Bilateral most-favored-customer pricing and collusion

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In a two-period differentiated products duopoly model, most-favored-customer (MFC) pricing policies allow firms to commit to prices above the Bertrand prices. It is shown here, however, that unless a restrictive and unappealing assumption is made about demand, there is no equilibrium in which both firms adopt MFC policies. The restrictive assumption is that at least one firm’s demand is more responsive to changes in its opponent’s price than to changes in its own price; otherwise, firms have an incentive to deviate from a greater-than-Bertrand price in the first period.

1. Introduction

In a simple Bertrand price-setting duopoly model, to generate an equilibrium that earns the firms greater-than-Bertrand profits one or both of the firms can adopt facilitating practices that allow for credible tacit collusion (Salop, 1986). One particular facilitating practice that has been considered is the most-favored-customer (MFC) pricing policy, in which a firm guarantees its first-period customers a rebate of the price difference if its second-period price is below its first-period price, and this credibly discourages the firm from deviating from a greater-than-Bertrand price in the second period. An often-cited example involves the two manufacturers of electric turbine generators—General Electric and Westinghouse—that used MFC pricing throughout the 1960s. To account for this behavior, Cooper (1986) uses a two-period, differentiated products duopoly model to demonstrate that there exists an equilibrium in which at least one firm adopts MFC pricing and both firms earn greater-than-Bertrand profits. In this article we use Cooper’s framework to demonstrate that an unreasonable assumption is needed to sustain an equilibrium in which both firms adopt MFC policies. Thus, while Cooper’s model can account for unilateral MFC pricing, it cannot account for General Electric’s and Westinghouse’s bilateral behavior.

In a two-period model, firms must alter their second-period best-response functions to sustain a Nash equilibrium that differs from the Bertrand equilibrium. Because of potential

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rebates, a MFC policy does alter the second-period best-response functions. We demonstrate, however, that when both firms adopt MFC policies, each firm has an incentive to deviate from its high first-period price unless a restrictive assumption is maintained that at least one firm’s demand is more responsive to changes in its rival’s price than to its own price. Without this assumption, each firm’s profit gain by deviating in the first period outweighs its loss of having a lower price in the second period. If the assumption is maintained, when firms face linear demands, for example, the condition necessary for the existence of a bilateral MFC equilibrium implies that a joint-profit-maximizing equilibrium does not exist. Accordingly, in this setting we believe that the existence of a bilateral MFC equilibrium is improbable.

This article is organized as follows. Section 2 describes the two-period extensive-form MFC game and derives second-period best-response functions for firms that adopt MFC pricing. Section 3 uses a symmetric linear demand example to solve for the equilibria of the extensive-form game and shows that, under reasonable assumptions, a bilateral MFC equilibrium does not exist. Section 4 extends the analysis to general demand functions. Section 5 offers a brief conclusion.

2. MFC best-response functions

Consider a two-period, differentiated products duopoly model in which the objective of each firm is to maximize the sum of (undiscounted) profits. There are two firms, denoted \( i \) and \( j \), and for each firm the sum of profits over both periods is

\[
\Pi_i = \Pi_{i1}(P_{i1}, P_{j1}) + \Pi_{i2}(P_{i2}, P_{j2})
\]

\[
\Pi_j = \Pi_{j1}(P_{i1}, P_{j1}) + \Pi_{j2}(P_{i2}, P_{j2}),
\]

where the first subscript denotes the firm, the second subscript denotes the period, \( P_i \) is the price charged by firm \( i \) in period \( t \), and \( \Pi_i(P_i, P_j) \) is the profit firm \( i \) earns in period \( t \) net of any rebates to customers from the previous period. Each firm has single-period best-response functions: \( R_i(P_{j}) \) for firm \( i \) and \( R_j(P_{i}) \) for firm \( j \). In a finite-period game, for two Bertrand players to sustain equilibrium prices that differ from the Bertrand prices, at least one of the firms must credibly alter its best-response function in the last period of the game by, for example, adopting a most-favored-customer pricing policy.

