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Commentary

A Comment on "Is Having More Channels Really Better? A Model of Competition Among Commercial Television Broadcasters"

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This paper shows that the analysis of Liu et al. (2004) contains a substantive error—the asserted pure-strategy Nash equilibrium leading to their Theorems 1 and 2 is really not an equilibrium. We show that in their model, either pure-strategy Nash equilibria do not exist or, unlike their asserted main result, when a pure-strategy equilibrium exists, increasing the number of commercial television broadcasters does not result in lower-quality programs. Possible modifications of Liu et al.'s model that may help restore the desired result are discussed.

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1. Introduction

Liu, Putler, and Weinberg (2004; hereforth LPW) provided an interesting analysis of equilibrium program choices made by imperfectly competitive commercial television broadcasters. In LPW's static model, viewers have different ideal points for program type, but they all prefer high-quality to low-quality programs. Taking viewers' preferences as given, two competing broadcasters simultaneously choose program types and quality levels to maximize profits—broadcaster's revenue from advertising slots minus the cost of producing the TV program. LPW focused on pure-strategy Nash equilibria and showed that in equilibrium, either the duopolists become local monopolists or the quality of the equilibrium programs is strictly lower than the quality level wanted by a monopolist; and, in either case, the duopolists always choose different program types. They also considered a two-period model in which viewers' lead-in effect can be taken into account.

This paper intends to point out a substantive error in LPW's analysis—the asserted pure-strategy Nash equilibrium leading to their Theorems 1 and 2 is really not an equilibrium. Our main theorem will show that in LPW's static model, a pure-strategy Nash equilibrium exists if and only if in equilibrium the duopolists become local monopolists, and thus the assertion that duopolists may provide lower-quality programs than a monopolist will be disproved.

That LPW failed to deliver their desired result is rather unfortunate, and we contend that it was their model rather than the equilibrium concept (i.e., Nash equilibrium) that should be responsible for this failure. In general, a monopolist's incentives to provide quality may differ from those of duopolists for two reasons. First, quality provision is costly, and compared to duopolists, a monopolist can better capture the social benefits resulting from its private efforts of quality provision; after all, the monopolist has no rivals by definition. This suggests that increasing the number of broadcasters may reduce program quality, an effect that LPW intended to show. However, it is also likely that the duopolists may provide more quality than their monopolistic counterpart, because the buyers can credibly threaten to switch from one firm to the other in the duopoly case but not in the monopoly case. For example, if viewers share the same ideal point for the program type, then the duopolistic broadcasters must engage in a Bertand-type quality competition, leading to an equilibrium quality level higher than the quality level a monopolist would choose. Even if viewers have heterogeneous ideal points, the same conclusion may follow if viewers care very little about program type relative to their concern about quality level. We believe that LPW's model places too much weight on viewers' concerns about program type, which rules out the possibility that program quality may be higher in the duopoly case than in the monopoly case.

Because LPW chose to focus on the above first effect, and because the desired result did not occur in equilibrium, one would ask how LPW's model might be modified to ensure that the equilibrium program quality is lower in the duopoly case than in the monopoly case. We offer several possible solutions in the conclusion section, including the recognition of rare resources that may be required to produce a stylish program, the sequentiality of the decisions about program type and program quality, the explicit modeling of how program choice transforms into advertising revenue, and the threat of retaliation in an infinitely repeated game.

The remainder of this paper is organized as follows. In §2, we review LPW's static model and their two theorems. In §3, we prove our main theorem, which, together with LPW's results, gives a complete characterization of the pure-strategy Nash equilibria for the LPW model. Possible modifications of LPW's model that may help restore LPW's desired result are discussed in §4.

2. The LPW Model and Main Results

LPW considered two TV broadcasters, A and B, facing a continuum of viewers in a model à la Hotelling (1929). Each broadcaster, i, can choose a program (v^i, d^i), where $d^i \in [0, 1]$ and $v^i \in [0, +\infty)$ stand for the program type and program quality, respectively. A viewer, k, is identified by his ideal point, x^k, for program type, and the collection of all viewers is represented by the distribution of x^k, which is uniform on the unit interval $[0, 1]$. Viewer k receives zero utility if he chooses not to watch any program, and he receives utility

$$u_k^i = v^i - |x_k - d^i|$$

if he watches broadcaster i's program (v^i, d^i). Viewers seek to maximize utilities, and broadcasters seek to maximize profits. Broadcaster i's profit given its program (v^i, d^i) is

$$\pi^i = q^i - c(v^i)^2,$$

where q^i is the population of viewers watching broadcaster i's program, and $c > 0$ is a cost parameter. Because a viewer can choose not to watch any program and a broadcaster i can always offer $v^i = 0$, u_k^i and π^i are both nonnegative in equilibrium.

