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ON COLLUSION SUSTAINABILITY WITH STACKED REVERSION

ABSTRACT

We consider a multi-period oligopoly model to analyze cartel sustainability where a subset of collusive firms is exogenously given. We assume that in case of cheating only the cheater is expelled from the cartel and collusion continues without the cheater. We show that, in our model, when firms compete in quantities and the cartel is sufficiently small, a Stackelberg leader cartel can always be sustained if firms are patient enough. Furthermore, in this case collusion is more easily sustained than when firms play grim trigger strategies. The opposite result is obtained in a price-setting supergame with differentiated products.

Keywords: *Collusion; Stacked reversion; Trigger strategies*
JEL Classification: *L13; L40; L41*

1. INTRODUCTION

The analysis of cartel formation in oligopoly markets has a long tradition in the economic literature. It is well-known that although there is a general firms' interest in the existence of a cartel, the benefits of cartel formation are not evenly distributed and often nonmembers obtain higher profits than cartel members.[3]

We address the issue of collusion success by considering a supergame-theoretic approach (see the seminal paper by Friedman (1971)). In this approach, seemingly independent but parallel actions among competing firms in an industry are driven to achieve higher profits and this is termed tacit or implicit collusion. The tacit collusion literature is immense and it has usually focused on the equilibrium that maximizes industry profits[4] (see for example Rothschild (1999)) using subgame perfect Nash equilibria -henceforth, SPNE- as solution concept although, in practice, it can be observed that many collusive agreements do not involve all firms in the industry. In this regard, a significant example is the citric acid industry where three North-American and five European firms were fined for fixing prices and allocating sales in the worldwide market. Their joint market share was around 60 percent (see Levenstein and Suslow (2006)). It is also well known that this repeated game setting exhibits multiple SPNE collusive agreements. Therefore, to select among those equilibria the literature has usually adopted the particular criterion of restricting strategies to grim trigger strategies (see for instance Escrihuela-Villar (2008)) in which defection ruins the relationship forever. These strategies do not consider the possibility that after a defection loyal cartel members might want to continue colluding. In other words, it seems plausible that a large number of firms may not simply fail to coordinate on a punishment strategy for one firm that

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[3] The intrinsic difficulty in convincing firms to constitute a cartel was pointed out by Stigler (1950, p. 25) in a discussion of mergers: "The major difficulty in forming a merger is that it is more profitable to be outside a merger than to be a participant".
[4] Among the few exceptions are Escrihuela-Villar (2008) that analyzes the price effects of horizontal mergers, Escrihuela-Villar (2009) that considers how the sequence of play between the cartel and the fringe affects cartel stability or Bos and Harrington (2010) that endogenize the composition of a cartel with heterogeneous production capacities.

deviates from the collusive equilibrium. In this sense, there exists empirical evidence that participants in a cartel are not always willing to risk the collapse of collusion by punishing deviators. As an example, the Sugar Institute case explained in Genesove and Mullin (2001) where occasional incidents of cheating were typically not retaliated against or cheating did occur but sparked only limited retaliation.

The main purpose of this paper is to analyze cartel sustainability considering a set of strategies that could eventually be less grim than the trigger strategies. To that extent, we consider that cheating on the cartel agreement results only in the ejection of the defector. Our work is most closely related to Eaton and Eswaran (1998) from where the present paper gets part of the inspiration. To the best of our knowledge, they are the first to propose a set of strategies where non cheating cartel members continue operating as a cartel. They termed this scenario stacked reversion. The present paper differs, however, in some important ways. To begin with, Eaton and Eswaran consider simultaneous decision between the cartel and the fringe. However, in Abreu (1986, 1988) a two-phase output path (with a stick-and-carrot pattern) it is proved to be optimal when firms simultaneously choose their output and, consequently, the optimal set of strategies has already been characterized in a simultaneous decision context.[5] Therefore, and since one of the most widely accepted structures to characterize collusive behavior is that of a leader cartel, we assume the existence of cartel leadership.[6] Second, Eaton and Eswaran provide numerical examples of cartel sustainability with stacked reversion whereas in the present paper, by assuming an inverse demand curve, fairly general results are obtained.