If a firm adopts an MFC pricing policy, it promises its present customers a rebate of the difference if next period’s price is less than the current price, and such a policy can be adopted for any price. Restricting attention to a two-period game, then, in the first period each firm chooses its price for that period and whether or not to adopt an MFC policy. The two firms make these choices simultaneously. In the second period the firms’ first-period choices are common knowledge, and the two firms simultaneously choose their second-period prices. A Nash equilibrium strategy combination consists of a decision of whether or not to adopt an MFC policy and a pricing plan for each firm. If neither firm adopts an MFC policy in the first period, the second-period subgame reduces to the usual Bertrand game. If, on the other hand, one or both firms adopt an MFC policy, the second-period best-response functions are altered.

To demonstrate how second-period best-response functions are derived, assume firm \( i \) adopts an MFC pricing policy. If firm \( i \)’s second-period price is less than its first-period

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1 See Cooper (1986) for assumptions guaranteeing stability of equilibria and upward-sloping reaction functions.
price, i.e., \( P_{i2} < P_{i1} \), it must rebate its first-period customers the amount \((P_{i1} - P_{i2})Q_{i1}\), where \( Q_{i1} \) is firm \( i \)'s first-period output. If a rebate is given, firm \( i \)'s second-period profit is

\[
\Pi_{i2} = \pi_{i2}(P_{i2}, P_{j2}) - (P_{i1} - P_{i2})Q_{i1},
\]

(2)

where \( \pi_{nt}(P_t, P_{jt}) \) is firm \( i \)'s profit in period \( t \) gross of any rebates.\(^2\) For \( P_{i2} < P_{i1} \), then, firm \( i \)'s second-period best-response function is found by setting

\[
d\Pi_{i2}/dP_{i2} = \partial\pi_{i2}/\partial P_{i2} + Q_{i1} = 0.
\]

(3)

For \( P_{i2} > P_{i1} \), firm \( i \)'s second-period best-response function is the same as if no MFC policy is adopted.

Let \( R_{i2}^R(P_{j2}) \) be the rebate best-response function defined by \( \partial\pi_{i2}/\partial P_{i2} + Q_{i1} = 0 \), and define \( P_{j2}^R \) to solve \( R_{i2}^R(P_{j2}^R) = P_{i1} \). Similarly, let \( R_{i2}^U(P_{j2}) \) be the Bertrand best-response function defined by \( \partial\pi_{i2}/\partial P_{i2} = 0 \), and define \( P_{j2}^U \) by \( R_{i2}^U(P_{j2}^U) = P_{i1} \). Note that \( R_{i2}^R(P_{j2}) > R_{i2}^U(P_{j2}) \) for all \( P_{j2} \), since the best-response function \( R_{i2} \) must set a price high enough to make up for profits lost by the rebate. Accordingly, \( P_{j2}^U > P_{j2}^R \), and firm \( i \)'s best-response function \( R_{i2}(P_{j2}) \) can now be defined by

\[
R_{i2}(P_{j2}) = \begin{cases} \frac{R_{i2}^R(P_{j2})}{P_{j2}} & \text{if } P_{j2} < P_{j2}^R \\ P_{i1} & \text{if } P_{j2}^R \leq P_{j2} \leq P_{j2}^U \\ \frac{R_{i2}^U(P_{j2})}{P_{j2}} & \text{if } P_{j2}^U \leq P_{j2} \end{cases}
\]

(4)

A best-response function for a firm with linear demand is shown in Figure 1, and the length of the vertical segment depends on the magnitude of \( Q_{i1} \).

If both firms offer MFC contracts in the first period, both firms’ second-period best-response functions are altered. For any \( P_{i2} < P_{i1} \), firm \( i \)'s second-period profit is given by (2). Similarly, for any \( P_{j2} < P_{j1} \), firm \( j \)'s second-period profit is

\[\text{FIGURE 1}\]
\[
\Pi_{j2} = \pi_{j2}(P_{i2}, P_{j2}) - (P_{i1} - P_{j2})Q_{j1},
\]  

(5)

where \( Q_{j1} \) is firm \( j \)'s first-period output. Given \( P_{i1} \) and \( P_{j1} \), then \( Q_{i1}, Q_{j1} \), and the second-period best-response functions \( R_{i2}(P_{j2}) \) and \( R_{j2}(P_{i2}) \) can be derived. Equilibrium in the second period requires that both firms price according to their appropriate second-period best-response functions.

