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Cooperative Supply Chains in Peace and at War.

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COOPERATIVE SUPPLY CHAINS IN PEACE AND AT WAR

PER J. AGRELL AND KOSTAS KARANTININIS

Abstract. In the competition between supply chains, governance structure and coordination mechanisms can be as important as cost-efficiency. Flexible and non-committing contracts among upstream suppliers in cooperative alliances may lead to lower chain surplus through internal competition and renders the coordinator's postition vulnerable for hostile take-overs. Cooperative supply chains are found in e.g. food industry, banking services, lawfirms and brokerage. The downstream processing or brand is owned collectively by the suppliers or service-providers. The supplier are linked to the chain by strong delivery (channel) rights and volume-based revenue-sharing schemes. The governance is flexible, promotes entry and market expansion. However, the decentralized decision making comes at a cost in terms of chain performance and resilience. A dynamic two-chain model with a captive and competitive market addresses the particular situation where the a competing chain aggressor has a cooperative governance structure. The overt aggression at merger may have more to do with shortcomings in the managerial incentive structure than with the pursuit of market power. The results from the dynamic game is illustrated with empirical findings among dairy cooperatives in Denmark.

1. Introduction

The management literature often endorses the value of loose or informal alliances to achieve supply network benefits in terms of product and process innovation, capacity provision and inventory pooling. The low threshold of entry and the low commitment may indeed attract firms and entrepreneurs that would balk at tighter contractual agreements with potential competitors. However, the conflicts between such friendly alliances may be both more fierce and less rewarding for the winner than alternative forms of governance. This paper is devoted to the competition among cooperative supply chains, typically found in food industry, banking services (credit cards), stock exchanges and law firms.

The traditional cooperative organization (one-man, one-vote) has particular characteristics when faced with imperfect markets, managerial incentives and industrial structural development. Neoclassical studies of producer cooperatives have been made by e.g. Sexton (1986). The joint ownership of a cooperative, without individual claim on the value of the firm, has allegedly an effect to discourage investments and retained earnings in favor of higher patronages. Many producer cooperatives have a higher proportion of debt than comparable firms in their industries and lower investment ratios. The preference for immediate rewards naturally hampers

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the development of value-added products and durable brands. At the heart of this problem is the decentralized decision making in the cooperative enterprises, where each member freely chooses delivered volume. As volume maximization comes at a high cost in terms of market gains in the commodity segment of the market, it may be beneficial for the cooperative management to reduce the cooperative competition. This observation puts our attention at the procedure for mergers among producer cooperative under imperfect competition, in particular to the obstacles for mergers and how/when they may be overcome.

Since the owners-producers have no right to individually sell the residual of their efforts, neither has the management of the cooperative. Assuming a certain managerial utility for heading the firm, such as in Williamson (1963), and considering the cultural inertia to establish competitive packages for executives in cooperatives, there are weak incentives for cooperative managers to induce mergers. As the information flow may be channeled through the current management to the members, there is also reason to believe that the cooperation of the management is necessary to effectively elicit support for a mutually beneficial merger. If such communication can be made credibly and convincingly, the members of the less powerful cooperative would in theory abandon their previous organization to voluntarily enter into the merged organization, plausibly after some contractual grace period.

However, the members may also have rational reasons to remain in their current organization, due to varying beliefs about managerial skills, production methods or investment ratios. There may also be uncertainty about the brand value in captive markets when the dominance becomes overwhelming. Examples may be organic versus traditional producers that compete on a joint market. In any of these cases, there are rational reasons and managerial incentives for financially dominating producer cooperatives to initiate, promote, urge and, if necessary, force horizontal integration. Given the low value-added of the output and the requirement to sell all delivered input, a price-war is a highly effective means of persuasion. In order to resist such aggression or to succeed in the endeavor, depending on which side one is studying, the correct level of equity for the operating risk is of uttermost importance.

This paper contributes to the literature by modeling the aggressive behavior by dominant producer cooperative, showing the relative strengths and weaknesses of the cooperative organization in presence of oligopoly with a competitive fringe. This extends the industrial organization literature on producer cooperatives under imperfect competition. It also sheds some light on current topics related to regulation of mergers among investor-owned and cooperative firms in the food industry.

Next, we present a mathematical model to explain the temptation and strategy behind the mergers, as well as giving a price on managerial independence. Finally, we illustrate the model with the pre-merger behavior of the largest dairy producer in Europe in 1999, MD Foods.

2. The Model

Two supply chains with identical processing cost, for simplicity called Leader and Follower, produce and sell a homogenous product[1]. Their processing cost functions have constant marginal cost c,

$$C(Q) = cQ + K$$

where Q is the processed quantity, K is a fixed period cost. If the processing cost would have been modelled using increasing marginal cost, no merger gains would prevail and the cooperative model would suggest the formation of N processors. A decreasing marginal cost also gives extreme solutions, as complete concentration is the outcome. Thus, if mergers prevail in the industry without resorting to natural monopolies, the linear structure with a fixed term is the most preferable. The inputs are purchased from N identical suppliers, m thereof are delivering only to Leader and the remaining $n < m$ are delivering only to Follower. The entry barrier corresponds to common cooperative contractual obligations with excessive transfer periods, geographical and cultural barriers. Each supplier has a quadratic cost function $f(Q)$ with linear marginal cost wQ,

$$f(Q) = \frac{1}{2} w Q^2$$

Two markets are studied, a captive market (1) with firms Leader and Follower as the only providers of the good and one competitive market (2) with a given market price $p_2 \geq c$, to which only Leader has access. The situation may correspond to two different state of brand recognition, market investment or, as in the illustration, a result of a prior collusive agreement. The inverse demand function of the captive market is given as

$$p(Q) = \alpha - \beta Q$$

where Q is the total milk supply and α, β are constants. Denote[2] the supply of Leader to the captive market by Q_1 and the competitive quantity as Q_2. Since distribution of profit is not the focus of the paper, the firms may be seen as vertically integrated under two different control regimes. The single-period profit functions for Leader $V(Q_1, Q_2)$ and Follower $v(q)$, where q is the captive supply of the Follower firm, may be formulated as

$$V(Q_1, Q_2) = p(Q_1 + q)Q_1 + p_2 Q_2 - C(Q_1 + Q_2) - m\, f\left(\frac{Q_1 + Q_2}{m}\right). \tag{2.1}$$

$$v(q) = p(Q_1 + q)q - C(q) - n\, f\left(\frac{q}{n}\right) \tag{2.2}$$

[1]Here the production analogy is followed, but in the case of services (such as credit cards), the processing would correspond to joint marketing, settlement and administration of purchases. The suppliers in this case would corresspond to the member banks and their cardholding clients.

