - \frac{1}{A})v$. This happens when $v = y$. There is a unique solution to $\int_{(2-\frac{1}{A})v}^1(2v - x)dF(x) = 0$. To see this, note that

$$\frac{d\int_{(2-\frac{1}{A})v}^1(2v - x)dF(x)}{dv} = 2(1 - F((2 - \frac{1}{A})v)) - 2\frac{v}{A}f((2 - \frac{1}{A})v).$$

This is positive when $\frac{f((2-\frac{1}{A})v)}{1-F((2-\frac{1}{A})v)} < \frac{A}{v}$ which is true by Assumption 2 for any $v < k$. Also note that $\int_{(2-\frac{1}{A})v}^1(2v - x)dF(x)$ is negative for small values of v (such as $v = 0$), and is positive for large values of v (such as $v = \frac{1}{2}$). So, there can be a unique value of v , denoted by y , that satisfies $\int_{(2-1/A)y}^1(2y - x)dF(x) = 0$.

Next, we need to show that $y < \bar{v}$. To see this, note that $\int_{(2-\frac{1}{A})v}^1(2v - x)dF(x)$ can be expressed as $\int_{(2-\frac{1}{A})v}^1((2 - \frac{1}{A})v + \frac{v}{A} - x)dF(x)$. This must be positive when evaluated at $v = \bar{v}$ since $\int_v^1(v + \frac{v}{A} - x)dF(x)$ is monotonically increasing in v when $v \geq \bar{v}$, and clearly $\bar{v}(2 - \frac{1}{A}) > \bar{v}$. Hence, $y < \bar{v}$.

Existence and uniqueness of a PBE $\Omega = [0, x_H]$, where $x_H \geq v$, follows from a graphical argument. Putting x_H on the horizontal axis and $\tilde{\lambda}$ on the vertical axis (as in Figure 2), let's see what equations (3) and (4) look like.

$$(3) : \quad \int_{x_H}^1(v + \tilde{\lambda} - x)dF(x) = 0 \\ (4) : \quad x_H = \tilde{\lambda} + (1 - \frac{1}{A})v,$$

To see that there exists a unique PBE, first note that equation (4) implies $\frac{d\tilde{\lambda}}{dx_H} = 1$ while equation (3) implies $\frac{d\tilde{\lambda}}{dx_H} = \frac{(v+\tilde{\lambda}-x_H)f(x_H)}{1-F(x_H)}$ up to an upper bound of x_H (which is less than $2v$) and 0 afterwards. When $x_H = v$, equation (4) implies $\tilde{\lambda} = \frac{v}{A}$ while equation (3) implies

$\tilde{\lambda} > \frac{v}{A}$. The latter follows from the fact that $\int_v^1 (v + \frac{v}{A} - x) dF(x)$ is monotonically increasing in v and therefore $\int_v^1 (v + \frac{v}{A} - x) dF(x) < 0$ when $v < \bar{v}$. For high values of x_H , on the other hand, equation (3) implies $\tilde{\lambda} = v$ whereas equation (4) implies $\tilde{\lambda} = \frac{x_H}{(1-\frac{1}{A})v} > v$. Since both equations are continuous and non-decreasing, they must intersect. At a PBE, it must be that $v + \tilde{\lambda} - x_H = \frac{v}{A}$. Hence, by Assumption 2, equation (3) must be upward-sloping with a slope of $\frac{d\tilde{\lambda}}{dx_H} < 1$ at a PBE. If the two equations intersect more than once, then they must have an odd number of intersections since equation (4) implies a lower value of $\tilde{\lambda}$ than equation (3) when $x_H = v$. In such a case, however, equation (3) must have $\frac{d\tilde{\lambda}}{dx_H} > 1$ at one of these intersections at least. This is impossible to happen at a PBE. So, the two equations can intersect at most once. ■

Proof of Lemma 5 This is clear from Propositions 1 and 2. ■

Proof of Lemma 6 Suppose, on the contrary, that some people continue watching. Then $\lambda = \hat{\lambda}$ has to be one of these viewers. If $\int_0^1 u(\hat{\lambda}, x) dF(x) > 0$, then the condition $B(\hat{\lambda}) = (\hat{\lambda} - v)$ is expressed as

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

Rearranging the left-hand side, we have

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

The left-hand side is at most $(\hat{\lambda} - v)F(\hat{\lambda} - v)$ which is always less than $(\hat{\lambda} - v)$. So, if $\int_0^1 u(\hat{\lambda}, x) dF(x) > 0$, then $E[u(\hat{\lambda}, x_2 | x_2 \notin \Omega)]$ cannot be positive.