We develop a multi-period oligopoly model with homogeneous firms, an exogenous subset of which are assumed to collude, while the remaining (fringe) firms choose their output levels non-cooperatively.[7] We use SPNE as solution concept assuming that in the event a cartel member cheats there is stacked reversion. Two different scenarios are considered: (i) firms set quantities and therefore, the cartel behaves as a Stackelberg leader with respect to the fringe in each period and (ii) there is cartel leadership with differentiated products and price competition. We obtain that with quantity competition, when the cartel is sufficiently small, a cartel can always be sustained with stacked reversion when firms are patient enough. In this case, stacked reversion also proves to be an easier way to sustain collusion than Nash reversion. Intuitively, the incentives that fringe firms have to free-ride on the cartel's collusive efforts disappear since a firm inside the cartel does not find it desirable to exit because each firm in the cartel earns higher profits than each fringe firm. One possible interpretation of this result is that the literature that deals with tacit collusion and cartel leadership should consider that Nash reversion might not constitute the right way to punish the cheater. On the contrary, these results do not carry over to a model with price competition and differentiated products. With price competition, each firm in the fringe always earns higher profits than each cartel firm. Thus, the free-rider problem that characterizes a cartel-fringe model arises and the cartel cannot generally be sustained with stacked reversion and price competition. In this case, therefore, collusion is always more easily sustained with Nash reversion than with stacked reversion.

The remainder of this paper is structured as follows. In section 2 we present the model and study cartel sustainability with quantity competition in a multi-period oligopoly model with stacked reversion and trigger strategies. In section 3 we also consider differentiated products and price competition. We conclude in section 4. All proofs are grouped together in the appendix.

[5] Abreu's notion of optimality implies that the range of time discount factors over which collusion is sustainable is maximized.

[6] There exist several real examples of cartel leadership like the Carbonless paper industry (see for instance Harrington (2006)).

[7] The assumption of a cartel involving a subset of firms is based on the fact that some of the best known examples of cartels involve only a part of the industry. Some significant cases are the citric acid, the carbonless paper or the North Atlantic shipping industries (see Levenstein and Suslow (2006)).

2 THE MODEL AND RESULTS

We consider an industry with *N>2* firms. Each firm produces a quantity of a homogeneous product and for simplicity it is assumed that the total production cost of the firms is equal to zero. The industry inverse demand is given by the piecewise linear function: *p(Q)=max(0,a-Q)*, where *Q* is the industry output, *p* is the output price, and *a>0.* We assume that $K \in [2, N]$ firms, indexed by *k=1,...,K* -henceforth, cartel firms- behave cooperatively so as to maximize their joint profits. The remaining (N-K) firms constitute the fringe and choose their output in a non-cooperative way. We assume that only one cartel is formed, and we take *K* as exogenously fixed.[8] The assumption of an exogenously given subset of firms colluding is based on the fact that cartels often involve an agreement between firms which can easily coordinate with each other (e.g. because they are based in the same country or have a common corporate culture). The fringe consists of foreign firms or new entrants that could not coordinate their behavior with the cartel firms even if they wish so.[9]

We assume that firms compete repeatedly over an infinite horizon with complete information (i.e. each of the firms either fringe or cartel observes the whole history of actions) and discount the future using a discount factor $\delta \in [0,1]$. Following the cartel and fringe literature, we assume that in each period the cartel behaves as a Stackelberg leader with respect to the fringe or equivalently, that the strategic advantage of the leadership is only available to cartel firms.[10] Time is discrete and dates are denoted by *t=1,2,...*. In this framework, a pure strategy for firm *k* is an infinite sequence of functions $\left\{S_k^t\right\}_{=1}^{\infty}$ with $S_k^t : \sum^{t-1} \rightarrow \vartheta$ where $\sum^{t-1}$ is the set of all possible histories of actions (output choices) of all cartel firms up to *t-1*, with typical element σ_j^τ, *j=1,...,K,* τ*=1,...,t-1*, and *Q* is the set of output choices available to each cartel firm. We restrict our attention to the case where each cartel firm is only allowed to follow the stacked reversion strategies in which in case of cheating, only the cheater is expelled from the cartel and collusion continues without the cheater.[11] Let *qK* and *qF* denote the output corresponding respectively to collusion when *K* firms maximize joint profits and non-cooperative behavior. At *t=1*, S_k^1 = *qK*, while at *t=2,3,…*