[2]For the conveniency of the reader, the produced quantities, rents and other results for Leader are denoted by upper case letters (Q, V), and analogously lower case letters denote results for Follower.

Regardless of control regime, investor-owned or cooperative, the larger firm has incentives to exploit monopoly rents by merging with the smaller. The particular angle of the paper is the threat of aggression to force the smaller out of the market, e.g., in case of a management refusal to accept the merger conditions or in the presence of merger law. In order to later compare the investor-owned control with the cooperative organization, we will study the optimal aggression of a dominant IOF towards a fringe IOF firm. The approach is straight-forward: First the attainable profits from duopoly (friendly coexistence) and monopoly are determined. Second, a dynamic price-war game is formulated, solved and interpreted for the IOF case.

2.1. **The IOF Duopoly Model.** Firm Leader acts as leader in a von Stackelberg duopoly model on the captive market, thus anticipating the reaction function of firm Follower,

$$q^*(Q_1) = \arg\max\{v(q) = p(Q_1 + q)q - C(q) - nf\left(\frac{q}{n}\right)\}$$

or, with the given price function for the captive market,

$$q^*(Q_1) = \frac{n\beta\left(\alpha - c - \beta Q_1\right)}{2n\beta + w}. \tag{2.3}$$

The resulting single-period duopoly profit for Leader is obtained as

$$V^* = \max_{Q_1,Q_2} \left\{ \begin{array}{c} V(Q_1,Q_2) = p(Q_1 + q^*(Q_1))Q_1 \\ +p_2Q_2 - C(Q_1+Q_2) - mf\left(\frac{Q_1+Q_2}{m}\right) \end{array} \right\} \tag{2.4}$$

With the given structure of the cost- and profit-functions, this gives the interior solution,

$$Q_1^* = \frac{n\beta\left(\alpha + c - 2p_2\right) + w\left(\alpha - p_2\right)}{2\beta\left(n\beta + w\right)} \tag{2.5}$$

$$Q_2^* = \frac{m}{w}\left(p_2 - c\right) - Q_1^* \tag{2.6}$$

$$q^*(Q_1^*) = \frac{n^2\beta\left(\alpha - 3c + 2p_2\right) + w\left(\alpha - 2c + p_2\right)}{2\left(2n\beta + w\right)\left(n\beta + w\right)}. \tag{2.7}$$

with the corresponding duopoly profits $V^* = V\left(Q_1^*, Q_2^*\right)$ and $v^* = v\left(q^*\left(Q_1^*\right)\right)$ (the expressions are fairly cumbersome and the details are given in Appendix 9.1), and consolidated profits $\Pi^* = V^*\left(\frac{\delta}{1-\delta}\right)$ and $\pi^* = v^*\left(\frac{\delta}{1-\delta}\right)$,where $\delta < 1$ is a discount factor.

2.2. **The IOF Monopoly Model.** If Follower and Leader merge, the market structure turns to a monopoly. We additionally assume that all primary producers join the merged entity, that consequently has N producers. The investor-owned merged firm solves problem (2.4) for the case $q^*(.) = 0$ and obtains the monopoly profit

$$V^{**} = \frac{\left(\alpha - p_2\right)^2}{4\beta} + \frac{N}{2w}\left(p_2 - c\right)^2 - K \tag{2.8}$$

for the interior solution quantities,

$$Q_1^{**} = \frac{\alpha - p_2}{2\beta}, \tag{2.9}$$

$$Q_2^{**} = \frac{N\beta\left(p_2 - c\right) - w\left(\alpha - p_2\right)}{2\beta w}. \tag{2.10}$$

The consolidated monopoly profit is $\Pi^{**} = V^{**}\left(\frac{\delta}{1-\delta}\right)$,which of course exceeds $\Pi^* + \pi^*$.

3. The Price-War Game for IOF

The market power and the reduction of fixed cost and variable costs (through the enrollment of more suppliers) motivate Leader to merge with Follower in the interest of both owners. For the case of investor-owned firms, this could be accomplished either as an open bid or as a hostile take-over, in case management or some owners would oppose the order of merger. However, the actual division of the gain $\Pi^{**} - (\Pi^* + \pi^*)$ would be a question of bargaining and is left out of this presentation. Now assume that for some reason, either an aversion against voluntary merger and/or the absence of a public stock-market (or any system of individual claims on equity), the dominant firm Leader is forced to wage a price-war against firm Follower to induce a merger. It is assumed that the production or service has to be continuous to uphold the market power and that once stalled, substantial entry-barriers would prohibit the reinstallation[3]. The length of the conflict is ultimately bounded by the equity U and u of firms Leader and Follower, respectively. The most aggressive price-war under the mixed production case $\alpha - p_2 \geq 0$ and $p_2 - c \geq 0$ would induce production at marginal cost, thus $p(Q_1 + q) = c$ and result in the single-period quantities

$$\begin{aligned} Q_1^W &= \frac{\alpha - c}{\beta} \\ Q_2^W &= \frac{N\beta\left(p_2 - c\right) - w\left(\alpha - c\right)}{\beta w} \\ q^*\left(Q_1^W\right) &= 0 \end{aligned} \tag{3.1}$$

However, this would imply the single-period net results of

$$\begin{aligned} V(Q_1^W, Q_2^W) &= \frac{m}{2w}\left(p_2 - c\right)^2 - \left(p_2 - c\right)\left(\frac{\alpha - c}{\beta}\right) - K \\ v\left(q^*(Q_1^W)\right) &= -K \end{aligned}$$

The payoffs above form the basis for a dynamic price-war game under perfect information played between the firms. The fringe firm Follower has the options to resist take-over and to continue as price taker ($Follow$) or to accept the invitation ($Surrender$). The dominant may choose to attack the fringe firm by lowering the price ($Fight$), to opt for status quo, the duopoly coexistence ($Truce$) or to exploit the market rents from a merger ($Monopoly$).

[3]The assumption is reasonable in both process-industry settings and service provision (payment operations, exchanges)..