Now, if $\int_0^1 u(\hat{\lambda}, x) dF(x) \leq 0$, then the condition $B(\hat{\lambda}) = (\hat{\lambda} - v)$ becomes

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

This condition can be rearranged as

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

The right-hand side is at least $(\hat{\lambda} - v)[1 - F(\hat{\lambda} - v)] > 0$. This contradicts $\int_0^1 (v - |\hat{\lambda} - x|) dx$ being non-negative. So, it has to be true that $E[u(\hat{\lambda}, x_2 | x_2 \notin \Omega)] < 0$.

Since $x_L = 0$, $E[u(\lambda, x_2) | x_2 \notin \Omega] = \int_{x_H}^1 \frac{(v+\lambda-x)}{1-F(x_H)} dF(x)$ for all $\lambda \leq \hat{\lambda}$. So,

$$\frac{\partial E[u(\lambda, x_2) | x_2 \notin \Omega]}{\partial \lambda} = 1.$$

Hence $E[u(\hat{\lambda}, x_2 | x_2 \notin \Omega)] < 0$ for all $\lambda \leq \hat{\lambda}$, no one with $\lambda \leq \hat{\lambda}$ keeps watching conditional on exposure to no tune-ins. ■

Proof of Proposition 3 First, note that there exists a $\hat{\lambda} > v$ when $B(v) > 0$, and this is true when $v < y$. The fact that $\hat{\lambda}$ and x_H are uniquely determined in a PBE in which $\Omega = [0, x_H]$, where $\hat{\lambda} > v$, follows from a graphical argument. Putting x_H on the horizontal axis and $\hat{\lambda}$ on the vertical axis (as in Figure 3), let's look at equations (5) and (6):

$$(5) : \hat{\lambda} = v + \int_{\hat{\lambda}-v}^{\min\{x_H, \hat{\lambda}+v\}} (v - |\hat{\lambda} - x|) dF(x) - \max \left\{ 0, \int_0^1 (v - |\hat{\lambda} - x|) dF(x) \right\},$$

$$(6) : x_H = v + (1 - \frac{1}{A})\hat{\lambda}.$$

To see that $\hat{\lambda}$ and x_H are uniquely determined in this PBE, suppose first that $E[u(\hat{\lambda}, x_2)] \geq 0$. Note that equation (6) implies $\frac{d\hat{\lambda}}{dx_H} = \frac{1}{(1-\frac{1}{A})} > 1$ while equation (5) implies $\frac{d\hat{\lambda}}{dx_H} = \frac{(v+\hat{\lambda}-x_H)f(x_H)}{(1-F(x_H))+(1-F(\hat{\lambda}-v))}$ when $x_H < v + \hat{\lambda}$ and 0 otherwise. So, equation (5) implies $\frac{d\hat{\lambda}}{dx_H} \geq 0$. When $x_H = (2 - \frac{1}{A})v$, equation (6) implies $\hat{\lambda} = v$ while equation (5) implies $\hat{\lambda} > v$. The latter follows from the fact that $B(v) > 0$ when $v < y$. For high values of x_H , on the other hand, equation (6) implies $\hat{\lambda} < y$ whereas equation (5) implies $\hat{\lambda} = \frac{x_H-v}{(1-\frac{1}{A})v} > y$. Since both equations are continuous and non-decreasing, they must intersect. At a PBE, it must be that $v + \hat{\lambda} - x_H = \frac{\hat{\lambda}}{A}$. Hence, by Assumption 2, equation (5) must be upward-sloping with a slope of $\frac{d\hat{\lambda}}{dx_H} < 1$ at a PBE. If the two equations intersect more than once, then they must have an odd number of intersections since equation (6) implies a lower value of $\hat{\lambda}$ than equation (5) when $x_H = v$. In such a case, however, equation (5) must have $\frac{d\hat{\lambda}}{dx_H} > \frac{1}{(1-\frac{1}{A})}$ at one of these intersections at least. This is impossible to happen at a PBE.