$$S_k^t(\sigma_j^\tau) = \begin{Bmatrix} q_K \text{ if } \sigma_{\mathrm{j}}^\tau = q_K \text{ for all } j = 1,...,K \text{ and } \tau = 1,...,\mathrm{t-1} \\ q_{K-1} \text{ if } \sigma_{\mathrm{j}}^\tau \neq q_K \text{ for a } j = 1,...,K \;\; j \neq k \text{ and } \tau = 1,...,\mathrm{t-1} \\ q_F \text{ if } \sigma_{\mathrm{K}}^\tau \neq q_K \text{ for any } \tau = 1,...,\mathrm{t-1} \end{Bmatrix} \quad (1)$$

In words, in the event a cartel member cheats instead of dissolving the entire cartel, the loyal members find in their own interest to continue to produce as a cartel but with one firm less. Regarding fringe firms, their optimal response consists of maximizing their current period's payoff in such a way that if each firm in a cartel with *K* members produces *qK*, then the output produced by each fringe firm (*qF*) is

$$q_F = \max\left\{0, \frac{a - K\mathrm{q_K}}{N - K + 1}\right\}$$

[8] The literature on endogenous cartels has frequently used the concept proposed by d' Aspremont et al. (1983) for cartel stability. In this case, cartels containing just over half the firms in the industry are stable (see for instance Donsimoni (1986) or Shaffer (1995)).
[9] As an example, three North-American and five European firms in the citric acid industry were fined for fixing prices and allocating sales in the worldwide market. Their joint market share was around 60 percent. The rest of the producers included a variety of minor companies based in Eastern Europe, Russia and China (see Levenstein and Suslow (2006)).
[10] The seminal papers in this literature are Selten (1973) and d' Aspremont et al. (1983).
[11] Simultaneous deviations are ignored since, as was remarked by Fudenberg and Tirole (1991), "in testing for Nash or subgame-perfect equilibria, we ask only if a player can gain by deviating when his opponents play as originally specified" (p. 281).

We assume also that if a cartel firm deviates fringe firms optimally respond to the deviation. We denote by $\Pi^C(N,K)$ and $\Pi^F(N,K)$ the profit function of a cartel firm and that of a fringe firm when cartel and fringe firms produce respectively qK and qF. Then, cartel firms producing qK in each period can be sustained as a SPNE of the repeated game with the strategy profile (1) if and only if for given values of N,K and δ, the following condition is satisfied

$$\frac{\Pi^{\mathrm{C}}(N,K)}{1-\delta} \geq \Pi^{\mathrm{D}}(N,K) + \frac{\delta\Pi^{\mathrm{F}}(N,K)}{1-\delta}, \qquad (2)$$

where $\Pi^D(N,K)$ denotes the profits attained by an optimal deviation from a collusive output. Then, we denote by δ_K the minimum δ required for the condition (2) to be satisfied. Observe that for the incentive compatibility condition (2) to make sense, it must also be the case that it is satisfied for $K\text{-}1$. Otherwise, $\Pi^F(N,K\text{-}1)$ would not be the profits that a cheater would obtain since the cartel of $K\text{-}1$ would not be itself robust against cheating. Consequently, (2) has to be also satisfied for cartels with less than K firms in such a way that the following set of necessary and sufficient incentive compatibility conditions must all be satisfied

$$\frac{\Pi^{\mathrm{C}}(N,\mathrm{h})}{1-\delta} \geq \Pi^{\mathrm{D}}(N,\mathrm{h}) + \frac{\delta\Pi^{\mathrm{F}}(N,\mathrm{h}-1)}{1-\delta} \quad \forall h = 2,3,\ldots,K \qquad (3)$$