Technically, Leader decides upon an action $H^t \in \{Fight, Truce, Monopoly\}$ in each period t which corresponds to the quantities $Q^t \in \left\{ \begin{array}{ccc} Q_1^W & Q_1^* & Q_1^{**} \\ Q_2^W & Q_2^* & Q_2^{**} \end{array} \right\}$. After the revelation of H^t, firm Follower responds with an action $h^t \in \{Follow, Surrender\}$, corresponding to the quantities $q^t \in \{q^*(Q_1), 0\}$. The draw $h^t = Surrender$ is an irreversible action, thus $h^t = Surrender \Longrightarrow h^\tau = Surrender, \tau > t$. As an additional assumption, we postulate that Follower will be forced to surrender at last when the total operating losses exceed the equity, $h^\tau = Surrender$ if $-\sum_{t<\tau} v(q^t) > u$. Summarize the actions in period t as $\mathbf{H}^t = (H^t, h^t|Fight, h^t|Truce, h^t|Monopoly)$. The competition is characterized in Proposition 1 below, which uses simple results for infinitely repeated games (e.g., Fudenberg, Levin and Maskin, 1986) and backward induction.

Proposition 1. *Given a discount factor $\delta < 1$, $\alpha - p_2 \geq 0$ and $p_2 - c \geq 0$, the price-war game (IOF) has two unique perfect equilibria*

a) $\mathbf{H}^t = (Truce, Follow|-) \quad \forall t$

b) $\mathbf{H}^1 = (Fight, Surrender|Fight, Follow|Truce, Follow|Monopoly)$ *and* $\mathbf{H}^t = (Monopoly, Surrender|-), t > 1$.

Proof. The payoff (Π, π) for the firms of strategy (a) is (Π^*, π^*). A deviation for Leader to fight is dominated for all cases unless it leads to a surrender by Follower, which happens at last at time $\widehat{\tau} = \left\lfloor \frac{u}{K} \right\rfloor$. Due to discounting, an earlier price-war dominates a later and there can never be optimal to insert periods of $Truce$ or $Monopoly$ into the price-war. The payoffs for the war ending with surrender at period $\tau \leq \widehat{\tau}$ is

$$\Pi(\tau) = \left[\frac{m}{2w}(p_2 - c)^2 - (p_2 - c)\left(\frac{\alpha - c}{\beta}\right) - K\right]\left(\frac{\delta - \delta^{\tau+1}}{1-\delta}\right) + V^{**}\left(\frac{\delta^{\tau+1}}{1-\delta}\right) \tag{3.2}$$

$$\pi(\tau) = -K\left(\frac{\delta - \delta^{\tau+1}}{1-\delta}\right) \tag{3.3}$$

If $\Pi(\widehat{\tau}) < \Pi^*$ the threat of the follower not surrendering is credible and $H^t = (Truce, Follow|-)$ dominates all other strategies.

If $\pi(\widehat{\tau}) \geq \pi^*$ the threat of the follower is not credible and using backward induction from the time τ of surrender leads to a minimization of losses for $\tau = 1$. The signal $H^1 = Fight$ is the proof to Follower that Leader will continue to wage war until it is won and that resistance is futile. Any other first-period signal by Leader would prolong the war and is thus dominated. Given that Follower surrenders in the first period, $Monopoly$ dominates $Truce$ and $Fight$ for all proceeding periods.

Hence,$H^1 = (Fight, Surrender|Fight, Follow|Truce, Follow|Monopoly)$ and $H^t = (Monopoly, Surrender|-), t > 1$ dominate all other strategies for $\Pi(\widehat{\tau}) \geq \Pi^*$. □

In fact, a constructive result about the minimum price of independence for the smaller entity may be derived, as in the Corollary below.

Corollary 1. *Given a discount factor $\delta < 1$, the minimum ratio of equity to fixed costs, $\widehat{\tau} = \frac{u}{K}$ is obtained by the relation*

$$\begin{aligned}\widehat{\tau} &= \frac{1}{\ln\delta}\ln\left\{V^* - \frac{m}{2w}(p_2 - c)^2 + (p_2 - c)\left(\frac{\alpha - c}{\beta}\right) - K\right\} \\ &\quad -\frac{1}{\ln\delta}\ln\left\{V^{**} - \frac{m}{2w}(p_2 - c)^2 + (p_2 - c)\left(\frac{\alpha - c}{\beta}\right) - K\right\}\end{aligned}$$

Proof. Follows directly from the Proposition 1 and (3.2) in its proof. The minimum ratio is defined from $\Pi(\widehat{\tau}) = \Pi^*$. □

4. The Cooperative Duopoly Model

The scenario above is revisited with the firms Follower and Leader acting as producer cooperatives. As above, cooperative Follower with n identical supplier-members acts as Stackelberg follower in the captive market. Cooperative Leader with $m > n$ identical supplier-members acts as Stackelberg leader in the captive market and has access to the competitive market. The cost functions are identical to those defined for the investor-owned firm and the cooperative behavior is modelled as in Albaek and Schultz (1998). The objective function of the cooperative is thus to maximize the welfare of its members and the production decision rests with the individual primary producer, i.e., with q_{-i} denoting the output of all producers-members of Follower but i and Q_1 the total output of cooperative Leader in the duopoly market,

$$v_i(q_i) = [p(q_{-i} + Q_1 + q_i)(q_{-i} + q_i) - C(q_{-i} + q_i)]\left(\frac{q_i}{q_{-i} + q_i}\right) - f(q_i)$$

As above, the distribution of operating profit is irrelevant. The first order condition is

$$\frac{dv_i}{dq_i} = \alpha - c - \beta Q_1 - \beta(q_{-i} + 2q_i) - wq_i - \frac{Kq_{-i}}{(q_{-i} + q_i)^2} = 0$$

which solving for the general equilibrium of the n producers with $q_{-i} = (n-1)q_i$ yields

$$\frac{dv_i}{dq_i} = \alpha - c - \beta Q_1 - (\beta(n+1) + w)q_i - \frac{K(n-1)}{n^2 q_i} = 0$$

Dropping the index i, denote the resulting reaction function $q^*(Q_1)$, which is given exactly below.

