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THE CHOICE OF COMMERCIAL BREAKS IN TELEVISION PROGRAMS: THE NUMBER, LENGTH AND TIMING*

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This paper examines the choice of commercial breaks by a television network in a monopoly setup. It is assumed that viewers dislike commercials, while the network seeks to maximize the total audience for these commercials through its choice of the number, length, and timing of commercial breaks. The model predicts that commercial breaks become more frequent toward the end of the program, and that the length of breaks is single-peaked. When the television program becomes more popular, the network runs commercials more frequently, and redistributes commercials so that late breaks become longer while early breaks become shorter.

I. INTRODUCTION

Over-the-air television programming is usually offered to the public for free. It nonetheless generates revenue for television networks because advertisers are willing to pay for commercial time that is inserted into the programs. Audiences, on the other hand, do not like commercials; they watch TV for the free programming and regard commercials as a price that they have to pay.[1] This presents networks with a fundamental tradeoff: The quality of network programming attracts and helps retain a viewing audience but generates no revenue; commercials generate revenue but cause the network to lose viewers as they switch to other channels or turn off the TV. One important way for the networks to control the loss of viewers is through its choice of commercial breaks. Although many countries regulate the amount

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[1] The typical behavior during a commercial break is to switch to another channel, go and get a drink, go to the rest room, talk to another person, or simply leave the room without coming back. See, for example, Thorson and Zhao (1997), Danaher (1995), and Steiner (1966). In 1952, the water commissioner in Toledo, Ohio, noticed that whenever *I Love Lucy* was shown on the city's only television station, each advertising break was marked by a huge drop in water pressure as thousands of toilets flushed at once (Knealy, 1988).

or frequency of television commercials, in the United States, networks enjoy complete freedom in choosing the number, timing, and length of the breaks.[2]

In this paper, we study the choice of commercial breaks by a monopoly network. Viewers can turn off their TVs but they do not have the option of switching to other channels. We assume that the network seeks to maximize the cumulative viewing audience during commercial breaks and that viewers turn off their TVs only during commercial breaks. The drop in the viewing audience that occurs with each break increases with the length of that break. To capture the idea that a longer programming interval builds viewer interest and makes them more likely to stay with the program, we assume that the fraction of the audience that turns off their TVs in any commercial break decreases with the length of the preceding programming interval. The model generates several empirically testable predictions. The programming intervals get shorter with each break, and the lengths of the commercial breaks are initially increasing and then decreasing. The intuition for these results is that the network's incentive for keeping viewers weakens as the program progresses, but earlier commercials are more profitable than later commercials. The interaction of these two effects gives rise to the 'single-peaked' property. Finally, we obtain a comparative static prediction that, when the popularity of the program increases, commercials are more frequent, early breaks are shorter, and later breaks are longer.

Given the importance of television commercials in business and everyday life, surprisingly little research has been done on the choice of commercial breaks. Epstein (1998) finds empirical evidence in support of the model's predictions of shorter programming intervals towards the end of the program. A different but closely related topic is the equilibrium timing of television programs (Cancian, Bills and Bergstrom, 1995; Barros, 1998; Nilssen and Sorgard, 1998), where the timing of a TV program is modeled as a single point in time without any length. The present paper is more complicated because the number and duration of commercial breaks are choice variables as well as the timing of the breaks. Gabszewicz, Laussel and Sonnac (1999) investigate how the program mix, the commercial time, and the price of commercials are determined simultaneously in a duopoly setup.

The paper is organized as follows: Section 2 presents the model; Section 3 characterizes the optimal frequency, timing and length of commercials; Section 4 presents comparative static results and Section 5 concludes.

[2] The National Association of Broadcasters, through its industry code, once limited the amount of TV commercials to be no more than 6 minutes per hour in prime time. The practice was declared to violate the antitrust law in 1981 and was abandoned thereafter. The only restriction that is left now is a law passed by Congress in 1992 requiring that the commercials in children's program not exceed 10.5 minutes per hour on weekdays and 12 minutes per hour on weekends.

II. THE MODEL

A single network (henceforth the monopolist) broadcasts a television program from time 0 to time 1. Let n denote the number of commercial breaks that are chosen by the network, c_i is the length of the ith break, and x_i is the length of the programming interval between the $(i-1)$th and the ith breaks, where $i = 1, 2, \ldots, n$.