It can be verified that the minimum discount factor needed for the joint profit maximization of cartel firms to be a SPNE of the repeated game with cartel firms playing (1) is

$$\delta_K = \frac{(-1+K)^2(2-K+N)^2}{(-1+K)^2K(4+K)-2(-1+K)K(3+K)N+(1+K)^2N^2+4(1+N)} \qquad (4)$$

This is true because δ_K is the minimum δ required for the condition (2) to be satisfied and since $\frac{\partial\delta_K}{\partial \mathrm{K}} > 0$ this implies that if $\delta \geq \delta_K$ no firm has incentive to deviate from a cartel with K firms. In other words, the set of conditions (3) are also satisfied. Consequently, the following definition applies.

Definition 1 *δ_K is said to be the minimum discount factor required for the cartel of K firms to be sustainable as a SPNE. Then, a cartel of K firms is said to be sustainable if $\delta \geq \delta_K$ and $\delta_K \in (0,1)$.*

Equivalently, a cartel of K firms is more easily sustained than a cartel of $\overline{K}$ firms whenever $\delta_K < \delta_{\overline{K}}$. We are now in the position to characterize cartel sustainability with stacked reversion.

Proposition 1 *For $N\geq 4$ if $K\leq f(N)\equiv \frac{1}{4}(5+3N-\sqrt{N(N-2)-7})$, there exists $\overline{\delta} \in (0,1)$ such that if $\delta\geq\overline{\delta}$ the cartel with K firms is sustainable. For $N=3$, the cartel $K=2$ is sustainable if $\delta\geq 0.18$.*

Proposition 1 establishes that whenever the size of the cartel is relatively small and firms discount the future sufficiently little collusion can always be sustained using stacked reversion strategies. The intuition behind this Proposition is as follows. The major difficulty in forming a cartel is that it is often more profitable to be outside the cartel than to be a participant. Consequently, cartels tend to be unsustainable because their members have incentives to free-ride on the profit-enhancing efforts of the cartel. However, this is not true when the cartel is relatively small. In other words, we can find a K small enough such that the profits of a fringe firm when a cartel with K-1 is active are lower than the profits that a firm would obtain being a participant in a cartel with K firms.[12]

A natural question that arises is whether collusion is easier to sustain with the stacked reversion or when players adopt trigger strategies. In the latter case, following Friedman (1971) these strategies are such that cartel firms adhere to the collusive agreement until there is a defection, in which case they revert forever to the static N-firm Nash equilibrium.[13] In this case, cartel firms producing qK in each period can be sustained as a SPNE of the repeated game if and only if, the following condition is satisfied

$$\frac{\Pi^{C}(N,K)}{1-\delta} \geq \Pi^{D}(N,K) + \frac{\delta \Pi^{N}(N)}{1-\delta}, \qquad (5)$$

where $\Pi^N(N)$ denotes the static N-firm Nash equilibrium. It is an standard exercise to verify that the minimum discount factor required for the cartel of K firms to be sustainable as a SPNE using trigger strategies (the minimum δ required for the condition (5) to be satisfied), that we denote by δ_K^T, is

$$\delta_K^T = \frac{(-1+K)^2(1+N)^2}{16K^3 + K^2(-15+N)(1+N) + (1+N)^2 + 2K(1+N)^2}. \qquad (6)$$

An easy comparison reveals the following result.

Proposition 2 *If $K \leq (N+3)/2$ the cartel of K firms is more easily sustained with stacked reversion strategies than with trigger strategies. The converse is true.*

When the cartel is small enough, the incentives that fringe firms have to free-ride on the cartel's collusive efforts disappear and fringe firms make fewer profits than in the static N-firm Nash equilibrium. Consequently, the stacked reversion is a harsher punishment than reverting to the Nash equilibrium and the repeated game with stacked reversion is more effective in enforcing an agreement than with Nash reversion. Interestingly, a different form of retaliation may inflict tougher punishments and thereby allow sustaining higher collusive prices just by ignoring the deviation.