The output of cooperative Leader is determined through a two-level process, with the suppliers acting with production quantities Q_i upon a managerial choice of the proportion of the processed output to be delivered to the captive market, $s \in [0, 1]$. The individual supplier of Leader faces the objective function (4.1) below, denoting the other Leader members' total production by Q_{-i} and the total production by cooperative Follower as $q^*(Q)$,

$$\begin{aligned}V_i(Q_i, q, s) &= p((Q_{-i} + Q_i)s + nq(Q_{-i} + Q_i))sQ_i \\ &\quad + p_2(1-s)Q_i - \frac{C(Q_{-i} + Q_i)Q_i}{Q_{-i} + Q_i} - f(Q_i) \qquad (4.1)\end{aligned}$$

The corresponding necessary conditions give after the simplification $Q_{-i} = (m-1)\,Q_i$ and the reaction function for $q = q^*\,(msQ_i)$

$$\alpha s - \beta n q^*\,(msQ_i) + p_2\,(1-s) - c - \left(\beta s^2\,(m+1) + w\right) Q_i - \frac{K\,(m-1)}{m^2 Q_i} = 0 \tag{4.2}$$

a quadratic equation that with the maximum root $Q_i^*\,(s)$. The chain coordinator at Leader subsequently[4] selects the s^* that maximizes $V_i\,(Q_i, s)$, i.e.,

$$s^* = \arg\max V_i\,(Q_i^*\,(s)\,, q^*\,(msQ_i)\,, s)$$

Thus, under the Stackelberg duopoly the two cooperatives enjoy total operating profits $V^* = mV_i\,(Q_i^*\,(s^*)\,, nq^*\,(ms^*Q_i^*\,(s^*))\,, s^*)$ and $v^* = nv_i\,(q^*\,(ms^*Q_i^*\,(s^*)))$, respectively. There is no closed form expression for the cooperative production plan, which has to solved numerically.

4.1. **The Cooperative Monopoly Model.** After a successful and costless merger,

the resulting monopoly cooperative has N identical members-suppliers. The member's welfare function (4.1), solved for the case $V_i\,(Q_i, 0, s)$, is used to obtain the reaction function $Q_i^{**}\,(s)$ under monopoly. The monopolist cooperative may report a producer gain of $V^{**} = NV_i\,(Q_i^{**}\,(s^{**})\,, 0, s^{**})$, where s^{**} is obtained from $s^{**} = \arg\max V_i\,(Q_i^{**}\,(s)\,, s)$. The corresponding discounted value is $\Pi^{**}$from (**??**).

The outcome of model (4.1) is illustrated in Figure 1 below. Note that the lack of explicit managerial control in the cooperative case causes some discontinuity in the reaction functions. In a manner of speaking, the management of Leader plays a two level game: an internal towards its suppliers using the market proportion variable s, and an external versus the Follower chain, using the aggregate supply $Q_1\,(s)$.

5. The Price-War Model for Cooperatives

We will now revisit the dynamic price-war model previously presented for profit-maximizing investor-owned firms.

Here, the management of Leader has no possibility of directly approaching the suppliers of Follower, who cannot individually decide upon a merger[5]. Neither is the management of Follower interested in a merger, in absence of compensation schemes that would offset the loss of managerial utility. Additional reasons for an aversion towards merger may be envisaged from the self-selected democratic organizational structure. Perhaps Follower has a different business strategy than Leader, based on e.g. organic production. In such case, the (fewer) members of the alternative cooperative Follower may risk to be overrun by the majority of the new structure. Note that in absence of a diverging managerial cultures or beliefs, the individual suppliers would join a single cooperative to realize maximal gains.

[4]The result Q^*, s^* is in this case identical to a simultaneous optimization over Q and s. However, the presentation expressively allows for alternative control strategies.

[5]The case where individual members may exit Follower and join Leader is excluded, for instance due to exit grace periods, geographical separation and diseconomies of double investments.

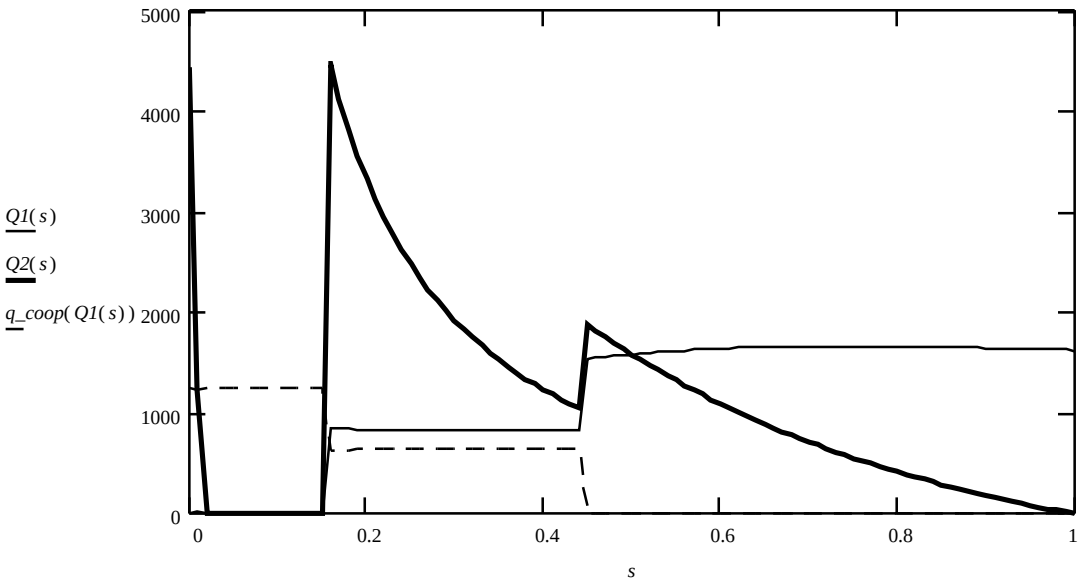

FIGURE 1. Cooperative Leader's member reaction functions, $Q_1(s)$ and $Q_2(s)$, and cooperative Follower's reaction function $q^*(Q_1(s))$ as a function of the duopoly proportion s.

The mere existence of several producer cooperatives on a market suggests such differences and actualizes the current model.

The maximal aggression by Leader has the intention to completely stall the production by Follower, who subsequently is forced to pay the fixed cost K until the conflict is resolved. However, due to the cooperative regime, this quantity is lower and thus less costly than for the investor-owned case. The explanation, which is formulated as a Proposition below, is that the individual supplier to the cooperative takes the sunk cost into account and seizes production earlier than in the IOF case. The condition is depicted in Figure 1.

