PROCESS INNOVATION ACTIVITY IN A MIXED OLIGOPOLY: THE ROLE OF COOPERATIVES

KONSTANTINOS GIANNAKAS AND MURRAY FULTON

This article develops a sequential game-theoretic model of heterogeneous producers to examine the market and welfare effects of cooperative involvement in process innovation activity in the agricultural sector. The analysis examines an open-membership, input-supplying cooperative (co-op) that maximizes member welfare and finances its innovation activity through retained earnings. Analytical results show that the presence of the co-op can increase the arrival rate of innovations while reducing the price of agricultural inputs. Cooperative involvement in innovation activity *can* thus be welfare enhancing and socially desirable with its effectiveness being determined by the degree of producer heterogeneity and the size of innovation costs.

Key words: cooperatives, innovation, mixed oligopoly, open membership, retained earnings.

Innovation activity is a critical element of business conduct affecting the competitiveness of firms, the arrival rate of innovations in the economy, productivity growth, and social welfare. The strategic interactions among innovating firms and their effect on innovation have received considerable attention. In particular, the main focus of the economic literature on innovation has been on R&D competition in a pure oligopoly—i.e., a market in which a small number of profit-maximizing, investor-owned firms (IOFs) operate.[1]

In agriculture, pure oligopolies are typically not observed, particularly at levels close to the primary production sector; instead, cooperatives (co-ops) are often involved in these sectors (Rogers and Sexton; Rogers and Marion; Gruber, Rogers, and Sexton). As figure 1 illustrates, cooperative organizations currently account for between 25% and 30% of total farm marketing and supply expenditures. Despite their prevalence, the effect of co-ops on innovation activity has not been considered. While previous research has focused on the strategic interaction between co-ops and IOFs in oligopolistic industries and the role that co-ops play in promoting competition, this research has not considered the impact that co-ops have on innovation activity in these mixed markets and the resulting impact of this activity on the firms' cost structure and pricing decisions.[2]

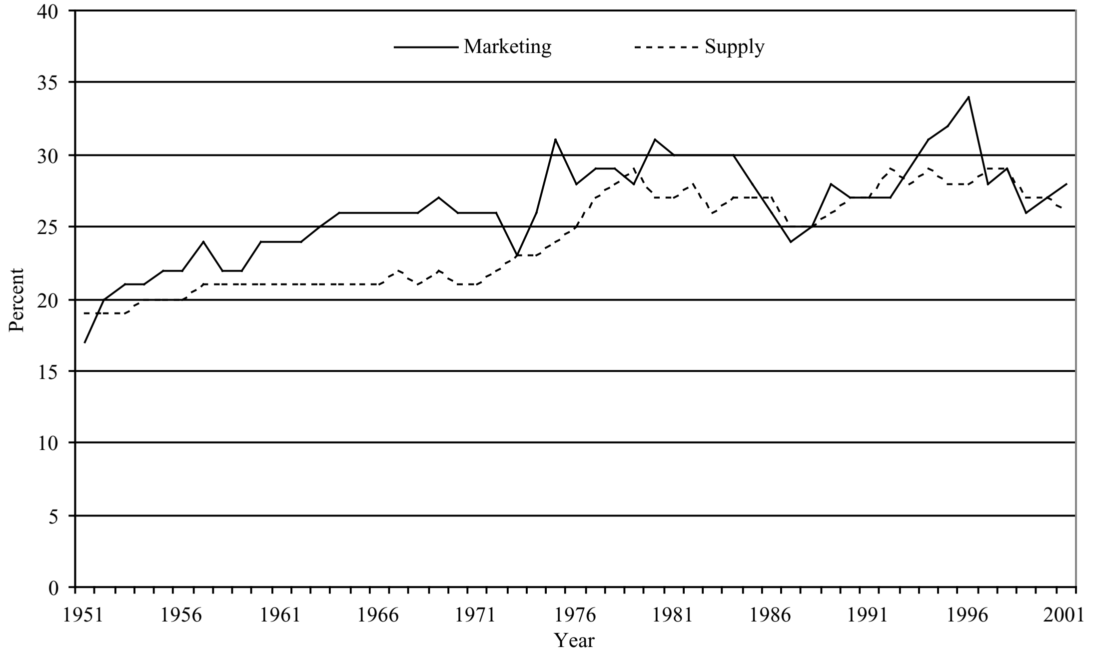
The objective of this article is to examine the impact of co-operative involvement in process innovation on the amount of innovation in an industry, the pricing behavior of the competitors before and after the innovation is undertaken, and the social welfare resulting from this competition. Specifically, the article examines a mixed duopoly where an open membership, welfare-maximizing co-op, and an IOF compete in supplying an input to agricultural producers. The open membership co-op is chosen for analysis because of its prevalence among co-ops and particularly among input supply