3 PRICE COMPETITION

In this section we test whether our results hinge on the assumption of quantity competition and homogeneous products by considering also differentiated products and price competition. To that extent, we assume that the industry produces non-spatial horizontally differentiated products such that the degree of differentiation between the products of any two firms is the

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[12] Note that $\frac{f(N)}{N} \in (\frac{1}{2}, 1)$.

[13] We note that, in this case, the punishment would also consist of cartel firms losing the strategic advantage of the leadership.

same. As in section 2, we assume that in each period the cartel sets the price before the fringe. The inverse demand function exhibits a Chamberlinian symmetry:

$$p_i=a-q_i-b\sum_{j\neq i} q_j$$

where p_i denotes the price of good *i* and q_j the quantity sold of good *j*. Alternatively, we can write the demand system as

$$q_i=\alpha-\beta p_i+\gamma\sum_{j\neq i} p_j$$

where $\alpha=\frac{a}{1+(N-1)b}$, $\beta=\frac{1+(N-2)b}{(1-b)(1+(N-1)b)}$ and $\gamma=\frac{b}{(1-b)(1+(N-1)b)}$. It is assumed $a,b>0$ and $0\leq b\leq 1$. The value range for *b* (the common degree of product substitutability) implies that the products are viewed as substitutes rather than complements and that the price of each product is more susceptible to changes on its own demand rather than changes on other product demand. Hence, $b=0$ implies that the products are completely independent and $b=1$ indicates that they are perfect substitutes.

We analyze cartel sustainability extending the analysis of the previous section to price competition and differentiated products when cartel firms follow the stacked reversion strategies. It is a standard exercise to obtain the critical value below which a cartel member does not have incentives to deviate. Although the expression of this cutoff cannot be easily simplified, we have the following result.

Proposition 3 *With price competition and stacked reversion strategies, sustainable cartels exist in only two cases: i) $K\leq 3$ and ii) $K=4$, $N=5$.*

This result establishes that in the game defined above cartel sustainability is rather difficult with price competition. Thus, the implications on cartel sustainability derived in Proposition 1 do not carry over when firms compete in prices. This difference follows from the fact that reaction functions are upward sloping in price games but downward sloping in quantity games. With cartel leadership, the reaction of fringe firms reinforces the initial price increase that results from the cartel price and therefore the intuitions provided in the previous section are reversed when firms compete in prices. Intuitively, with price competition a cartel cannot (generally) be sustained with stacked reversion because the continuity of the cartel is not a severe enough punishment since fringe firms free ride on the cartel's collusive efforts to increase price. However, for a sufficiently small cartel the conferring of leadership status to the cartel allows collusion to be sustained with stacked reversion strategies. In this case, losing the leadership after defection inflicts a sufficiently harsh punishment on fringe firms in order for the cartel to be sustainable.

As in the previous section, we compare cartel sustainability with stacked reversion and under Nash reversion strategies. This leads to the following result.

Proposition 4 *With price competition a cartel is more easily sustained under trigger strategies than with stacked reversion strategies.*

Proposition 4 does not come as a surprise and it is perfectly in line with Proposition 3 and its intuition. When firms compete in prices, a Nash reversion inflicts a harsher punishment than continuing with the cartel without the defector. The intuition is that fringe firms always benefit more from a cartel than do the members and consequently, the cartel operating without the defector does not constitute (generally) an enforceable punishment.

4 CONCLUDING COMMENTS

We have developed a theoretical framework to study cartel sustainability using a more sophisticated set of strategies than the usual trigger strategies. Following Eaton and Eswaran (1998), we assume that in case of defection only the defector is ejected. We obtain that in a quantity-setting industry where the cartel produces before the fringe, when firms are patient enough collusion can be sustained with stacked reversion strategies. Furthermore, if the cartel is relatively small collusion is more easily sustained with stacked reversion than with trigger strategies. Conversely, with differentiated products and price competition, a cartel cannot generally be sustained with the stacked reversion strategies.