Now suppose that $E[u(\hat{\lambda}, x_2)] < 0$. The slope of equation (6) remains the same while equation (5) now implies $\frac{d\hat{\lambda}}{dx_H} = \frac{(v+\hat{\lambda}-x_H)f(x_H)}{(1-F(x_H))+(2F(\hat{\lambda})-F(\hat{\lambda}-v))}$ when $x_H < v + \hat{\lambda}$ and 0 otherwise. At a PBE, it must be that $v + \hat{\lambda} - x_H = \frac{\hat{\lambda}}{A}$. Hence, by Assumption 2, equation (5) must be upward-sloping with a slope of $\frac{d\hat{\lambda}}{dx_H} < 1$ at any equilibrium. Hence, the two equations can intersect at most once.

Uniqueness of a PBE in which $\Omega = [0, v + (1 - \frac{1}{A})\hat{\lambda}]$, where $\hat{\lambda} > v$, when $F(\hat{\lambda}) + F(\hat{\lambda} - v) < 1$ is proved with the help of the following two auxiliary lemmas. Suppose $F(\hat{\lambda}) +$

$F(\hat{\lambda} - v) \leq 1$ and there exists another PBE in the form (this is the only possibility) $\Omega' = \{(x_L, x_H) \mid x_L > 0\}$. In this new PBE,

Lemma A.1 $E[u(\lambda, x_2) \mid x_2 \notin \Omega'] < 0$ for all $\lambda \in [v, x_L + v]$.

Proof Take some $\lambda \in [v, x_L + v]$ and suppose that $E[u(v, x_2) \mid x_2 \notin \Omega'] \geq 0$, on the contrary. Then, $\int_0^{x_L}(v - |\lambda - x|)dF(x) + \int_{x_H}^1(v - |\lambda - x|)dF(x) \geq 0$. Note that, for all these λ , $\int_{x_L}^{x_H}(v - |\lambda - x|)dF(x) > 0$. Therefore, we must have $E[u(\lambda, x_2)] > 0$. So, for all $\lambda \in [v, x_L + v]$,

$$\begin{aligned} B(\lambda) &= \int_{x_L}^{x_H}(v - |\lambda - x|)dF(x) + \int_0^{x_L}(v - |\lambda - x|)dF(x) + \int_{x_H}^1(v - |\lambda - x|)dF(x) \\ &\quad - \int_0^1(v - |\lambda - x|)dF(x) \\ &= 0. \end{aligned}$$

But then $B(\lambda) < \lambda - v$ for all $\lambda > v$ since $\partial B(\lambda)/\partial\lambda < 1$. So, it must be that $\hat{\lambda} = v$. However, this contradicts the initial assumption that $x_L > 0$. Hence, $E[u(\lambda, x_2) \mid x_2 \notin \Omega'] < 0$ for all $\lambda \in [v, x_L + v]$. ■

Lemma A.2 $E[u(\lambda, x_2) \mid x_2 \notin \Omega'] < 0$ for all $\lambda \in (x_L + v, \hat{\lambda}]$.

Proof Take some $\lambda \in (x_L + v, \hat{\lambda}]$ and suppose that $E[u(\lambda, x_2) \mid x_2 \notin \Omega'] \geq 0$, on the contrary. Then, $\int_0^1 u(\lambda, x)dF(x) - \int_{x_L}^{x_H} u(\lambda, x)dF(x) \geq 0$. Therefore, if $\int_{x_L}^{x_H} u(\lambda, x)dF(x)$ is non-negative, so is $\int_0^1 u(\lambda, x_2)dF(x)$.

Suppose that $\int_{x_L}^{x_H} u(\lambda, x)dF(x) \geq 0$. Then, we have

$$\begin{aligned} B(\lambda) &= \int_{\lambda-v}^{x_H} u(\lambda, x)dF(x) - \int_{x_L}^{x_H} u(\lambda, x)dF(x) \\ &= - \int_{x_L}^{\lambda-v} (v - \lambda + x)dF(x) \\ &= (\lambda - v)[F(\lambda - v) - F(x_L)] - \int_{x_L}^{\lambda-v} x dF(x). \end{aligned}$$

Note that $\int_{x_L}^{\lambda-v} x dF(x) > \int_{x_L}^{\lambda-v} x_L dF(x) = x_L[F(\hat{\lambda} - v) - F(x_L)]$. So, we have

$$B(\lambda) < (\lambda - v - x_L)[F(\lambda - v) - F(x_L)].$$

However, since $x_L > 0$ and $F(\lambda - v) - F(x_L) \leq 1$, we must have $B(\lambda) < \lambda - v$ for all $\lambda \in (x_L + v, \hat{\lambda}]$.