Konstantinos Giannakas is associate professor, Department of Agricultural Economics, University of Nebraska, Lincoln; Murray Fulton is professor, Department of Agricultural Economics, University of Saskatchewan.

The authors thank two anonymous reviewers for their helpful comments. Journal Series No. 14477, Agricultural Research Division, University of Nebraska, Lincoln.

[1] The focus of this literature has been on the impact of R&D competition on market structure and the arrival rate of innovations (see Fudenberg et al.; Grossman and Shapiro; Sutton; Delbono; Aoki; and Malueg and Tsutsui). For Schumpeterian models of innovation competition see Aghion and Howitt (1992, 1998); and Segerstrom, Avant, and Dinopoulos.

[2] A number of papers have examined the impact of agricultural cooperative involvement on prices and output in an oligopolistic market. Tennbakk considers the effect of a fixed membership marketing co-op on the equilibrium conditions of a Cournot oligopoly. Fulton and Giannakas examine an open membership consumer co-op that is involved in price competition in a model where consumers differ in their commitment to the co-op and an IOF. Sexton models a processing co-op that competes with an IOF, where the co-op and the IOF are spatially separated. He considers both an open and a closed membership co-op and analyzes the equilibrium conditions under different conjectural variations of the competing firms. Output competition between a co-op and an IOF is also considered by Karantininis and Zago, while Cotterill implicitly considers price competition between the two firms. Sexton and Sexton consider the barriers to entry faced by a co-op and an IOF. None of these papers considers the innovation activity in the mixed oligopoly, however.



Source: USDA (1998, 2003).

Figure 1. U.S. farmer co-ops' share of total farm marketing and supply expenditures, 1951–2001

co-ops (Cook).[3] To determine the impact of cooperative involvement in innovation activity, the case of a pure oligopoly is also analyzed and used as a benchmark for the analysis.

The analysis in this article explicitly accounts for the distinctive manner in which many agricultural co-ops finance their innovation activities. As reported by USDA (2003), U.S. farmer co-ops in 2001 financed approximately 42% of their assets with member equity; the figure for supply co-ops was roughly equal to the average for all co-ops. A primary source of member equity is earnings retained from previous periods—in U.S. agricultural co-ops, over 50% of member equity is in the form of member equity certificates and credits (Chesnick). As will be outlined in the Cooperative Investment Activity section, this reliance on retained earnings is a result of the distinct property right structure of open membership co-ops and can limit the investment capital available to the co-op. Hence, explicit consideration of this issue is critical when examining the co-op's investment decision.

An important result of this article is that, despite their reliance on retained earnings, the focus on member welfare maximization enables co-ops to compete effectively with their IOF counterparts. The results of this article thus shed important light on open membership co-ops' ability to survive in the agricultural sector despite the constraints imposed by their property right structure.