Proposition 2. *A cooperative Stackelberg follower stalls production earlier than an investor-owned follower.*

Proof. Following (3.1), the investor-owned follower continues production until the price equals marginal cost, that is

$$Q_1^W = \frac{\alpha - c}{\beta}$$

The exact reaction function for the Follower cooperative under duopoly is given by the roots of

$$-\left(\beta\left(n+1\right)-w\right)q^2 + \left(\alpha - c - \beta Q_1\right)q - \frac{K\left(n-1\right)}{n^2} = 0$$

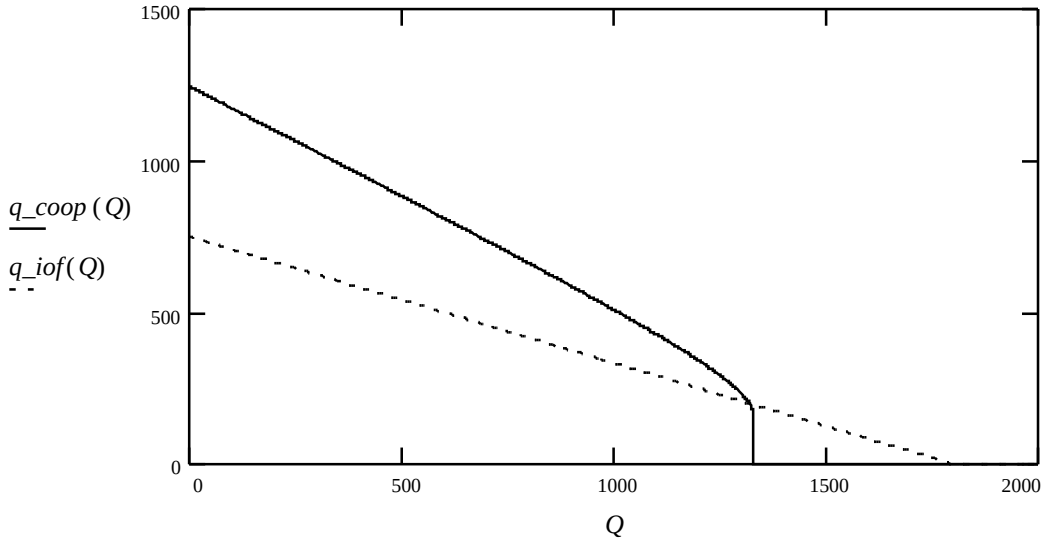

FIGURE 2. Follower's reaction functions $q_{coop}(Q)$ and $q_{iof}(Q)$, where Q is the Leader's total supply. Parameter settings as in Example 1.

that is,

$$q^*(Q_1) = \frac{\alpha - c - \beta Q_1}{2\beta(n+1) - 2w} \pm \sqrt{\frac{1}{4}\left(\frac{\alpha - c - \beta Q_1}{\beta(n+1) - w}\right)^2 - \frac{K(n-1)}{n^2(\beta(n+1) - w)}}$$

The reaction function lacks real valued roots when the expression under the root sign in $q^*(Q_1)$ is negative,

$$\begin{aligned} 0 &> n^2(\alpha - c - \beta Q_1)^2 - 4K(n-1) \\ Q_1 &> \frac{\alpha - c}{\beta} - \frac{2}{n\beta}\sqrt{K(n-1)(\beta(n+1) - w)} \\ Q_1 &< \frac{\alpha - c}{\beta} + \frac{2}{n\beta}\sqrt{K(n-1)(\beta(n+1) - w)} \end{aligned}$$

The cooperative follower stalls production at the discontinuous point Q_1^{WC}

$$Q_1^{WC} > \frac{\alpha - c}{\beta} - \frac{2}{n\beta}\sqrt{K(n-1)(\beta(n+1) - w)}$$

for which $Q_1^{WC} < Q_1^W$. □

Thus, the dynamic game between the two cooperative chains has somewhat different properties, more generous towards the aggressor. The missing second link of the optimal aggression (Q_1^{WC}, Q_2^{WC}) is found from the first order conditions for the Leader. First, the aggression policy is derived for the investor-owned firm.

Proposition 3. *The least cost aggressor policy by an investor-owned Leader is given by the quantities*

$$\begin{aligned} Q_1^{WC} &= \frac{\alpha - c}{\beta} - \frac{2}{n\beta}\sqrt{K(n-1)(\beta(n+1)-w)} + \varepsilon \\ Q_2^{WC} &= \frac{m}{w}(p_2 - c) - Q_1^{WC} \end{aligned}$$

where ε is a small positive scalar and the expression under the root sign is assumed non-negative.

Proof. For the aggression must hold $Q_1^{WC} > Q_1^*$ or else there is no opponent, thus Q_1^{WC} is imposed and Q_2 optimized. The policy follows directly from Proposition 2 and the first order condition (2.6). □

The cooperative leader faces a somewhat more complex problem, as he cannot *a priori* impose Q_1^{WC} (or any quantity) but has to find the control variable s to implicitly accomplish the result. We state the result as a proposition without repeating the proof.

Proposition 4. *The least cost aggressor policy by a cooperative Leader is given by the policy*

$$\begin{aligned} s^W &= \min_s \left\{ Q^*(s)\, s \geq \frac{\alpha - c}{\beta} - \frac{2}{n\beta}\sqrt{K(n-1)(\beta(n+1)-w)} + \varepsilon \right\} \\ Q_1^{WC} &= Q^*\left(s^W\right) s^W \\ Q_2^{WC} &= Q^*\left(s^W\right)\left(1 - s^W\right) \end{aligned}$$

where $Q^*(s)$ is from (8), ε is a small positive scalar and the expression under the root sign is assumed non-negative.

Let game (COOP) be analogous to game (IOF), but with cooperative players That is, in each period t, chain Leader decides upon an action $H^t = \{Fight, Truce, Monopoly\}$, reveals it to Follower who responds with an action $h^t = \{Follow, Surrender\}$.

Proposition 5. *Given a discount factor $\delta < 1$, $\alpha - p_2 \geq 0$ and $p_2 - c \geq 0$, game (coop) has two unique perfect equilibria*

a) $H^t = (Truce, Follow|-)\ \forall t$

b) $H^1 = (Fight, Surrender|Fight, Follow|Truce, Follow|Monopoly)$ and $H^t = (Monopoly, Surrender|-), t > 1$.