The program begins with an audience size $r_0 = 1$. Viewers do not like commercials; they stay with the channel as long as it is showing programming, but some will leave when a commercial break begins. Once a viewer leaves the program, he never comes back.[3] For simplicity we assume that the exodus of viewers happens at the beginning of each commercial break.[4] Let r_i denote the audience size (sometimes also called the rating) of the ith break, for $i = 1,2,\ldots,n$ and denote the drop function by $f(x_i, c_i)$. Then

$$r_i = r_{i-1} - f(x_i, c_i), \quad i = 1, 2, \ldots, n.$$

The audience size is a downward step function of time as shown in Figure 1.

The above drop function is a reduced form description of how viewers decide to turn off their TVs. It implicitly assumes that viewers are somewhat myopic because the drop in audience size at the beginning of the ith break is influenced by only two factors: the length of the programming immediately preceding the break, x_i, and the length of the break itself, c_i. It is consistent with some studies on viewer behavior. 'Research has long emphasized the passivity of viewers.' (Owen and Wildman, 1992, p.10). Barwise and Ehrenberg (1988) acknowledge that, '$\cdots$ we are not always aware of which channel we are watching.' (p.6.)

For simplicity, we shall assume that f takes the form

$$f(x_i, c_i) = g(x_i) + h(c_i),$$

where g and h are non-negative, continuous, differentiable, and convex functions. The following properties are assumed:

Assumption 1: (i) $g'(x) < 0$, $h'(c) > 0$ and (ii) $g''(x) > 0$, $h''(c) \geqslant 0$.

[3] In reality, some viewers leave the program temporarily during a commercial break and come back when the program resumes. Then the loss of audience should be interpreted as a net loss. Another interpretation is that there exists a competing network, e.g., the PBS, which does not show any commercials. Once a viewer is driven to PBS by commercials, he is trapped there and never comes back.

[4] This assumption is not essential and is only for the convenience of computation. A more natural formulation is for the audience size to drop continuously during a commercial break. By appropriately defining the immediate drop of audience size at the beginning of breaks, the two approaches are mathematically equivalent. From the viewpoint of the network, who cares only about the cumulative viewership of commercials, the instantaneous drop of audience size at the beginning of a commercial break rather than a continuous decline during the break is simply a convenient reduced form of its objective function.

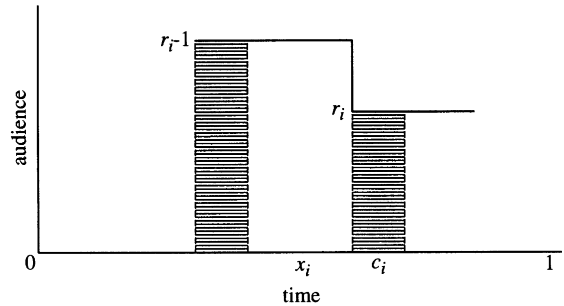

Figure 1
Audience size as a function of time.

Assumption 1(i) states that the drop in viewing audience during a commercial break decreases with the length of the preceding programming interval and increases with the length of the commercial. Longer programming intervals help retain viewers by building their interest in the program, making it more costly for them to turn off their TVs. Viewers are also often annoyed when commercial breaks occur too frequently. The marketing literature has long recognized that longer commercials drive more viewers away from the program. Siddarth and Chattopadhyay (1998) found that 'longer advertisements have a higher probability of being switched off.' Danaher (1995) made the same discovery. Van Meurs (1998, p.47) pointed out that 'one of the most obvious causes of switching is the duration of the break. The longer it lasts, the greater the chance that the audience will start switching.' Condition (ii) states that h is convex while g is strictly convex.

In addition, we impose the following conditions to rule out trivial boundary solutions.

Assumption 2: (i) $g(0)+h(1) > 1$ and (ii) $g(1)+h(0) < 1$.

Condition (i) implies that, if the network tries to fill the entire hour with commercials, then no one will watch the program. Condition (ii) states that the drop in audience after a sufficiently long programming interval is less than one. It implies that the network can run at least one profitable commercial.

The monopolist's objective function is the cumulative total commercial audience:

$$\pi = \sum_{i=1}^{n} c_i r_i.$$

The monopolist chooses n, $\{c_i\}_{i=1}^{n}$ and $\{x_i\}_{i=1}^{n+1}$ to maximize π subject to the constraints: $c_i \geqslant 0$, $x_i \geqslant 0$, $\sum_{i=1}^{n+1} c_i + \sum_{i=1}^{n+1} x_i = 1$.