By focusing on open membership co-ops that are constrained to raising capital through retained earnings, the research reported in this article fills an important gap in the literature on innovation activity in mixed duopolies, which to date has focused on either public or labor-managed firms (LMFs).[4] Public firms are typically assumed to maximize total economic welfare, while a co-op considers only the welfare of its members. In addition, public firms have access to public funds to finance their investments in innovation. Models of LMFs typically assume closed membership. As well, closed membership co-ops may be less reliant on retained earnings to finance investment; a good example are the New Generation co-ops

[3] USDA (2003) data indicate that approximately 38% of farmer co-ops in 2001 were farm supply co-ops; these co-ops accounted for 57.5% of the co-op members. Most supply co-ops are open membership.

[4] Poyago-Theotoky, and Delbono and Denicolò provide an overview of the literature on innovation by public firms. See Neary and Ulph, and Okuguchi for an overview of the literature on LMFs.

that often raise their equity capital through the sale of up-front tradable investment shares (Harris, Stefanson, and Fulton). These differences suggest that open membership input supply co-ops are likely to behave quite differently than do public firms, LMFs, or closed membership co-ops and hence require separate analysis as is done in this article.[5]

The rest of the article is organized as follows. The next section discusses how the unique property right features of open membership co-ops create challenges for raising investment capital and how co-ops have used retained earnings as a partial response to these challenges. The section following describes the methodological framework of this study, followed by the development of a simple model of horizontal differentiation where agricultural producers differ in the returns they receive from the use of inputs supplied by different agri-business firms. The article then analyzes price and innovation competition between two profit-maximizing IOFs, followed by an examination of these strategic interactions in the mixed oligopoly. The effect of cooperative involvement on innovation activity, the pricing of agricultural inputs and the welfare of the groups involved (agricultural producers and input suppliers) is analyzed before the concluding section of the article.

Cooperative Investment Activity

A co-op is an organization in which the owners are also the users of the products/services supplied by the organization (USDA 1995; Hansmann). This dual role of the member creates both advantages and disadvantages for the co-op. With members as both owners and users, the co-op is typically assumed to have a different objective function than its IOF counterparts. By focusing on member welfare rather than profits, the co-op is able to generate more competitive pricing (see references in footnote 1), which is generally beneficial to both members and nonmembers of the co-op.

The cooperative structure also has some drawbacks. These drawbacks revolve around the so-called property rights problems that have been identified in co-ops. These property rights problems typically emerge because of the nondiscriminatory nature of most traditional open membership co-ops (Vitaliano; Cook). Since all members have access to the benefits of the co-op regardless of their investment in the organization, free-rider problems emerge. As well, the lack of tradability in ownership shares that is typically found in open membership co-ops has been linked to portfolio (Knoeber and Baumer) and horizon problems (Porter and Scully; Rey and Tirole).

As Knoeber and Baumer point out, co-ops have addressed some of these property rights issues by relying on cash flow or retained patronage to finance growth. Chaddad and Cook, in a test of financial constraints in U.S. agricultural co-ops, find that co-ops depend on internal funds for capital expenditures with this dependence being largest for large co-ops. This reliance on retained earnings can restrict the amount of investment capital available to the co-op.

Despite these property rights problems and the constraints that they impose, there is no compelling evidence that they have crippled co-ops in their operations. An examination of co-ops' aggregate market share (see figure 1) indicates that U.S. co-ops have been able, at least historically, to compete effectively with IOFs. Co-ops were able to maintain a significant role in the U.S. marketing and farm supply areas for the last half of the 20th century—indeed, over the 1951–71 period, co-ops' market share rose significantly. Although their share of total farm marketing and supply expenditures has dropped off in the late-1990s, co-ops have nevertheless exhibited an ability to compete with their IOF counterparts. These observations are consistent with the findings of Sexton and Iskow, who, in a review of sector analyses of cooperative performance, find no evidence that co-ops operate less (or more) efficiently than IOFs.