Consideration of both periods, however, restricts the set of possible equilibria. In Neilson and Winter (1992) it is shown that if demand is stable through time, any firm adopting an MFC policy must, in equilibrium, charge the same price in both periods. Cooper (1986) demonstrates that an equilibrium exists in which at least one firm adopts an MFC policy. In the General Electric–Westinghouse case, however, both firms adopted MFC policies, and the question is whether there exists an equilibrium in which MFC policies are adopted bilaterally. When both firms offer MFC contracts in the first period, a further restriction on equilibrium is demonstrated in Figure 1. The second-period best-response functions intersect at point \( F \), where firm \( i \) sets price \( P_i \) and firm \( j \) sets price \( P_j \). As shown with \( P_i > P_{i2}^L \) and \( P_j > P_{j2}^L \), though, firm \( i \) setting price \( P_i \) in both periods and firm \( j \) setting price \( P_j \) in both periods is not an equilibrium. For example, it is possible to demonstrate that firm \( i \) wishes to lower its price in both periods.

To do this, let \( P_i \) fall to \( P_i - \delta \) in both periods, causing \( Q_{j1} \) to fall by approximately \( \left( \partial Q_{j1} / \partial P_{i1} \right) \delta \), and, since firm \( i \) treats firm \( j \) as a Bertrand player in the first period, \( P_{j1} \) does not change. Because of this, the height of the horizontal portion of \( R_{j2}(P_{i2}) \) stays the same, but its length becomes shorter, causing \( P_{j2}^L \) to increase to, say, \( P_{j2}^L + \epsilon \). For sufficiently small \( \delta \), \( P_{i2}^L + \epsilon < P_i - \delta \), and so firm \( j \) does not change its second-period price. As a result, firm \( i \)'s profit increases, since its price falls and firm \( j \)'s price stays the same.

The above argument demonstrates that if a bilateral equilibrium exists, it must correspond to a point like \( E \) in Figure 2. More formally, let the equilibrium be \( (P_{i}, P_{j}) \) in both periods, with corresponding output \( (Q_i, Q_j) \) in both periods. Construct \( R_{i2}^L(P_{j2}) \) to solve \( \partial \pi_{i2} / \partial P_{i2} + Q_i = 0 \) and \( R_{j2}^L(P_{i2}) \) to solve \( \partial \pi_{j2} / \partial P_{j2} + Q_j = 0 \), then define \( P_{i2}^L \) by

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FIGURE 2

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\(^4\) For a further analysis of the unilateral case, see Neilson and Winter (1992).
For $(P_i, P_j)$ to be an equilibrium, it must be the case that $P_i = P_{j2}^L$ and $P_j = P_{j2}^U$. These conditions are necessary conditions for equilibrium, that is, they are necessary conditions for individual firms to credibly commit to the equilibrium prices. As we show in the next two sections, however, unless an unappealing restriction on demand is made, both firms want to deviate from this price pair.

3. Equilibria with symmetric linear demand

To illustrate the issues governing the existence of bilateral MFC equilibrium, consider the case of stable, symmetric linear demand:

$$Q_{ij} = a - bP_{it} + cP_{jt},$$

$$Q_{ji} = a - bP_{jt} + cP_{it},$$

with $a$, $b$, and $c$ all strictly positive. We also assume that costs are zero, so that

$$\pi_{it} = aP_{it} - bP_{it}^2 + cP_{jt}.$$  \hspace{1cm} (7)

Best-response functions can be constructed from (7). If firm $i$ is a Bertrand player in period $t$, set $\partial \pi_{it}/\partial P_{it} = 0$ to get

$$R_{i2}^U(P_{j2}) = (a + cP_{j2})/2b.$$  \hspace{1cm} (8)

If firm $i$ is an MFC player, given values for $P_{i1}$ and $Q_{i1}$ (or, equivalently, $P_{i1}$ and $P_{j1}$), there are prices $P_{j2}^L$ and $P_{j2}^U$ such that $i$’s best-response function is given by (4). Since $R_{i2}^U(P_{j2})$ is given by (8), it is straightforward to find

$$P_{j2}^U = (2bP_{i1} - a)/c.$$  \hspace{1cm} (9)

The rebate best-response function $R_{i2}^L(P_{j2})$ solves $\partial \pi_{i2}/\partial P_{i2} + Q_{i1} = 0$, or

$$R_{i2}^L(P_{j2}) = (a + cP_{j2} + Q_{i1})/2b,$$  \hspace{1cm} (10)

and hence

$$P_{j2}^L = (2bP_{i1} - a - Q_{i1})/c.$$  \hspace{1cm} (11)