Proof. Analogous to the proof of the (IOF) game, using the payoff $V\left(Q_1^{WC}, Q_2^{WC}\right)$ during the period of conflict. □

The interesting finding is that the cooperative aggressor, earning less during duopoly and monopoly than its investor-owned counterpart due to the decentralized decision making, is less penalized during conflict. For the Example 1, presented in Table 1 below, the cooperative Leader is severely handicapped by the presence of the Follower cooperative. Due to a similar member behavior as in Figure 2, the Leader is prohibited to exploit fully the duopoly market. The profitability, measured as operating surplus per delivered quantity, is higher for the Follower than for the Leader. Thus, there is no unambiguous signal of managerial competence to be sent by the Leader to the members of the Follower. However, Proposition 5 in combination with 3 restates that the Leader has strong coercive powers at

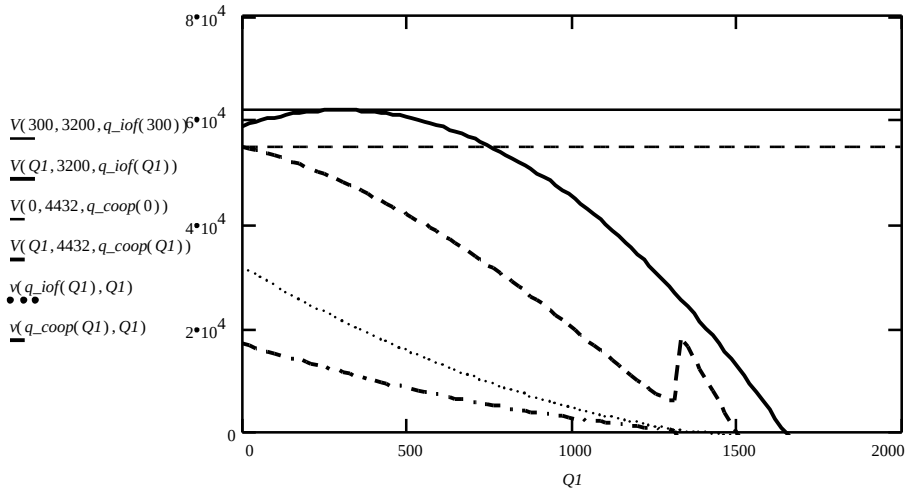

FIGURE 3. Operating profits $V(Q_1, Q_2, q^*(Q_1))$ and $v(q^*(Q_1), Q_1)$ under the IOF and COOP regimes, as a function of the Leader's duopoly quantity Q_1. Parameters as in Example 1.

his disposal. In the example in Table 1, the cooperative Follower needs to have more than three times higher equity to discourage aggression. Furthermore, as opposed to the situation in the price-war between the investor-owned firms, the Leader suffers no net loss during the conflict. This latter condition is of importance for the cooperative suppliers participation constraint.

The graphs of operating profit depicted in Figure 3 may shed some light on the mystery. Notice especially the discontinuity of the cooperative Leader's profit function for the point of seized production, Q_1^{WC} .The cooperative aggressor theorem summarizes the chapter, stating some of the model's support for the cooperative regime as a reason for a more aggressive behavior.

Theorem 1. *In a Stackelberg duopoly and a leader-exclusive competitive fringe, aggression between investor-owned firms is always less profitable (for some discount factor $\delta < 1$) than aggression between cooperative firms.*

We sketch an idea to a proof: The profitability of a threat of aggression is given by $\Gamma(\tau) = \Pi(\tau) - \Pi^*$. Denote the cooperative entities with a C and the investor-owned with I. It remains to be proved that $\Gamma_C(\tau) - \Gamma_I(\tau) > 0$,

$$\left[V\left(Q^*\left(s^W\right), s^W\right) - V\left(Q_1^W, Q_2^W\right)\right]\left(\frac{\delta - \delta^{\tau+1}}{1-\delta}\right) + \left[V_C^{**} - V_I^{**}\right]\left(\frac{\delta^{\tau+1}}{1-\delta}\right) - \left[V_C^* - V_I^*\right]\left(\frac{\delta}{1-\delta}\right) > 0$$

$$\left[V\left(Q^*\left(s^W\right), s^W\right) - V\left(Q_1^W, Q_2^W\right)\right](1-\delta^\tau) + \left[V_C^{**} - V_I^{**}\right]\delta^\tau - \left[V_C^* - V_I^*\right] > 0$$

Since the reaction function of the cooperative cannot improve profit, $V_C^* \leq V_I^*$. Proposition 2 yields that $Q_1^{WC} < Q_1^W$ which indicates that $V\left(Q^*\left(s^W\right), s^W\right) > V\left(Q_1^W, Q_2^W\right)$, since the cooperative Leader always will show a positive profit on each market. Finally the difference in monopoly profit. We know from Appendix 9.3 that $V_C^{**} \leq V_I^{**}$ since the cooperative over- or underproducing unless the condition $K = \frac{(\alpha - p_2)^2}{4\beta}$ holds. By adjusting the discount factor δ^τ accordingly, the value of these monopoly gains will be reduced and the conjecture will hold.

Example 1. *Compare two cooperative and investor-owned firms playing the Stackelberg game with parameter values:* $m = 100$, $n = 50, \alpha = 100, \beta = 0.05, c = 10, w = 1, p_2 = 45, K = 200, \delta = 0.95$. *The results are given in Table 1, where it is noted that the cost of aggression is considerably lower for the cooperative Leader than for the investor-owned and that the difference in monopoly gain is rather limited.*

Table 1. Model results for Example 1.

	Regime	
Variable	IOF	COOP
Q_1^*	300	0
Q_2^*	3200	4432.77
$q\left(Q_1^*\right)$	625	1245.44
V^*	61875	54899.68
v^*	21437.5	17022.34
Q_1^{**}	550	550.00
Q_2^{**}	4700	5049.26
V^{**}	105000	104593.38
Q_1^W	1800	1524.06
Q_2^W	1700	1916.26
$q\left(Q_1^W\right)$	0	0
$V\left(Q_1^W, Q_2^W\right)$	-3750	26917.23
$v\left(q\left(Q_1^W\right)\right)$	-2000	-2000.00
$\widehat{\tau}$	9.85	19.9

6. Incentive Structure and Information Disclosure

Albeit less harmful than IOF aggression, the results above do not suggest that cooperatives price wars would be part of the equilibrium path. Under complete information, the suppliers of the less viable cooperative chain would immediately enroll in the cooperative leader chain to share the fruits of coordination. Analogously, in the presence of actual differences in efficiency among the cooperatives, the members would instantaneously abandon the inefficient incumbent in favour of the entrant. Thus, at a quick theoretical glance, there seems to be limited interest in the pre-merger, merger and entry conditions under cooperative governance.