Suppose now that $\int_{x_L}^{x_H} u(\lambda, x) dF(x) < 0$. Note that $\int_0^1 u(\lambda, x) dF(x) \geq 0$ in this case, because we would then have $B(\lambda) = \int_{\lambda-v}^{x_H} u(\lambda, x) dF(x) - \int_{x_L}^{x_H} u(\lambda, x) dF(x)$, and the previous reasoning would follow. Suppose that $\int_0^1 u(\lambda, x) dF(x) < 0$. Then,

$$\begin{aligned} B(\lambda) &= \int_{\lambda-v}^{x_H} u(\lambda, x) dF(x) + \int_0^1 u(\lambda, x) dF(x) - \int_{x_L}^{x_H} u(\lambda, x) dF(x) \\ &= \int_0^1 u(\lambda, x) dF(x) - \int_{x_L}^{\lambda-v} (v - \lambda + x) dF(x). \end{aligned}$$

Note from the previous argument again that $-\int_{x_L}^{\lambda-v} (v - \lambda + x) dF(x) < \lambda - v$. Since $\int_0^1 u(\lambda, x) dF(x) < 0$ by assumption, we again have $B(\lambda) < \lambda - v$.

Hence, there is no value of $\lambda \in (x_L + v, \hat{\lambda}]$ such that $B(\lambda) \geq \lambda - v$. Together with Lemma A.1, then, the marginal person watching TV in the first period must be the one located at v . But, then $\Omega = \emptyset$. Therefore, we must have $E[u(\lambda, x_2) | x_2 \notin \Omega] < 0$ for all $\lambda \in (x_L + v, \hat{\lambda}]$. ■

With Lemma A.1 and Lemma A.2 at hand, it is now easier to proceed. First, note that

$$\frac{\partial E[u(\lambda, x_2) | x_2 \notin \Omega]}{\partial \lambda} = \begin{cases} \frac{(1-F(x_H)-F(\lambda))+(F(x_L)-F(\lambda))}{1-F(x_H)+F(x_L)}, & \lambda < x_L \\ \frac{1-F(x_H)-F(x_L)}{1-F(x_H)+F(x_L)}, & x_L \leq \lambda < x_H \\ \frac{(1-F(x_L)-F(\lambda))-(F(\lambda)-F(x_H))}{1-F(x_H)+F(x_L)}, & \lambda \geq x_H \end{cases}.$$

By assumption, $F(\hat{\lambda}) + F(\hat{\lambda} - v) \leq 1$. But then $F(x_H) + F(x_L) \leq 1$, since $x_L < \hat{\lambda} - v$ and $x_H < \hat{\lambda}$. So, $\frac{\partial E[u(\lambda, x_2) | x_2 \notin \Omega]}{\partial \lambda} > 0$ for all $\lambda \leq \hat{\lambda}$. Since $E[u(\hat{\lambda}, x_2) | x_2 \notin \Omega] < 0$, we must have $E[u(\lambda, x_2) | x_2 \notin \Omega] < 0$ for all $\lambda \leq \hat{\lambda}$. So, no one from the first-period audience keeps watching TV in the absence of a tune-in. But then the TV station is better off airing a tune-in for all $x_2 \leq \hat{\lambda}$. This contradicts the initial assumption that a PBE $\Omega' = \{(x_L, x_H) | x_L > 0\}$ exists. Hence, $\Omega = \{[0, x_H) | x_H \geq \hat{\lambda}\}$ is the unique PBE when $F(\hat{\lambda}) + F(\hat{\lambda} - v) \leq 1$. ■

Proof of Proposition 4 This is quite straightforward. x_H is bounded above by $(1 - \frac{1}{A})y + y$. Here, y is always less than $\frac{1}{2}$ since $\int_{v(2-1/A)}^1 (2v - x) dF(x) > 0$ when $v = \frac{1}{2}$. ■