A television network derives its revenues solely from selling commercial time to advertisers, while the production cost of the program is sunk at the time the network chooses commercial breaks. Obviously, advertisers care about the total number of viewers who watch their commercials: the higher the rating of the program, the more advertisers are willing to pay for commercial time. Consequently, networks seek to maximize the program's rating, which is simply the size of the audience.[5]

Current monitoring techniques can only report the rating of the whole program, i.e., the commercial audience cannot be distinguished from the programming audience.[6] Another possible (and seemingly more natural) specification of the objective function would be the rating times the total length of commercials, where the rating is represented by the total audience of the whole program. (Note that the total audience itself cannot be the objective function because that would lead the monopolist to broadcast no commercials at all.) In this case, a network has a strong incentive to broadcast commercials later rather than earlier in the program in order to retain a bigger audience for the early part of the program. All of the commercials are likely to appear at the end of the program, at which point, viewers will turn off their TVs. Obviously, advertisers would demand that their commercials be aired earlier. This implies that a network must give greater weight to the commercial audience than to the programming audience. Simulations on the ratings as weighted averages of commercial audience and programming audience complicates the computations but adds no additional insights.

III. THE MONOPOLIST'S OPTIMAL CHOICE

III(i). *The frequency of breaks*

We begin by observing that the program should always end with a commercial break, that is, $x_{n+1} = 0$. The reason is that programming after the last commercial break generates zero revenue so the network is better off using that time before the last break, thereby increasing the audience size for

[5] In principle, an advertiser should care about the exact position of his commercials either in the program or in a series of commercials in a break, and the concern should be reflected in the pricing of different positions. While this might be true for a special event such as the Super Bowl, normally a contract between a network and an advertiser goes no further than specifying the frequency of any particular commercial in a certain program, e.g., four times per week in the 6:30 evening news program.

[6] What happens is that a meter is attached to the TV set in a sample family and automatically records the duration of tuning to any channel for at least 5 minutes. Since normally a commercial break does not last for more than 3 minutes, it is simply not possible for this monitoring system to record the audience of any particular commercial break. We were told by Nielson Research Institute that they were developing a technique to monitor the audience minute by minute, or even second by second. This development justifies the assumption that a network should care about the commercial audience rather than the program audience.

the last commercial. But, if the programming is over, why should anyone watch the last commercial? The reason is that the network often uses part of the last commercial break to advertise the next episode of the program or the next show, and some viewers will want to stick around to watch this advertisement. This suggests that the revenue and drop functions associated with the last commercial break may differ from those of previous commercial breaks. However, as long as some viewers are willing to watch a sufficiently short final commercial, the main results of the model are not affected so, for simplicity, we have ignored any differences.

Given that the program ends with a commercial, the constraint faced by the monopolist becomes

$$\sum_{i=1}^{n}(x_i + c_i) = 1. \tag{1}$$

Rewrite the audience size of the ith break as $r_i = 1 - \sum_{t=1}^{i} f(x_t, c_t)$ and let $f_i = f(x_i, c_i)$. Then

$$\pi = \sum_{i=1}^{n} c_i r_i = \sum_{i=1}^{n} c_i - \sum_{j=1}^{n}\left(\sum_{i=j}^{n} c_i\right) f_j.$$

The monopolist chooses an integer n, and $x_i \geqslant 0$, $c_i \geqslant 0$ ($i = 1, 2, \ldots, n$) to maximize π, subject to constraint (1).

The next point to note about the optimal solution is that the program cannot start with a commercial, that is, x_1 must be positive. To see why, suppose $x_1 = 0$ and $n \geqslant 2$. Let λ be the Lagrangian coefficient of constraint (1). Then first order conditions give (the second order conditions are always satisfied):

$$\frac{\partial \pi}{\partial c_j} = 1 - \sum_{i=1}^{j} f_i - \left(\sum_{i=j}^{n} c_i\right) h'(c_j) = \lambda, \tag{2}$$

$$j = 1, 2, \ldots, n$$

$$\frac{\partial \pi}{\partial x_j} = -\left(\sum_{i=j}^{n} c_i\right) g'(x_j) = \lambda, \tag{3}$$

$$j = 2, \ldots, n$$

$$\frac{\partial \pi}{\partial x_1} = -\left(\sum_{i=1}^{n} c_i\right) g'(x_1) \leqslant \lambda. \tag{4}$$