The model developed in this article explicitly accounts for both advantages and disadvantages of cooperative ownership structure. Specifically, in examining the co-op's investment decision, the article assumes that co-ops seek to maximize member welfare; the article also assumes that the co-op must raise its investment capital through retained earnings, thus capturing this important institutional feature. The need to rely on retained earnings, when combined with the fact that the co-op must compete with the IOF, means that the co-op faces a trade-off. While it is able to raise additional capital by raising its price, doing so diminishes the competitiveness of the co-op and reduces the number of producers who

[5] For instance, as Sexton shows, the difference in objectives between closed and open membership agricultural co-ops gives rise to different behavior; this difference is significant enough that separate modeling of these two organizational forms is required.

find it optimal to patronize the co-op and finance its investment activities. Although the co-op is constrained in its ability to raise investment capital, the results of the model show that the co-op can nevertheless remain competitive with the IOF. This ability to remain competitive stems from the different objective function ascribed to the co-op.

To set the context for the theoretical model developed in the next section, it is useful to consider an open membership co-op that has been successful in using process innovation to remain competitive. Federated Cooperatives Limited (FCL) and the member retailers that comprise the Cooperative Retailing System (CRS) in western Canada have been very successful over the last twenty years. FCL is a cooperative wholesaler owned by its member retail co-ops who supply basic farm inputs (e.g., fuel) and groceries to their members. In 2003, FCL recorded its twelfth year of record profits; in 2002, the return on members' invested capital was 30.1% (Fairbairn).

Fairbairn argues that the success of CRS can be linked to FCL's investments in its oil refinery (the most recent investment was completed in 2003 at a cost of \$Cdn 400 million); innovations and investments made in warehousing and inventory control, along with a focus on marketing, have also been important. These investments, which have been financed almost entirely from retained earnings, have allowed FCL to maintain its cost competitiveness *vis-à-vis* its competitors (the major oil companies, e.g., Esso, on the fuel side and the major retailers, e.g., Safeway, on the grocery side), which in turn has generated profits that could be used to finance further investments. The profits that have not been retained for further investment have been passed, via patronage returns, to the local retail co-ops and through them to their members.

Methodological Framework

The strategic interaction between the input suppliers in the pure and mixed oligopoly cases considered in this article is modeled as a three-stage sequential game. In stage 1, the two agribusiness firms compete in prices and a new process innovation is announced. In stage 2, the firms determine the optimal level of their investment in the new cost-reducing innovation. In stage 3, the (post-innovation) production costs are fixed and the two rivals engage in price competition. In what follows, the three stages of the game will often be referred to as the "pre-innovation stage" (stage 1), the "innovation stage" (stage 2), and the "post-innovation stage" (stage 3).

To avoid Nash equilibria involving noncredible strategies, the different formulations of the game are solved using backward induction (Gibbons)—the pricing behavior of the two input suppliers in the post-innovation stage is analyzed first, the optimal investment in the cost-reducing innovation is determined next and the solution to the pre-innovation pricing problem determines the subgame perfect equilibrium amount of innovation, the pricing of the agricultural inputs, and the farmers' purchasing decisions and welfare in the pre- and post-innovation stages.

In the mixed oligopoly, the strategic interaction between the firms at the pre-innovation stage explicitly considers the need of the co-op to finance its innovation through retained earnings generated at this stage. Specifically, at the pre-innovation stage the co-op seeks to maximize the welfare of its members subject to raising the capital required for its subsequent investment in the new cost-reducing innovation. Consideration of the pre-innovation stage allows for an identification of the group of producers that find it optimal to patronize the co-op and hence to fund its subsequent innovation activity.

Producer Decisions and Welfare

Prior to analyzing the innovation and pricing decisions in the pure and mixed oligopolies, it is useful to consider the manner in which agricultural producers make their purchasing decisions at the pre- and post-innovation stages of the game and to derive the producer demands for the inputs supplied by the two firms. In analyzing producer behavior, a distinct feature of this article is that it relaxes the conventional assumption of producer homogeneity. Instead, farmers are postulated to differ in such things as farm location, quality of land, education, experience, management skills, and the technology adopted. Farmer heterogeneity in terms of production factors is a key component in our model and captures the differences in the relative returns received by farmers from the use of inputs supplied by the different firms in both the pre- and post-innovation stages of the game.