Proof of Proposition 5 Viewers' problem is exactly the same as before. So, equations (3) and (5) will remain valid. Then, it suffices to show that $\frac{dK}{d\lambda} > 0$ for some $x_2 \in \Omega^S$ when $y \leq v < \bar{v}$ and that $\frac{dK}{d\lambda} > 0$ for some $x_2 \in \Omega^S$ when $v < y$. This follows from the fact that the social planner's problem, namely equation (7), will imply a smaller slope than equation (4) when y

$\leq v < \bar{v}$, and a smaller slope than equation (6) when $v < \underline{v}$. Hence, the graphical arguments in the proofs of Proposition 2 and Proposition 3 will apply here.

Let the marginal person to watch the first program under the social planner's solution be denoted by $\hat{\lambda}^S$ when $\hat{\lambda}^S > v$, and the marginal person to continue watching the second program in the absence of a tune-in be denoted by $\tilde{\lambda}^S$.

Suppose v is large enough and we have $\tilde{\lambda}^S \leq v$ (so, $\hat{\lambda}^S = v$). Then, the social planner's problem will be:

$$q(x_2) = \begin{cases} 1, & v - x_H + \tilde{\lambda}^S + \frac{K}{NpA} \geq \frac{v}{A} \\ 0, & \text{otherwise} \end{cases} .$$

$\frac{K}{N}$ can easily be calculated:

$$\frac{K}{N} = \begin{cases} \int_{\max\{0, x_2 - v\}}^{\tilde{\lambda}^S} (v - |\lambda - x_2|) d\lambda, & x_2 \leq \tilde{\lambda}^S + v \\ - \int_{\tilde{\lambda}^S}^{\min\{v, x_2 - v\}} (v + \lambda - x_2) d\lambda, & x_2 > \tilde{\lambda}^S + v \end{cases} .$$

It is easy to see that $\frac{1}{N} \frac{dK}{d\tilde{\lambda}^S} = vf(\tilde{\lambda}^S) > 0$ for all x_2 . Now suppose that v is small enough and we have $\hat{\lambda}^S > v$ (so, $\tilde{\lambda}^S = v$). Note that, in this situation, no one from the first-period audience continues watching TV in the absence of a tune-in. Then, we will have:

$$\frac{K}{N} = \begin{cases} \int_0^{x_2+v} (v - |\lambda - x_2|) d\lambda, & x_2 \leq \hat{\lambda}^S - v \\ \int_{\hat{\lambda}^S}^{\max\{0, x_2 - v\}} (v - |\lambda - x_2|) d\lambda, & x_2 > \hat{\lambda}^S - v \end{cases} .$$

$\frac{dK}{d\tilde{\lambda}^S} = 0$ when $x_2 \leq \hat{\lambda}^S - v$, and $\frac{1}{N} \frac{dK}{d\tilde{\lambda}^S} = vf(\tilde{\lambda}^S) > 0$ when $x_2 > \hat{\lambda}^S - v$. So, $\frac{1}{N} \frac{dK}{d\tilde{\lambda}^S} > 0$ for some $x_2 \in \Omega^S$. This means that, for all $\Omega^* \neq \emptyset$, there exists a $\Omega^S \supset \Omega^*$. When $v \geq \bar{v}$, the monopolist's solution is $\Omega^* = \emptyset$. It is easy to show that a social planner would air a tune-in for $x_2 \leq v$ when $v = \bar{v}$, since $K > 0$ for all $x_2 \leq v$. Hence, there exists a $v^S > \bar{v}$ such that $\Omega^S \supset \Omega^*$ for all $v < v^S$ and $\Omega^S \equiv \Omega^*$ for all $v \geq v^S$. ■