From (3) and (4), $(\sum_{i=1}^{n} c_i)g'(x_1) \geqslant (\sum_{i=j}^{n} c_i)g'(x_j)$ for certain $j \geqslant 2$. Because $g' < 0$ and $(\sum_{i=1}^{n} c_i) > (\sum_{i=j}^{n} c_i)$, we have $g'(x_1) > g'(x_j)$, which by $g'' > 0$ immediately implies that $x_j < x_1 = 0$, a contradiction. Therefore, if $x_1 = 0$, then $n = 1$: if a program starts with a commercial, the entire program time is filled with commercials. It then follows from Assumption 2(i) that no one will watch, so the network earns zero revenues. Since Assumption 2(ii) implies that the network can earn positive profits with one commercial break, the network will never start its program with a commercial.[7]

Having ruled out all the corner solutions, we can now turn the inequality in (4) into an equality:

$$\frac{\partial \pi}{\partial x_1} = -\left(\sum_{i=1}^{n} c_i\right) g'(x_1) = \lambda. \tag{4'}$$

Then

Proposition 1: $x_i > x_j$ *whenever* $i < j$.

Proof: From (3) and (4′),

$$\left(\sum_{t=i}^{n} c_t\right) g'(x_i) = \left(\sum_{t=j}^{n} c_t\right) g'(x_j).$$

Because $i < j$, we have $\sum_{t=i}^{n} c_t > \sum_{t=j}^{n} c_t$. Since $g'(x_t) < 0$ for $t = 1, 2, \ldots, n$,

$$g'(x_i) > g'(x_j).$$

Since $g'' > 0$, $x_i > x_j$. Q.E.D.

The proposition says that the length of programming intervals, x_i, is decreasing over i. In other words, commercial breaks should become more frequent toward the end of the program. This is because when the network loses a viewer, it loses the potential revenue from the viewer for the remaining part of the program, as the viewer never comes back once he leaves. Consequently the network's incentive for keeping viewers declines as the program proceeds. Because a longer programming interval keeps more

[7] There are many commercials before the broadcast of a sporting event like the Super Bowl, but we do not regard the program as having started until the game actually begins. This is because in sports the arrangement of commercial breaks (the number, frequency, length, timing) is determined by the pace of the game (time-out, foul play, etc.), while in an ordinary television program the decision is made by the network. What we want to study in this paper is a network's choice of commercial breaks, not a coach's, referees' or team owner's. When a game is scheduled to start at 3 pm, the actual kickoff usually is a few minutes later, and that time becomes the golden time for commercials. By contrast, when a network says its evening news program starts at 6:30, it starts at 6:30 sharp, not a second late.

It should be pointed out that the conclusion is sensitive to the assumption that the network is unable to charge different prices for commercials appearing at different times of the program.

viewers, the network optimally chooses shorter and shorter programming intervals, and therefore more frequent commercial breaks, towards the end of the program.

III(ii). *The lengths of breaks*

In line with the argument that programming intervals should become shorter toward the end of the program, one might expect the lengths of breaks to grow longer. After all, a shorter break serves the same purpose as a longer programming interval in keeping the audience. This guess, however, is incorrect. Unlike that of programming intervals, the length of breaks, c_i, enters the objective function in two ways. First, it directly influences the audience size of each break: $r_i = r_{i-1} - f(x_i, c_i)$. Second, it is the weight of audience sizes in the network's revenue: $\pi = \sum_{i=1}^{n} c_i r_i$. The two forces operate in opposite directions. On the one hand, the network's incentive for keeping viewers weakens as the program proceeds, so breaks tend to grow longer. On the other hand, because the audience size declines monotonically, later breaks are less important in generating revenues for the network. As a result, breaks tend to become shorter. The interaction between the two forces leads to the following conclusion.

Proposition 2: If $c_i \leqslant c_{i-1}$, then $c_{i+1} < c_i$.