However, several institutional particularities of cooperative governance prompt for further analysis in this respect.

First, the complete information assumption is likely to be invalid under cooperative governance for several reasons. The mere fact that the supplier-members (of this stylized cooperative) have no residual claim rights nor delivery obligations may limit their involvement in its affairs. Adopting a myopic perspective, the individual supplier who receives a higher revenue from a fringe cooperative chain is not likely

to abandon the structure until the aggressor has signalled that it is committed to liquidate it. Since there is neglible equity at stake, the equilibrium strategy of the member is to switch only when the expected profitability drops below competing offers.

Second, the management compensation mechanism in a cooperative chain may contribute to the effect above. In the absence of residual claim rights and associated derivative instruments (options, futures, convertibles), the compensation schemes are historically limited to fixed reimbursements $U = K_0$ and volume-based commissions $U = K_0 + K_1 q$ for the coordinator. In combination with a potentially incomplete market for executives in cooperatives (few agents, particular qualifications), the risks attributed by the governance principle itself would have been compensated with a "golden parachute"-type contract in a comparable industry. Without adequate alternative exit compensation, the management of the cooperative fringe firm has disincentives in communicating merger gains. In practice, the sizable managerial compensations for comparable enterprises would likely be subject to member criticism when applied to a cooperative. The cooperative leader, who cannot credibly commit to sharing the expected profits with the seeding management team, is left to other means.

The dominant may try to communicate the future benefits directly to members, bypassing the management in their "golden cage" . However, albeit theoretically sufficient, the individual fringe members enjoying higher profit margins may find ex ante predictions of future gains to be less convincing than the past performance of their current organization.

Hence, there is an inherent managerial compensation problem in the cooperative governance that may actualize aggressive pre-merger behavior. As opposed to the IOF case, where both management and owners of the acquired firm have private rationality reasons to accept a smooth merger, the cooperative merger may potentially involve a costly pre-merger aggression. This operation, that is further facilitated by the results showing the feasibility of the dominant to wage a relatively long conflict, serves to lower the reservation wages for the management and to signal definite take-over to the membership. The fringe members, while noticing the price war, may deviate to the dominant under the belief that the aggression is only launched if the dominant has sufficient resources to win it.

7. Cooperative Merger, Aggression and Resolution in Scandinavia

Based in Denmark, MD Foods , the largest cooperative dairy chain in Europe in 2000, has 9 500 producers, over 13 500 employees, a turnover of 23 Gkr and an annual output of 4.9 Gkg raw milk. Since late 2000, when a merger with the largest dairy cooperative in Sweden, Arla , became effective, the dairy giant Arla Foods will have a raw milk volume of 7.0 Gkg and 17 900 employees in 23 countries. The history of this cooperative Goliath provides an excellent illustration to the mathematical model. Further analysis on the actual merger scenario is found in Agrell and Karantininis (1999)

During 1992-1999, MD Foods has fought at least two major price-wars on the Danish market, culminating with the turbulent acquisition of the only other Danish producer, Kloever maelk, in March 1999 when monopoly power finally was obtained. Up until the final battle, the four times larger MD Foods had unsuccessfully attempted to persuade the members of the smaller, but more profitable, dairy.

In fact, the KLOEVER MAELK membership increased in 1997/98. During the actual conflict in 1999, the aggressor stood stronger due to a settlement after a previous price-war in 1992, where the two cooperatives agreed upon a common production structure and a common export organization, dominated by MD FOODS. Three smaller dairies, ENIGHEDEN[6], LANDMANDSLYST[7], and RANDERS & VIBORG[8] were acquired and subsequently closed down during the period.

The subsequent merger between MD FOODS and ARLA in 2000 was conducted peacefully. One may speculate whether the fact that the cooperatives were fairly large, operating in separate (geographical) markets and had complementary interests contributed to the convergence. Another reason may also be the relative balance of power: MD FOODS has an equity/assets ratio of 24% in 1998[9], compared to 42% for its Swedish neighbor ARLA[10].

8. CONCLUSION

The results of the Stackelberg model suggests that cooperative supply chains are not more aggressive in general, being hampered from waging even short-term conflicts below cost. Rather, it turns out that niche cooperative chains are weaker than their investor-owned counterparts due to high decentralization towards its suppliers. Thus, the explanation to the observed tendency in cooperative dairy industry may be that oligopolistic cooperative markets are inherently instable. Unable to make smooth transfer of equity rights and suffering from managerial merger disincentives due to the organizational form, the cooperative firms are limited to force (close to) market exit to induce a mutually beneficial merger.

From a policy and mechanism design viewpoint, the results prompt for a careful review of the managerial compensation packages in large and small cooperative organizations. The lower commitment from the members in combination with a potentially curbed managerial compensation package is not without implications for the long-term development of the firm.

From a theoretical side, the paper shows that the strength of the investor-owned follower in the Stackelberg model with a fringe does not have a correspondence in the cooperative setting. It also extends the literature on cooperative economics with the discontinuous supply curve and equilibria for monopoly and duopoly with a competitive fringe.

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[6]Aquired in March 1995 under a settlement of continued operation until 1998, closed prematurely in Jan 1996.

[7]Aquired and closed in 1995 after having been launched as the only national competitior to the two market dominants.

[8]Five dairies with an annual raw milk volume of 135 Mkg, aquired in 1996 after a bidding contest and immediately closed .

[9]Annual report 1997/98

[10]Annual report 1997/98.

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9. Appendix

9.1. **Appendix.** The exact profit expressions for the IOF duopoly game are given as

$$v^* = (\alpha - c - \beta Q_1^*)\, q^* - \left(\frac{w}{2n} + \beta\right)(q^*)^2 - K$$

$$\begin{aligned} V^* &= \left(\alpha - c - \beta q^* - \frac{wQ_2^*}{m}\right) Q_1^* + \left(p_2 - c - \frac{wQ_1^*}{m}\right) Q_2^* \\ &\quad - \left(\frac{w}{2m} + \beta\right) Q_1^{*2} - \frac{w}{2m} Q_2^{*2} - K \end{aligned}$$

where Q_1^*, Q_2^* and q^* are given in equations (2.5), (2.6) and (2.7), respectively.