LPW first showed that for a monopolist, the optimal program is

$$(v^m, d^m) = \begin{cases} \left(\dfrac{1}{2}, \dfrac{1}{2}\right) & \text{if } 0 < c \le 2, \\ \left(\dfrac{1}{c}, d\right) & \text{otherwise,} \end{cases}$$

where $1/c \le d \le 1 - 1/c$. The corresponding monopoly profits in the above two cases are $\pi^m = 1/c$ and $\pi^m = 1 - c/4$, respectively.

LPW then considered the duopoly market. The game proceeds as follows. Broadcasters A and B first choose their programs (v^A, d^A) and (v^B, d^B) simultaneously. Upon seeing both (v^A, d^A) and (v^B, d^B), viewers decide which program to watch, or watch neither program. Then, π^A and π^B are realized, and the game ends. A pure-strategy Nash equilibrium for this game is a pair of programs (v^A, d^A, v^B, d^B) such that for $i, j \in \{A, B\}$, $j \neq i$, given broadcaster j's program (v^j, d^j), (v^i, d^i) maximizes π^i.

LPW showed that in the duopoly market, no pure-strategy Nash equilibria can exist if $0 < c < 8/3$; and if $c \ge 4$, then in equilibrium, the two broadcasters become local monopolists with $v^A = v^B = \pi^A = \pi^B = 1/c$.

In the remaining case, where $8/3 \le c < 4$, LPW showed that in equilibrium, $v^A = v^B = 1/4$, and (d^A, d^B) equals either $(1/4, 3/4)$ or $(3/4, 1/4)$, resulting in the profits $\pi^A = \pi^B = 1/2 - c(1/4)^2$. Because $v^A = v^B = 1/4 < v^m$ when $8/3 \le c < 4$, having more competitors reduces equilibrium program quality in this case. Moreover, with $d^A \neq d^B$, the equilibrium program types chosen by the two broadcasters exhibit the counterprogramming property. Based on these observations, LPW reported their two main theorems:

Theorem LPW-1. *In a duopoly market, television broadcasters tend to differentiate from each other and adopt a "counterprogramming" strategy.*

Theorem LPW-2. *Having more competitors can result in each competitor offering lower-quality programs compared to a situation with fewer competitors.*

Our main theorem in the next section will disprove Theorem LPW-2 and show that LPW's analysis for the case $8/3 \le c < 4$ contains a substantive error.

3. Main Theorem

Our main theorem (Theorem 1) below will show that in LPW's static model, no pure-strategy Nash equilibrium can exist if $8/3 \le c < 4$. Thus, combined with LPW's results for the cases $0 < c < 8/3$ and $c \ge 4$, our theorem will imply that an equilibrium exists if and only if $c \ge 4$, in which the two broadcasters must become local monopolists in equilibrium. Hence, in the LPW model, increasing the number of competitors need not result in lower program quality.[1]

Lemma 1. *Suppose that $8/3 < c < 4$. In any equilibrium, $\pi^A, \pi^B < 1/c$ and $q^A, q^B > 0$.*

Proof. We first show that $\pi^A, \pi^B \le 1/c$. Observe that for broadcaster $i = A, B$,

$$\pi^i = q^i - c(v^i)^2 \le 2v^i - c(v^i)^2 \le \frac{1}{c} = \pi^m,$$

where all three equalities hold if and only if $v^i = 1/c$ and $q^i = 2v^i = 2/c$. Thus, if $\pi^i = 1/c$, then

$$q^i = 2\left(\frac{1}{c}\right) > 2\left(\frac{1}{4}\right) \quad\Rightarrow\quad q^j < \frac{1}{2} < \frac{2}{c} \quad\Rightarrow\quad \pi^j < \frac{1}{c}.$$

However, expecting (v^i, d^i), broadcaster j could have chosen $(v^j, d^j) = (v^i + \epsilon, d^i)$ and captured all broadcaster i's viewers, which would have generated a profit greater than or equal to

$$q^i - c(v^i + \epsilon)^2 = \pi^i - c(2v^i\epsilon + \epsilon^2) = \frac{1}{c} - c(2v^i\epsilon + \epsilon^2) > \pi^j,$$

where the last inequality holds for sufficiently small $\epsilon > 0$ because $\pi^j < 1/c$. Hence, (v^j, d^j) does not maximize π^j given (v^i, d^i), a contradiction to the assumption that (v^A, d^A, v^B, d^B) is an equilibrium.