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FIGURE 1
Two possible PBEs

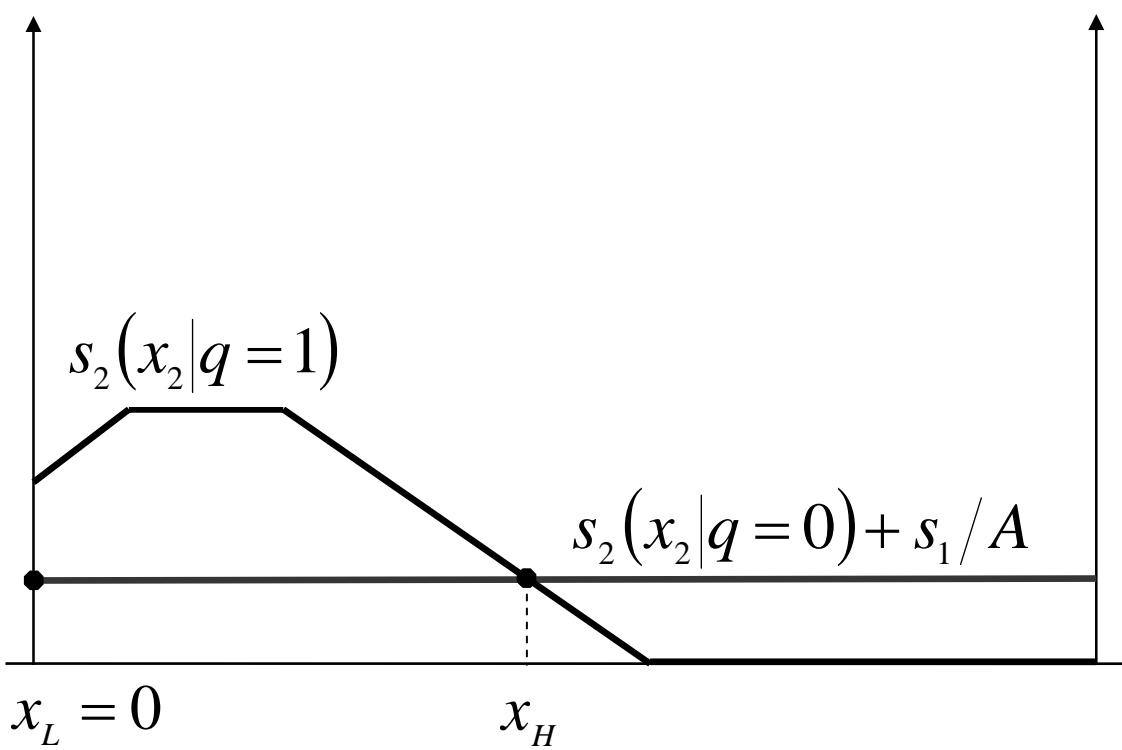
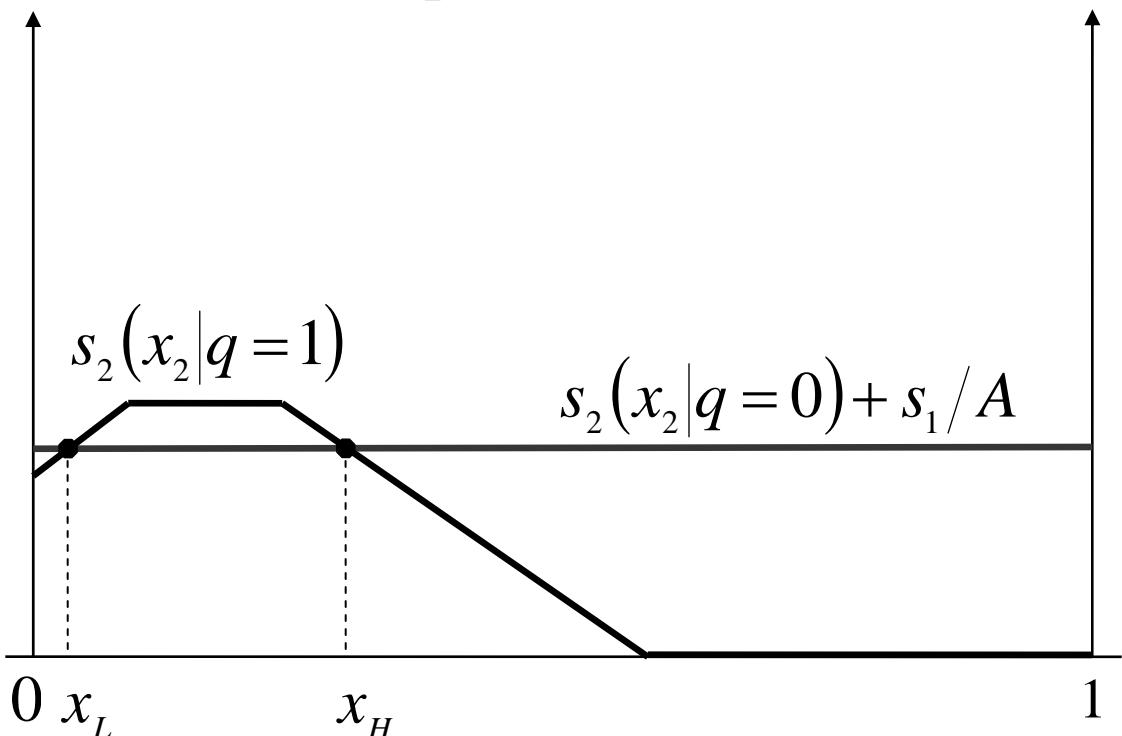