Our results suggest that with quantity competition and cartel leadership, a set of strategies that could be less grim than the trigger strategies should also be considered to analyze cartel sustainability. An alternative interpretation is that the existence of price wars can be limited not only by firms' ability to punish a potential deviation but also because a cartel may find optimal not to punish the deviator. In other words, usually retaliation includes temporary price wars, leading to profits below normal levels for some period of time and it may also include actions that are targeted at reducing the profits of the deviant firm. However, we proved that it may turn out to be the case that cartel firms find it optimal to leave the deviation unpunished which could be an additional explanation for the absence of price wars after retaliation.

The framework we have worked with is, admittedly, a particular one. To analyze real-world cases of cartels, firms' capacities, cost asymmetries or an extension to a wider range of demand functions should also be considered. Another natural question is also how the cartel could be able to impose its most preferred timing in a cartelistic model or considering renegotiation-proof strategies. We believe that those are subjects for future research.

APPENDIX

Proof of Proposition 1. From (4) it can be easily verified that δ_K is always positive and smaller than 1 whenever $K \leq \frac{1}{4}(5+3N-\sqrt{N(N-2)-7})$. This inequality has a real root whenever $N(N-2)-7 \geq 0$ which is true for $N \geq 4$. If $N=3$ and $K=2$, $\delta_K = 0.18$. ■

Proof of Proposition 2. From (4) and (6), it is immediate to verify that $\delta_K < \delta_K^T$ whenever $K \leq (N+3)/2$. ■

Proof of Proposition 3. The minimum discount factor required for the cartel of K firms to be sustainable as a SPNE using stacked reversion with price competition can be easily obtained but cannot be simplified (the expression and further details are available from the author upon request). We denote this cutoff by $\delta_K^P(b,K,N)$.

Easy calculations show that $\delta_K^P(0,K,N) = \frac{1}{2}(K-1)$.

Consequently, since $\left.\frac{\partial \delta_K^P(d,K,N)}{\partial d}\right|_{d=0} = \frac{1}{4}(K-3)(K-1) \leq 0 \ \forall K \leq 3$, there exists $\delta_K^P(b,K,N) \in (0,1)$ for $K \leq 3$.

On the other hand,

$$\delta_K^P(b,K,N)=\frac{9(1-2N)^4(N-3)^2(2+N)^2}{2628+N(-7332+N(11977+N(-9978+N(4089+4N(-182+N(-30+N(-78+25N)))))))}$$

which is only smaller than 1 if $N<\frac{1}{22}(11+\sqrt{55(109+6\sqrt{345})})\simeq 5.505$. Consequently, for $K=4$, only when $N=5$ there exists $\delta_K^P(b,K,N)\in(0,1)$. Finally, for the case of $K>4$ since $\delta_K^P(b,K,N)$ is decreasing with b, it is enough to verify that $\delta_K^P(1,K,N)\geq 1$. To that extent, it is easy to prove that $\frac{\partial\delta_K^P(1,K,N)}{\partial N}>0$. Thus, it suffices to check the value of $\delta_K^P(b,K,N)$ for the minimum possible value of N which is $K+1$. Then, we have that

$\delta_K^P(1,K,K+1)=\frac{(1+2K)^4(1-3K+2K^2)^2}{1+K(1+2K)(-2+K(-5+2K(9+K(7+2K(-11+K(-1+6K))))))}$ which is increasing in K and larger than 1 when $K>4.609$ which proves that if $K>4$, the cartel is not sustainable. ■