Now suppose that in equilibrium, $q^i = 0$, so that $\pi^i = -c(v^i)^2$, implying that $v^i = 0 = \pi^i$. Expecting (v^i, d^i), broadcaster j becomes a monopolist and $\pi^j = 1/c$, which is a contradiction to the above first assertion. □

Lemma 2. *Suppose that $8/3 < c < 4$. In any equilibrium, the program types chosen by the two broadcasters must differ, i.e., $d^i \neq d^j$.*

Proof. Suppose instead that $d^i = d^j = d$. First, suppose that $v^i = v^j = v$. This implies that $q^i = q^j = q$ and $\pi^i = \pi^j = \pi$. Expecting (v^i, d^i), broadcaster j could have chosen $(v^j, d^j) = (v + \epsilon, d)$ and captured all broadcaster i's viewers, which would have generated for broadcaster j a profit greater than or equal to

$$2q - c(v + \epsilon)^2 = \pi + q - c(2v\epsilon + \epsilon^2) > \pi = \pi^j,$$

where the last inequality holds for sufficiently small $\epsilon > 0$ because $q > 0$ (Lemma 1). This implies that (v^j, d^j) does not maximize π^j given (v^i, d^i), a contradiction.

Now suppose that $v^i > v^j$. This implies that $q^j = 0$, a contradiction to Lemma 1. □

Because of Lemma 2, if $8/3 < c < 4$, then $d^i \neq d^j$ in equilibrium, and we assume $d^A < d^B$ without loss of generality.

[1] We thank an anonymous referee for recommending the following proof to us, which is much more concise than our original proof.

Lemma 3. *Suppose that $8/3 < c < 4$. In any equilibrium, with $d^A < d^B$, $d^A = v^A$ and $1 - d^B = v^B$.*

Proof. By symmetry, we will only prove that $d^A = v^A$. Recall that by definition of a Nash equilibrium, (v^A, d^A) must maximize π^A given (v^B, d^B). We show that this cannot hold if either $d^A > v^A$ or $d^A < v^A$.

(1) First, suppose that $d^A > v^A$. In this case, viewers with ideal points $x_k \in [0, d^A - v^A)$ do not watch any program. (Otherwise, some viewers may choose to watch broadcaster B's program, but then $q^A = 0$, which contradicts Lemma 1.) There are two possible cases: either (i) $d^A + v^A \ge d^B - v^B$ or (ii) $d^A + v^A < d^B - v^B$. Note that in case (i), there is a (nonnegative) population of viewers x_k with $u_k^A \ge 0$ and $u_k^B \ge 0$ (and only some of these viewers choose to watch broadcaster A's program). By contrast, in case (ii), all viewers x_k with $u_k^A \ge 0$ must have $u_k^B < 0$.

- Consider (i). We claim that in case (i), given (v^B, d^B), $(v^A, d^A - \epsilon)$ yields a higher profit than (v^A, d^A) for broadcaster A, where $d^A - v^A > \epsilon > 0$. Note that replacing (v^A, d^A) by $(v^A, d^A - \epsilon)$ involves moving broadcaster A's program type from d^A to $d^A - \epsilon$ (away from d^B by a small distance of $\epsilon > 0$). Two effects result from this program change: it would attract a population ϵ of new viewers with ideal points on the left of d^A, but it would also cause a loss of some viewers with ideal points on the right of d^A. However, the population of the lost viewers never exceeds ϵ!
- Next, consider (ii). In this case, $q^A = 2v^A$, and by Lemma 1, $\pi^A = 2v^A - c(v^A)^2 < 1/c$. This implies that broadcaster A is a local monopolist in equilibrium, and yet its program quality is too low relative to the monopoly optimal level ($v^A < 1/c$). Thus, broadcaster A could have benefited from replacing (v^A, d^A) by $(v^A + \epsilon, d^A)$, where $1/c - v^A > \epsilon > 0$, which contradicts the assumption that (v^A, d^A) maximizes π^A given (v^B, d^B).