Proof: From equation (2) we have:

$$(c_i + c_{i+1} + \cdots + c_n)h'(c_i) = f_{i+1} + (c_{i+1} + c_{i+2} + \cdots + c_n)h'(c_{i+1})$$

Rearranging terms yields:

$$c_i h'(c_i) + \left(\sum_{t=i+1}^{n} c_t\right)[h'(c_i) - h'(c_{i+1})] = f_{i+1}. \tag{5}$$

Likewise,

$$c_{i-1} h'(c_{i-1}) + \left(\sum_{t=i}^{n} c_t\right)[h'(c_{i-1}) - h'(c_i)] = f_i. \tag{6}$$

Now suppose $c_i \leqslant c_{i-1}$ but $c_{i+1} \geqslant c_i$. Because $h'' > 0$, we have $h'(c_i) \leqslant h'(c_{i-1})$ and $h'(c_{i+1}) \geqslant h'(c_i)$. Then from (5) and (6) we get

$$c_i h'(c_i) \geqslant f_{i+1} \quad \text{and} \quad c_{i-1} h'(c_{i-1}) \leqslant f_i.$$

Because $c_i \leqslant c_{i-1}$, we find $0 < h'(c_i) \leqslant h'(c_{i-1})$. Then $c_i h'(c_i) \leqslant c_{i-1} h'(c_{i-1})$, which means $f_i \geqslant f_{i+1}$. On the other hand, from Proposition 1, $x_i > x_{i+1}$, so $g(x_i) < g(x_{i+1})$. By assumption, $c_i \leqslant c_{i+1}$, so $h(c_i) \leqslant h(c_{i+1})$. As $f(x, c) = g(x) + h(c)$, we find $f_i < f_{i+1}$, thus the contradiction. Q.E.D.

Proposition 2 can be roughly understood as saying that the length of breaks is single-peaked.[8] It is never optimal for the network to decrease the length of breaks first and then increase the length later. At the beginning of the program the network does not want the breaks to be long for fear of driving viewers away too early. It does not want long breaks at the end either, as the audience size is already small. In real life, the last break tends to be short and is often filled with other 'non-program elements' such as station declarations or 'coming up next $\cdots$'.

IV. COMPARATIVE STATICS

So far we have characterized the monopolist's optimal choice in terms of break frequency and lengths. This is done for a general drop function $f(x, c)$. In this section we investigate how the choice of commercial breaks is affected by the program's popularity. We are also interested in seeing how a constraint on the total commercial time, perhaps due to regulation, affects the network's choice. In particular, does a tighter constraint lead to shorter, more frequent breaks or fewer, longer breaks?

We assume throughout this section that the drop function takes the form:

Assumption 3: The drop function $f(x, c) = g(x) + h(c) = e^{-kx} + ac$, with $k > 0$, and $a > 0$.

A specific functional form is needed because we need a parameter to represent the popularity of the program, and also because analytical solution is unattainable in the constrained optimization problem, especially when the optimal number of breaks is concerned. As such, parameter k indicates how attractive the programming is: it measures the rate at which viewers leave the program when a programming interval becomes shorter: $k = -g'(x)/g(x)$. The higher is k, the more attractive is the program.[9]

We are interested in the effect of the parameter k on the network's choice of the number of breaks, and the length and timing of each break. Because of the complexity of the problem, analytical results are unattainable

[8] In fact, we are unable to exclude a flat peak (two adjacent breaks are equally long, and the length is the longest among all breaks). But from the proof it is clear that the plateau can only happen at the peak, and at most two breaks can be on the plateau.

[9] An alternative way to represent the program popularity is to use the audience size at the beginning of the program, r_0, which was normalized to 1 in the model. A higher r_0 means a more popular program. Under this interpretation, some comparative results can be reached without specifying the functional forms: From the first order conditions, it can be seen that a marginally more attractive program has no impact on n (since it is an integer), but causes c_i to increase, x_i to decrease, and C to increase. Numerical calculations indicate that the optimal number of breaks is very insensitive to the change in r_0. Therefore, using either k or r_0 to represent the program popularity leads to roughly the same comparative statics results.

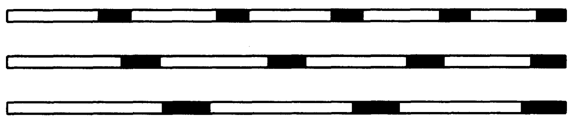

Figure 2
The effect of parameter k. A larger k represents a more popular program.

even for the specific functional form.[10] Simulation leads to the following conclusions:

Observation 1: When the program becomes more attractive (k becomes larger),

(i) breaks are more frequent;
(ii) the total commercial time increases;
(iii) for fixed number of breaks, breaks occur earlier;
(iv) for fixed number of breaks, early commercials become shorter while later commercials become longer.