FIGURE 2
Determination of PBE when $\underline{v} \leq v < \bar{v}$

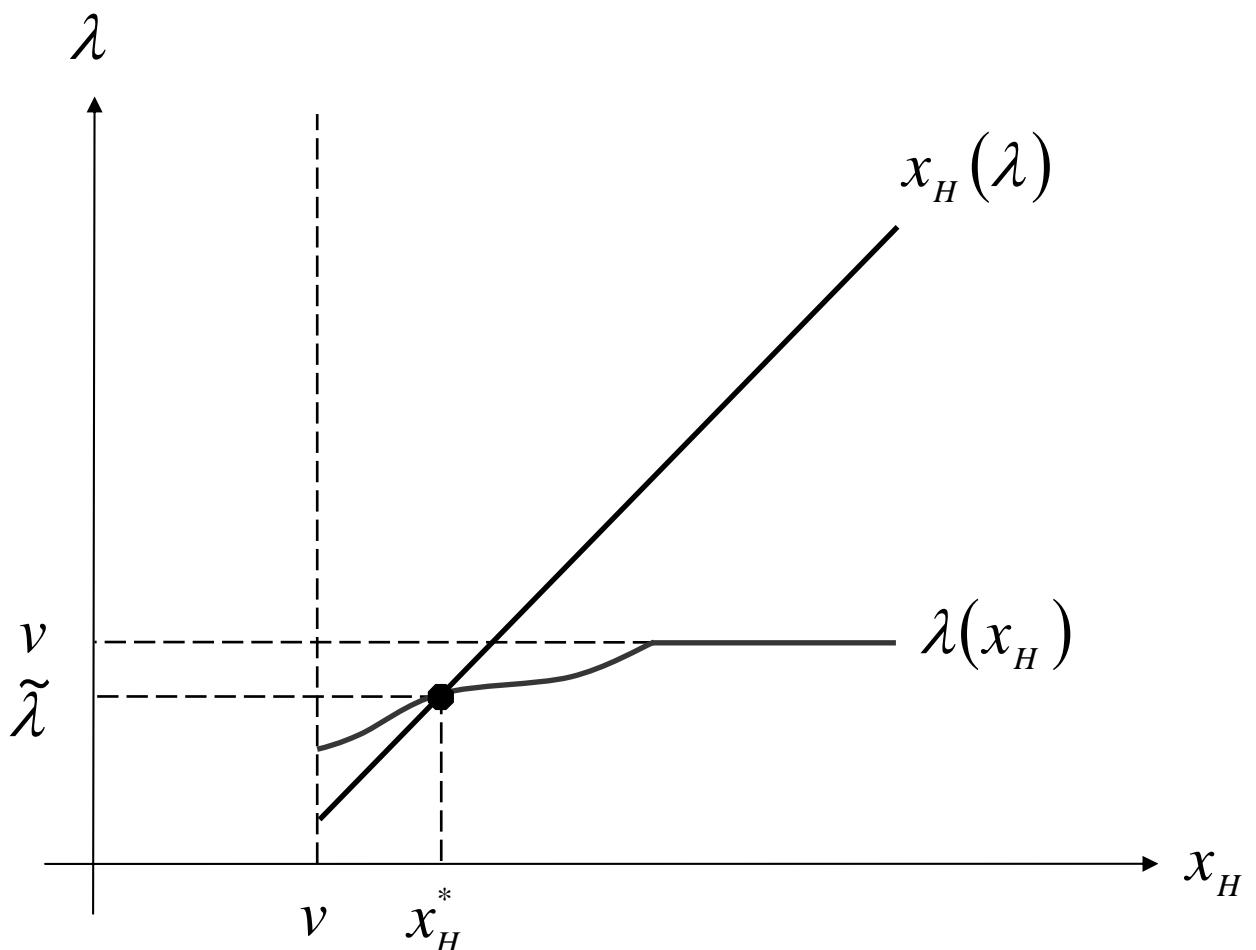
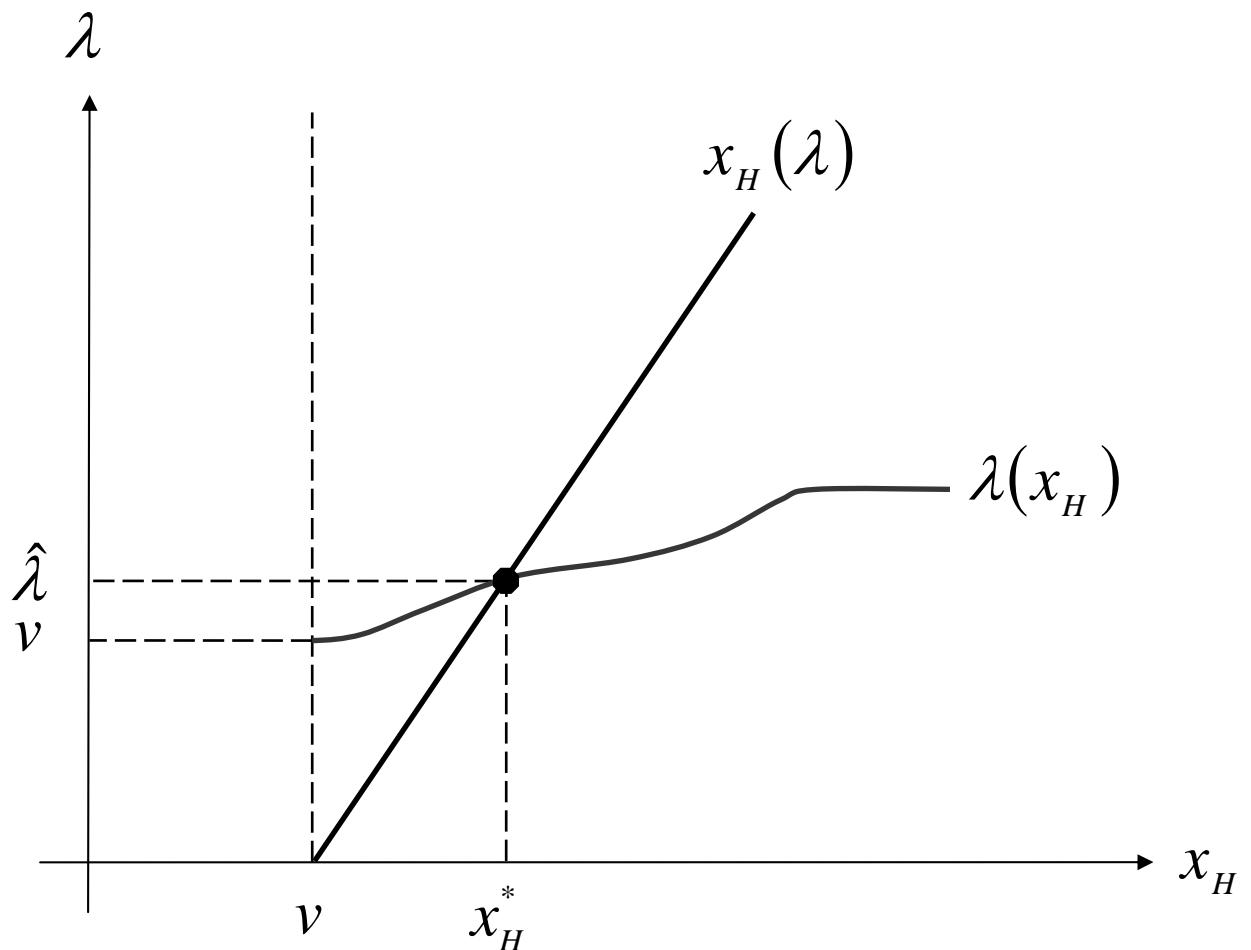


FIGURE 3
Determination of PBE when $v < \underline{v}$



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