Combining these yields the MFC best-response function

$$R_{i2}(P_{j2}) = \begin{cases} 
(a + cP_{j2} + Q_{i1})/2b & \text{if } P_{j2} < P_{j2}^L \\
P_{i1} & \text{if } P_{j2}^L \leq P_{j2} < P_{j2}^U \\
(a + cP_{j2})/2b & \text{if } P_{j2} \geq P_{j2}^U.
\end{cases}$$  \hspace{1cm} (12)

In the first period of the game both firms must set first-period prices and decide whether or not to adopt MFC contracts. In the second period the firms observe their opponents’ first-period actions and set second-period prices. In a pure-strategy equilibrium, each firm must set a first-period price and make a price-protection decision that is a best response to the price and protection decisions of the other firm. Consequently, the prices chosen must be optimal given the MFC adoption decisions made by the two firms. This allows attention to be restricted to four cases: Neither firm adopts an MFC policy, only firm $i$ adopts an MFC policy, only firm $j$ adopts an MFC policy, and both firms adopt MFC policies. If they exist, the first equilibrium candidate corresponds to the Bertrand equilibrium, the second and third are unilateral MFC equilibria, and the fourth is a bilateral MFC equilibrium. We now turn attention to the existence of bilateral MFC equilibrium.

To find the bilateral MFC equilibrium, recall that both firms must be on their rebate best-response functions. Therefore, a candidate solution must have $P_{i1} = P_{j2} = P_i$, $P_{i1} = P_{j2} = P_j$, $R_{i2}^L(P) = P_i$, and $R_{j2}^U(P_i) = P_j$. Furthermore, since the problem is symmetric,
we require \( P_i = P_j = P \). Setting \( P_i^2 = P_j^2 = P \), as in Figure 2, yields the equilibrium price candidate

\[
P = \frac{2a}{3b - 2c}.
\]  

(13)

Price and output are positive if \( c < \frac{3}{2}b \).

As stated at the end of the previous section, a positive price in (13) is not a sufficient condition for a bilateral MFC equilibrium to exist. It remains to be shown that this price is actually an equilibrium, i.e., that neither firm wishes to change its price. Since a firm’s first-period price fixes its second-period price, consider deviations of the form \( P_{i1} = P_{i2} = P_j, P_{j1} \neq P \). First, note that firm \( j \) cannot respond in the first period to a change in \( P_{i1} \) by the assumption that firms are Bertrand players in the first period. As can be seen from Figure 2, raising \( P_i \) generates no price response from firm \( j \) in either period, so

\[
d\Pi_i = 2(ab - 2bP_i + cP_i) = -\frac{2ab}{3b - 2c} = -bP
\]  

at the solution given by (13), and if \( c < \frac{3}{2}b \), this is negative. Reducing \( P_i \) by \( \delta \) does generate a response by firm \( j \) in the second period. Since firm \( j \)'s first-period output falls by \( cb \) and \( P_{i2} \) falls by \( \delta \), from (12) firm \( j \) reduces its price by \( \frac{c}{b} \delta \). Consequently, firm \( i \)'s profit change is given by

\[
d\Pi_i = 2a - 4bP_i + 2cP_j + \frac{c^2}{b} P_i = \frac{2a}{3b - 2c} \left( \frac{c}{b} - b \right) = P \left( \frac{c^2}{b} - b \right)
\]  

(15)

at the solution given by (13). A price decrease results in lower profit if and only if (15) is positive, that is, if and only if \( b < c \). To summarize, then, a bilateral MFC equilibrium exists if \( b < c < \frac{3}{2}b \).

Intuitively, what happens in the bilateral MFC problem is that the two firms decide before the first period what price to set for the next two periods. The candidate for equilibrium is the price given by (13). If \( b > c \), however, each firm has an incentive to deviate from (13) by lowering its price. If \( b < c \), this incentive is removed. To interpret the condition \( b < c \), note that \( b \) measures demand response to the firm’s own price, and \( c \) measures demand response to the opponent’s price. If \( b < c \), firm \( i \)'s demand is more responsive to a change in \( j \)'s price than to its own price, and vice versa, and this seems less realistic than the opposite relationship. Additionally, if \( b < c \) there does not exist a finite joint-profit maximizing price, since demand for both products increases when both firms raise prices. Together these two arguments support the assumption that \( b > c \), in which case bilateral MFC equilibrium does not exist. The results of this section are summarized in the following proposition.