9.2. **Appendix.** The necessary optimality conditions for the Leader cooperative chain are given by

$$\begin{aligned} \frac{\partial V(Q,s)}{\partial Q_i} &= (\alpha - \beta(sQ_{-i} + sQ_i + q^*(sQ_{-i} + sQ_i)))\, s \\ &\quad -\beta\left(\frac{\partial q^*}{\partial Q_1} + 1\right) Q_i s + p_2(1-s) - c - \frac{KQ_{-i}}{(Q_{-i} + Q_i)^2} - wQ_i = 0 \\ \frac{\partial V(Q,s)}{\partial s} &= (\alpha - \beta(sQ_{-i} + sQ_i + q^*(sQ_{-i} + sQ_i)))\, Q_i \\ &\quad -\beta(Q_{-i} + Q_i)\left(\frac{\partial q^*}{\partial Q_1} + 1\right) Q_i s - p_2 Q_i = 0 \end{aligned}$$

Using the identity property of the primary producers, $Q_{-i} = (m-1)\,Q_i$, $Q = mQ_i$ and rearranging the terms obtains a quadratic expression,

$$[\alpha - \beta\,(msQ_i + q^*\,(msQ_i))]\,s - \beta sQ_i\left(\frac{\partial q^*}{\partial Q_1} + 1\right) + p_2\,(1-s) - c - \frac{K\,(m-1)}{m^2 Q_i} - wQ_i = 0$$

$$\left[\alpha - \beta msQ_i + \beta q^*\,(msQ_i) - \beta ms^2 Q_i\left(\frac{\partial q^*}{\partial Q_1} + 1\right) - p_2\right] Q_i = 0$$

$$(\alpha - \beta\,(msQ_i + q^*\,(msQ_i)))\,s + p_2\,(1-s) - c - \frac{K\,(m-1)}{m^2 Q_i} - wQ_i = \frac{(\alpha - \beta\,(msQ_i + q^*\,(msQ_i)))}{m} - \frac{p_2}{m} = 0$$

which may be somewhat simplified to

$$Q_i^2\,[\beta s\,(ms-1) - w] + Q_i\left[(\alpha s - \beta sq^*\,(msQ_i))\left(s - \frac{1}{m}\right) + p_2\left(\frac{m+1}{m} - s\right)\right] - \frac{K\,(m-1)}{m^2} = 0$$

and numerically solved, using the two derivatives as $Q^*\,(s) = mQ_i\,(s, q^*\,(msQ_i))$.

9.3. **Appendix.** Part of the proof of Theorem where the deviation for a cooperative producer under monopoly is studied.

Recall the necessary conditions from Appendix 9.2 for the cooperative Leader under monopoly market structure.

$$\alpha s - \beta s^2\,(N+1)\,Q_i + p_2\,(1-s) - c - \frac{K\,(N-1)}{N^2 Q_i} - wQ_i = 0 \tag{9.1}$$

$$[\alpha - 2\beta sNQ_i - p_2]\,Q_i = 0 \tag{9.2}$$

Assuming tentatively that $Q_i \neq 0$, (9.2) may be simplified to

$$s^{**} = \frac{(\alpha - p_2)}{2\beta NQ_i}$$

and substituted in (9.1) to obtain

$$\frac{1}{2\beta NQ_i}\left[\left(\frac{N-1}{2N}\right)\left((\alpha - p_2)^2 - 4\beta K\right) + 2\beta N\left((p_2 - c)\,Q_i - wQ_i^2\right)\right] = 0 \tag{9.3}$$

with the solution(s)

$$Q_i^{**} = \frac{p_2 - c}{2w} \pm \sqrt{\left(\frac{p_2 - c}{2w}\right)^2 + \left(\frac{N-1}{wN^2}\right)\left(\frac{(\alpha - p_2)^2}{4\beta} - K\right)}$$

However cumbersome this may seem, it follows from (9.2) that

$$Q_1^{**} = Q^{**}s^{**} = NQ_i s^{**} = \frac{(\alpha - p_2)}{2\beta}$$

which is identical to the investor-owned correspondence (2.9). For comparison, study the IOF monopoly problem with the decision variables (Q, s) such that $Q_1 = Qs$ and $Q_2 = Q(1-s)$, i.e., the objective function

$$V_I(Q,s) = (\alpha - \beta Qs)\, Qs - p(1-s)\, Q - cQ - Nw\left(\frac{Q}{N}\right)^2 - K$$

with necessary optimality conditions

$$\begin{aligned} \alpha s - 2\beta s^2 Q + p(1-s) - c - \frac{w}{N}Q &= 0 \\ \alpha Q - 2\beta s Q^2 - pQ &= 0 \end{aligned}$$

from which a correspondence to (9.3) is derived in an analogous manner,

$$\begin{aligned} \frac{1}{2\beta Q}\left[2\beta Q(p_2 - c) - 2\beta\frac{w}{N}Q^2\right] &= 0 \\ \frac{Q}{N} - \frac{p_2 - c}{w} &= 0 \end{aligned}$$

Thus, by letting $N = 1$ we may verify the correctness and the sign of the difference in monopoly profit by substituting $Q_i = \frac{p_2 - c}{w}$, which yields the optimal solution, into (9.3):

$$\begin{aligned} &(\alpha - p_2)^2\left(\frac{N-1}{2N}\right) - \frac{2\beta K(N-1)}{N} \\ &\qquad + (p_2 - c)\, 2\beta N\left(\frac{p_2 - c}{w}\right) - 2\beta w N\left(\frac{p_2 - c}{w}\right)^2 \lesseqgtr 0 \end{aligned}$$

$$\begin{aligned} \left(\frac{N-1}{2N}\right)\left((\alpha - p_2)^2 - 4\beta K\right) + 2\beta N\frac{(p_2 - c)^2}{w} - 2\beta N\frac{(p_2 - c)^2}{w} &\lesseqgtr 0 \\ \left(\frac{N-1}{2N}\right)\left((\alpha - p_2)^2 - 4\beta K\right) &\lesseqgtr 0 \\ \left((\alpha - p_2)^2 - 4\beta K\right) &\lesseqgtr 0 \end{aligned}$$

Thus, we have three cases:

(i) $K > \frac{(\alpha - p_2)^2}{4\beta}$ then the cooperative is underproducing, leading to a suboptimal profit,

(ii) $K < \frac{(\alpha - p_2)^2}{4\beta}$ then the cooperative is overproducing with suboptimal results,

(iii) $K = \frac{(\alpha - p_2)^2}{4\beta}$ then there is no profit difference due to coordination regime.

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