(2) Now suppose that $d^A < v^A$. We first claim that $v^B < v^A + (d^B - d^A)$. Note that if $v^B > v^A + (d^B - d^A)$, then every viewer strictly prefers broadcaster B's program to broadcaster A's program, and hence $q^A = 0$, a contradiction to Lemma 1. On the other hand, if $v^B = v^A + (d^B - d^A)$, then viewers with ideal points on the left of d^A feel indifferent about the two programs, but viewers with ideal points on the right of d^A strictly prefer broadcaster B's program to broadcaster A's program, and hence $q^A = d^A/2$. However, broadcaster A could have chosen $(v^A + \epsilon, d^A)$ and obtained all the viewers with ideal points on the left of d^A, which would have yielded a profit greater than or equal to

$$\pi^A + \frac{q^A}{2} - c(2v^A\epsilon + \epsilon^2) > \pi^A$$

if $\epsilon > 0$ is sufficiently small. This is another contradiction. Now, given that $v^B < v^A + (d^B - d^A)$, we claim that (v^A, d^A) is dominated by $(v^A, d^A + \epsilon)$, where $0 < \epsilon < v^A - v^B + d^B - d^A$: moving broadcaster A's program type from d^A to $d^A + \epsilon$ (moving toward d^B by a distance of ϵ) does not cause any loss of viewers with ideal points on the left of d^A, but it allows broadcaster A to gain more viewers with ideal points on the right of d^A. This proves that (v^A, d^A) does not maximize π^A given (v^B, d^B), a contradiction.

We thus conclude that in equilibrium, $d^A = v^A$ and, by symmetry, $1 - d^B = v^B$. □

Lemma 4. *Suppose that* $8/3 < c < 4$. *In any equilibrium,* $v^A \leq 1/c$.

Proof. Recall that the marginal revenue of v^i is 2 in the monopoly case,

$$\frac{\partial q^i}{\partial v^i} = \frac{\partial (2v^i)}{\partial v^i} = 2.$$

By Lemma 3, $d^A = v^A$, and thus the marginal revenue of v^A is strictly less than 2 in the duopoly case: raising v^A to $v^A + \epsilon$, say, does not gain a population of new viewers by more than ϵ because there are no viewers with ideal points on the left of $x_k = 0$! Because the marginal cost function of v^A, which is $2cv^A$, remains the same in both the monopoly case and the duopoly case, the duopoly equilibrium choice v^A can never exceed the monopolist's optimal choice $1/c$. □

Note that LPW's asserted equilibrium satisfies all four lemmas derived above, and, hence, it does look like an equilibrium. Moreover, Lemma 4 shows that the equilibrium program quality in the duopoly case can never exceed the quality level chosen by a monopolist, and, hence, if there exists one equilibrium, then Theorem LPW-2 will be valid. Unfortunately, our main theorem below shows that no equilibrium can actually exist if $8/3 < c < 4$.

Theorem 1. *No pure-strategy Nash equilibrium can exist in the static model of LPW if* $8/3 < c < 4$.

Proof. Suppose instead that there is a pure-strategy Nash equilibrium (v^A, d^A, v^B, d^B) with $d^A < d^B$. By Lemma 1, we have $\pi^B < 1/c$. By Lemmas 3 and 4, we have $v^A = d^A \leq 1/c$. However, in this case, broadcaster B could have replaced (v^B, d^B) by $(v^{B'}, d^{B'}) = (1/c + \epsilon, 1/c)$ to capture all broadcaster A's viewers and to obtain a profit

$$\frac{1}{c} - c\left(\frac{2}{c}\epsilon + \epsilon^2\right) > \pi^B,$$

where the inequality holds if $\epsilon > 0$ is small enough. This proves that (v^B, d^B) does not maximize broadcaster B's profit given (v^A, d^A), a contradiction. □

LPW used a numerical example to demonstrate their asserted equilibrium. In that example, $c = 2.7$, and LPW asserted that $(v^A, d^A) = (1/4, 1/4)$ and $(v^B, d^B) = (1/4, 3/4)$ formed a Nash equilibrium. Following Theorem 1, however, $(v^A, d^A, v^B, d^B) = (1/4, 1/4, 1/4, 3/4)$ is actually not a Nash equilibrium because expecting broadcaster B's strategy $(v^B, d^B) = (1/4, 3/4)$, broadcaster A could have chosen $(v^{A'}, d^{A'}) = (1/2.7 + 10^{-100}, 1 - 1/2.7)$ and obtained a profit strictly greater than broadcaster A's profit in LPW's asserted equilibrium, which is $1/2 - 2.7(1/4)^2$.