Proof of Proposition 4. Like in the proof of Proposition 3, the minimum discount factor required for the cartel of K firms to be sustainable as a SPNE using trigger strategies with price competition can be easily obtained but cannot be simplified. We denote this cutoff by $\delta_K^{P,T}(b,K,N)$. Then, $\delta_K^{P,T}(b,K,N)\equiv\frac{\Pi^D(N,K,b)-\Pi^C(N,K,b)}{\Pi^D(N,K,b)-\Pi^N(N,K,b)}$, where we denote the Nash equilibrium profits by $\Pi^N(N,K,b)$. Since obviously, $\Pi^D(N,K,b)>\Pi^C(N,K,b)$ and $\Pi^D(N,K,b)>\Pi^N(N,K,b)$ $\delta_K^{P,T}(b,K,N)>0$. On the other hand, it can be easily checked that $\delta_K^{P,T}(b,K,N)\leq 1$ because $\Pi^C(N,K,b)>\Pi^N(N,K,b)$ which implies that $\delta_K^{P,T}(b,K,N)\in(0,1)$. Then, it suffices to check that $\delta_K^{P,T}(b,K,N)<\delta_K^P(b,K,N)$ when $\delta_K^P(b,K,N)\in(0,1)$. From Proposition 3, we only have two cases where the latter is true. It is immediate to verify that $\delta_K^{P,T}(b,4,5)<\delta_K^P(b,4,5)\ \forall b$ since $\delta_K^{P,T}(b,4,5)=\delta_K^P(b,4,5)$ has 3 different real roots, $b=-(1/3)$, $b=-(1/4)$ and $b=-0.285714$. Also from the continuity of $\delta_K^{P,T}(b,K,N)$ and $\delta_K^P(b,K,N)$, we have that $\lim_{b\to 0}\delta_K^{P,T}(b,K,N)=\frac{1}{2}$, $\delta_K^{P,T}(1,4,5)=0.708$ and $\lim_{b\to 0}\delta_K^P(b,4,5)=\frac{3}{2}$, $\delta_K^P(1,4,5)=0.95$ which proves that $\delta_K^{P,T}(b,4,5)<\delta_K^P(b,4,5)$.

On the other hand, if $K\leq 3$, it can be verified that $\delta_K^{P,T}(b,K,N)=\delta_K^P(b,K,N)$ has no real roots in $b\in(0,1)\ \forall N,K=2,3$. We have that $\lim_{b\to 0}\delta_K^P(b,K,N)=\frac{(K-1)}{2}$ which implies that $\delta_K^P(0,K,N)>\delta_K^{P,T}(0,K,N)\ \ \forall N,K=2,3$. Finally,

$$\delta_K^P(1,3,N)=\frac{(1-2N)^4(-2+N)^2(1+N)^2}{88+N(-308+N(568+N(-580+N(372+N(-192+N(109+N(-70+17N)))))))}$$

$>\delta_K^{P,T}(1,3,N)=\frac{(1-2N)^4}{76+N(-108+N(124+N(-132+41N)))}$ and

$\delta_K^P(1,2,N)=\frac{(1-2N)^4(-1+N)N^2}{-16+N(80+N(-205+N(325+4N(-91+N(71+N(-37+9N))))))}>$

$\delta_K^{P,T}(1,2,N)=\frac{(1-2N)^4}{73+4N(-47+N(60+N(-44+13N)))}$, which proves that

$\delta_K^P(b,K,N) > \delta_K^{P,T}(b,K,N)$ $\forall N,K=2,3$. ■

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ODRŽIVOST KOLUZIJE PRI „STACKED REVERSION“

SAŽETAK

Razmatramo multiperiodni model oligopola kako bismo analizirali održivost kartela u kojem je podskup koluzivnih tvrtki dan egzogeno. Pretpostavljamo da u slučaju prevare samo varalica biva izbačen iz kartela te se koluzija nastavlja bez prevaranta. Na našem modelu pokazujemo da kad tvrtke konkuriraju u količinama a kartel je dovoljno malen, Stackelberg leader kartel može uvijek biti održan ako su tvrtke dovoljno strpljive. Nadalje, u ovom slučaju, koluzija se jednostavnije održava nego kad tvrtke igraju „grim trigger“ strategije. Obrnuti se rezultat dobiva u cjenovnom nadigravanju s diferenciranim proizvodima.

Ključne riječi*: koluzija, „stacked reversion“, „trigger“ strategije (strategije „brzog odgovora“).*

JEL klasifikacija: *L13; L40; L41*