**Proposition 1.** If \( b > c \), there exist exactly two pure-strategy equilibria corresponding to the two unilateral MFC equilibria.

**Proof.** By the preceding discussion, bilateral MFC equilibrium does not exist if \( b > c \). By Cooper (1986), there exists an equilibrium in which at least one firm adopts an MFC policy, and both firms earn profits higher than the Bertrand level. Since there is no equilibrium in which both firms adopt MFC policies, there must be an equilibrium in which only one firm adopts an MFC policy. By symmetry, there are two such unilateral MFC equilibria. Because the unilateral MFC equilibrium generates higher profit for the adopting firm than the Bertrand level, there is no equilibrium in which neither firm adopts an MFC policy. \( Q.E.D. \)

Cooper (1986) demonstrates that there exists an equilibrium in which at least one firm adopts an MFC policy. Proposition 1 refines Cooper’s result by showing that unless an
unreasonable restriction is made on the symmetric linear model, only one firm adopts an MFC policy in equilibrium. If one firm adopts an MFC policy, the best response of the other firm is to remain as a Bertrand player by not adopting an MFC policy, because bilateral MFC pricing is not an equilibrium. If one firm elects to be a Bertrand player, the other firm’s best response is to unilaterally adopt an MFC policy. The next section uses general demand functions to extend the result that the only equilibria that exist are unilateral MFC equilibria.

4. Equilibria with general demand functions

Before addressing the general case, it is expedient to begin with the stable, asymmetric linear-demand case, still assuming that costs are zero. Demand is given by

\[ Q_{ii} = a_i - b_i P_{ii} + c_i P_{ji} \]
\[ Q_{jj} = a_j - b_j P_{ji} + c_j P_{jj} \]  

(16)

Because of the asymmetry, the two firms have different best-response functions and no longer charge the same price in equilibrium. Following an argument similar to that in the previous section, firm i’s rebate best-response function is given by

\[ R_{i2}(P_{j2}) = \frac{a_i + c_i P_{j2} + Q_{i1}}{2b_i} \]  

(17)

which differs from (10) only in that the parameters are firm-specific. The equilibrium prices, if they exist, can be found by solving (17) for both firms, which yields

\[ P_i = \frac{6a_i b_j + 4a_j c_i}{9b_i b_j - 4c_i c_j} \]  

(18)

which reduces to (13) if demand functions are symmetric.

Clearly, one condition for equilibrium to exist is that (18) is positive, which requires that the denominator be positive. The incentive for firms to deviate in the first period must also be removed.

Proposition 2. A bilateral MFC equilibrium exists with stable, asymmetric linear-demand functions if and only if

\[ b_i b_j c_i c_j < \frac{9}{4} b_i b_j \]  

For proof, let \((P^*_i, P^*_j)\) be the equilibrium price vector, and consider the effect of deviations from \(P^*_i\) by firm i, as in Section 3. First suppose i increases its price by \(\delta\). Then, since j does not respond, i’s profit rises by

\[ \frac{d \Pi_i}{dP_i} = 2(a_i - 2b_i P^*_i + c_i P^*_j) = -\frac{b_i (6a_i b_j + 4a_j c_i)}{9b_i b_j - 4c_i c_j} = -b_i P^*_i < 0. \]  

(19)

Now suppose firm i reduces its price by \(\delta\). Firm i’s first-period output rises by \(b_i \delta\), and j’s first-period output falls by \(c_j \delta\). Firm j responds by reducing its own price by \(\frac{c_j}{b_j} \delta\), so that i’s second-period output rises by \(\left(b_i - \frac{c_i c_j}{b_j}\right) \delta\). Therefore, i’s two-period profit rises by

\[ \frac{d \Pi_i}{dP_i} = -P_i \left(2b_i - \frac{c_i c_j}{b_j}\right) + 2Q^*_i \]
\[ = \frac{3a_i b_j + 2a_j c_i}{9b_i b_j - 4c_i c_j} \left(\frac{c_i c_j}{b_j} - b_i\right) \]
\[ = P_i \left(\frac{c_i c_j}{b_j} - b_i\right). \]  

(20)
For (20) to be positive (so that price reductions reduce profit), it must be the case that \( b_i b_j < c_i c_j \). Q.E.D.