4. Concluding Remarks

In this section, we propose several modifications to LPW's static model, which may help restore Theorem LPW-2. First, in the LPW model, a duopolist can always mimic its rival's program style without much difficulty, which implies that a duopolist has nearly the same capability as a monopolist of internalizing the surplus generated by its private effort of quality provision. This explains why low-quality programs cannot be sustained in equilibrium, or equivalently, no equilibrium can exist (Lemma 4 shows that whenever an equilibrium exists, then the duopolists must offer low-quality programs). In reality, however, producing TV programs with distinguished styles (or "program types," in the terminology of LPW) usually requires special and scarce resources. TV celebrities like Larry King, Connie Chung, and David Letterman, for example, represent key resources in the production of stylish TV programs, and one broadcaster cannot access these scarce resources if the latter are under contracts with another broadcaster. The scarcity of these resources suggests that mimicking the program type of a rival may be more difficult than assumed in LPW's model. Hence, a model that recognizes the effects of scarce resources is more likely to admit an equilibrium.

Second, LPW assumed that broadcasters' choices of program type and quality level cannot affect r. This assumption may not be so innocuous as it may seem at first. Gal-Or and Gal-Or (2005) considered how a monopolistic broadcaster facing two competitive advertisers should optimally design the schedule R charged to each advertiser as a function of the type and the number of commercials that the advertiser wishes to air (where R corresponds to the advertising revenue rq in the LPW model). An important implication of Gal-Or and Gal-Or's analysis is that a high-quality TV program may allow only a few commercial breaks, which imposes a more stringent upper bound on the capacity of advertising time slots than a low-quality program.[2] More precisely, a program with a large v may produce a large q, but it may reduce r at the same time! By considering the relationships between the capacity constraint of time slots,

[2] We thank Steve Shugan for directing our attention to the two articles by Gal-Or and Gal-Or (2005) and Steenkamp et al. (2005), which have enriched our discussions in this section.

the program quality, and the feasible number of commercial breaks, a new model may work better in discouraging broadcasters from mimicking each other's program types: mimicking the rival's program type can be profitable only if it is accompanied by a quality level higher than the rival's, but that would imply very few commercial breaks, resulting in lower advertising revenue. Thus, an equilibrium is more likely to exist after r is explicitly modeled and endogenously derived.

Third, the timing of events in LPW's model matters also. LPW assumed that a broadcaster can choose program type d and program quality v at the same time. In reality, it is not unusual that in producing a program, a broadcaster must first choose d, but v cannot be determined until production starts. This may happen if, for example, there is uncertainty about the cost parameter, c, at the time that d is chosen. In this sequential version of LPW's model, a Bertrand-type quality competition may occur in subgames where d^A and d^B are close to each other, and rationally expecting this unpleasant consequence, the broadcasters would rather make d^A and d^B sufficiently differentiated, which in turn implies an equilibrium quality level lower than the monopoly quality level. The idea that competitors try to differentiate in an early stage to avoid aggressive competition in a later stage is not new; it has also appeared in the analysis of Gal-Or and Gal-Or (2005), among others.

Fourth, if the interactions between the broadcasters last indefinitely, and if the broadcasters care enough about their future profit streams, then the well-known folk theorem (see, for example, Chapter 5 in Fudenberg and Tirole 1991) ensures that the duopolists can attain collusive profits with their program choices approximating those of a monopolistic broadcaster capable of offering two programs to viewers at one time. If such a monopolistic broadcaster existed, would it offer two different programs to viewers, and would the quality levels of the offered programs be lower than v^m? The answer is apparently positive: the monopolist should offer two different programs instead of one, and for each program the monopolist, expecting fewer viewers than when it can only offer one program, should choose a quality level strictly lower than v^m.[3]

Finally, we remark on the solution concept of Nash equilibrium. It is often proposed that dynamic equilibrium analysis can be replaced by a conjectural variation in the static model, in which firms choose not to compete aggressively because they "conjecture" that retaliation may follow if they take actions to hurt their rivals. Such a conjectural variation is incompatible with the concept of Nash equilibrium. In a static model, by definition, the firms can act only once, and any conjecture that involves the rivals' retaliation is incorrect. To incorporate the rivals' retaliation into the analysis, one does not have to abandon Nash equilibrium; explicitly formulating the long-term interactions between strategic broadcasters in a dynamic model and finding the (subgame perfect) Nash equilibrium, in our view, is more promising than the above conjectural variation approach.

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[3] Although we advocate the merits of a dynamic model, we do not contend that static models are never adequate in correctly capturing the rational program choices made by commercial television broadcasters. In fact, the recent findings of Steenkamp et al. (2005) show that the net outcome of most promotion and advertising attacks in their sample is not influenced by the defender's reaction. Put differently, the ultimate competitive impact of most advertising and promotion attacks is due primarily to the nature of consumer response, not to the vigilance of competitors.