The reason for the first two conclusions is easy to understand. When the program becomes more attractive (k is larger), viewers are less likely to be driven away by commercials. The network takes advantage of the viewers' increased loyalty by running longer commercials more frequently. To see an example, let $a = 3$. When $k = 20$, the optimal number of breaks is $n = 3$, and the total length of commercials $C = \sum_{i=1}^{n} c_i = 0.242$. When k increases to 30, the optimal n becomes 4, with $C = 0.260$. Finally, when k further increases to 40, $n = 5$ and $C = 0.271$. (Figure 2).

Since the number of breaks can only be a positive integer, a small increase in k generally leads to a rise in the total commercial time but does not affect the optimal number of breaks. If that is the case, how does k affect the distribution of commercial time among breaks? We find that the expansion is distributed unevenly. When k increases, late breaks become longer, but early breaks become shorter. Because a viewer is less likely to leave when the program is more attractive (k increases), keeping the viewer during the early part of the program becomes more valuable to the network. Therefore, for fixed number of breaks, early breaks should be shorter while late breaks should be longer. Because longer breaks tend to drive away more viewers, the preceding programming intervals have to lengthen. Therefore, early

[10] If we further restrict the length of each break to be the same, some analytical results can be derived (see footnote 11). This restriction does not distort the solution by much, as without the restriction, the length of breaks would be close to each other anyway. Of course, we are going to lose the conclusion about the distribution of commercials among breaks (item (iv) of Observation 1), but all other conclusions remain valid.

programming intervals shrink while late intervals expand. Putting it another way, breaks occur earlier in the program.

In some countries the government imposes constraints on the total commercial time in television programs. How would such a constraint affect the choice of commercial breaks and, in particular, the frequency of breaks?

Observation 2: When the constraint on the total commercial time becomes tighter:

(i) the optimal number of breaks remains unchanged;
(ii) the length of each break is shorter; and
(iii) the length of each programming interval is longer.

We have already observed that when $k = 30$ and $a = 3$, the optimal number of breaks is $n = 4$ with $C = 0.260$. Suppose the network faces a binding constraint on C. Surprisingly, when the constraint becomes tighter (C decreases from 0.25 to 0.05), the optimal number of breaks remains unchanged at $n = 4$. Basically, the optimal n is not very responsive to the changes in C.[11] If the number of breaks does not vary with C, then each break has to become shorter as C decreases, and each programming interval becomes longer.

V. CONCLUSION

This paper offers some useful insights in understanding the fundamental tradeoff faced by a network in choosing the number, length, and timing of the breaks. Some testable predictions are derived. Our ultimate goal is to understand the choice of commercial breaks in a more realistic environment, i.e., in a setting where several networks compete against each other. Viewers in that environment have more options for evading commercials: they can

[11] If we assume that each break has the same length, then for $f(x, c) = e^{-kx} + ac$, we can find the analytical solution of the length of each news interval for given C and n, where C is the total amount of commercials, and n is the number of breaks. The solution is

$$x_i = \left[\frac{1-C}{n} - \frac{\ln(n!)}{nk}\right] + \frac{\ln(n+1-i)}{k}, \; i = 1, 2, \ldots, n.$$

Then the network's profit can be expressed as

$$\pi = C\left[1 - \frac{a}{2}\frac{n+1}{n}C - e^{\frac{\ln(n!)-k(1-C)}{n}}\right].$$

Now if n is treated as a continuous variable, the optimal n and C can be solved simultaneously from the profit function by taking derivatives with respect to the two choice variables. When $a = 3$ and $k = 30$, we find that $n = 5.52$ and $C = 0.28$. Now let the binding C decreases from 0.27 to 0.08. Then the optimal n would decrease accordingly from 5.49 to 4.60. However, if n is restricted to be an integer, the optimal n would remain at 5 when C changes.

turn off their TV or jump back and forth between channels. As a result, networks will have a strategic concern in choosing the timing of their commercial breaks. For example, many people have noticed that commercial breaks tend to be synchronized across channels, especially when the same type of programs are broadcast simultaneously on several channels. In moving beyond the monopoly model, the key issue is how to model in a realistic way the behavior of viewers who can switch among programs. After some attempts, we find this task to be most challenging.

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