The difference between the symmetric and asymmetric linear cases is that in the latter, only one firm must be more responsive to changes in the other firm’s price than to changes in its own price. The condition \( b_i b_j < c_i c_j \) is inconsistent with the existence of a joint-profit-maximizing price pair.

Now consider the general case, letting \( D_i(P_i, P_j) \) be a general demand function for firm \( i \) assumed to be differentiable in both arguments. For a given price vector \((P_i^0, P_j^0)\) there exists a tangent \( D_i^T \) to the demand function \( D_i \) at that price vector such that \( D_i^T \) is linear in both arguments, \( D_i^T(P_i^0, P_j^0) = D_i(P_i^0, P_j^0) \), and

\[
\frac{\partial D_i^T(P_i, P_j)}{\partial P_i} = \frac{\partial D_i(P_i^0, P_j^0)}{\partial P_i},
\]

and \( \frac{\partial D_i^T(P_i, P_j)}{\partial P_j} = \frac{\partial D_i(P_i^0, P_j^0)}{\partial P_j} \), with a similar construction for firm \( j \)’s demand.

In other words, \( D_i^T \) is the linear approximation to \( D_i \) at the chosen point, and therefore it has the same value at that point and the same partial derivatives.

**Definition.** The linearized version of a game at a given point is obtained from that game by replacing each firm’s demand function by its tangent at that point.

**Proposition 3.** If a price vector is a bilateral MFC equilibrium in a game with differentiable demand, then it is also a bilateral MFC equilibrium in the linearized version of the game.

**Proof.** Let \((P_i^*, P_j^*)\) denote the bilateral MFC equilibrium for the general version of the game, and suppose that it is not a bilateral MFC equilibrium for the linearized version of the game. Since both sets of demand functions have the same partial derivatives, the first-order conditions and equation (17) (the rebate best-response functions) are the same locally for both versions, and therefore the linearized version satisfies the first-order conditions for equilibrium. If \((P_i^*, P_j^*)\) is not an equilibrium in the linearized version, then by Proposition 2 it must be the case that \( b_i b_j > c_i c_j \), where \( b_i, b_j, c_i, \) and \( c_j \) denote the obvious partial derivatives evaluated at \((P_i^*, P_j^*)\).

In particular, \((Q_i^*, Q_j^*)\) is the output vector corresponding to \((P_i^*, P_j^*)\) for both sets of demand functions, and that by the proof of Proposition 2, the left-hand side of (21) is equal to \( P_i^* \left(b_i - \frac{c_i c_j}{b_j}\right) \). If \( b_i b_j > c_i c_j \), then (21) does not hold, providing a contradiction. Q.E.D.

Proposition 3 establishes that a local version of the incentive compatibility criterion must be in force for equilibrium to exist in the general version of the problem, thereby extending the result of the previous section. If bilateral MFC equilibrium is to exist, it must be the case that one firm’s demand is locally more responsive to changes in its rival’s price than to changes in its own. This unpalatable restriction effectively rules out the bilateral use of MFC pricing policies as a facilitating practice in this setting.

5. Conclusion

In recent literature surveys, most-favored-customer pricing is hailed as a simple yet powerful commitment device that can facilitate collusion, and the General Electric–Westinghouse case, in which both firms adopted MFC pricing policies, is often cited as an example (Salop, 1986; Tirole, 1988; and Shapiro, 1989). Cooper (1986) demonstrates that in a two-period, differentiated products duopoly model, an equilibrium exists in which at least one
firm adopts MFC pricing and both firms earn greater-than-Bertrand profits. We refine Cooper’s result by demonstrating that an equilibrium in which both firms adopt MFC pricing does not exist unless one applies a restrictive assumption that at least one firm’s demand is more responsive to changes in its rival’s price than to its own price. In a linear-demand setting, maintaining this assumption implies that a joint-profit-maximizing equilibrium does not exist. In light of this, we believe that alternative, noncollusive explanations for MFC pricing, such as those proposed by Butz (1990, 1991) and Png (1991), are needed.

References