Specifically, consider a producer whose net return depends on the agricultural input that is purchased from an agribusiness firm. It is assumed that two suppliers—Supplier I and Supplier C—supply the input. The net returns earned by the farmer depend on the input employed in the production process. The returns differ because farmers differ in terms of attributes mentioned above and because the prices charged by the two firms may be different.[6] To capture these elements, let $a \in [0, 1]$ denote the attribute that differentiates producers. A producer with attribute a has the following net returns function at the pre- and post-innovation stages of the game:

$$(1) \qquad \Pi^F_{I(k)} = p^F_{(k)} - (p_{I(k)} + \mu a) \quad \text{If a unit of Supplier I's input is purchased}$$

$$\Pi^F_{C(k)} = p^F_{(k)} - \lfloor p_{C(k)} + \mu(1-a) \rfloor \quad \text{If a unit of Supplier C's input is purchased}$$

where k denotes the stage of the game; $\Pi^F_{I(k)}$ and $\Pi^F_{C(k)}$ are the farmer's net returns associated with unit output production using the input supplied by Supplier I and Supplier C, respectively; $p_{I(k)}$ and $p_{C(k)}$ are the price of the input supplied by Supplier I and Supplier C, respectively; and $p^F_{(k)}$ is the farm price (net of all production costs except for the input) of the output produced by the farmer. The nonnegative parameter μ reflects the degree of producer heterogeneity. *Ceteris paribus*, farmers with large values of the differentiating attribute a prefer the input provided by Supplier C, while producers with low values of a prefer the input provided by Supplier I. The greater is μ, the greater are the differences in producer benefits from the two inputs.

To ensure positive market shares for the two agri-business firms, it is assumed that μ is greater than the difference in input prices (see equations (3) and (4) below), while, to retain tractability of the model, the analysis assumes that producers are uniformly distributed between the polar values of a.[7] Each farmer produces one unit of the farm output using one unit of the farm input; the choice of input supplier at the pre- and post-innovation stages of the game is determined by the relationship between $\Pi^F_{I(k)}$ and $\Pi^F_{C(k)}$.

Figure 2 illustrates the decisions and welfare of producers. The downward sloping curve graphs the net returns when Supplier I's input is purchased, while the upward sloping line shows the net returns when Supplier C's input is purchased for different values of the differentiating attribute a (i.e., for different farmers). The intersection of the two net return curves determines the level of the differentiating attribute that corresponds to the indifferent producer. The producer with differentiating characteristic $a_{I(k)}$ given by:

$$(2) \quad a_{I(k)} : \Pi^F_{I(k)} = \Pi^F_{C(k)} \Leftrightarrow p^F_{(k)} - \left(p_{I(k)} + \mu a_{I(k)}\right) = p^F_{(k)} - \lfloor p_{C(k)} + \mu\left(1 - a_{I(k)}\right)\rfloor \Rightarrow a_{I(k)} = \frac{p_{C(k)} + \mu - p_{I(k)}}{2\mu}$$

is indifferent between buying from Supplier I and buying from Supplier C—the net returns from using these two inputs are the same. Producers "located" to the left of $a_{I(k)}$ (i.e., producers with $a \in [0, a_{I(k)})$) purchase from Supplier I while those located to the right of $a_{I(k)}$ (i.e., producers with $a \in (a_{I(k)}, 1]$) buy from Supplier C. Aggregate producer welfare at the kth stage of the game is given by the area underneath the effective net returns curve shown as the (bold dashed) kinked curve in figure 2.

Since producers are uniformly distributed with respect to their differentiating attribute a, the value of a corresponding to the indifferent producer, $a_{I(k)}$, also determines the share of farm output produced with the input provided by Supplier I. The share of farm output produced with the input provided by Supplier C is given by $1 - a_{I(k)}$. Assuming fixed proportions between the input and farm output, $a_{I(k)}$ and $1 - a_{I(k)}$ give the market shares of the

[6] The framework for examining farmer heterogeneity developed in this article is that of horizontal product differentiation (Shy), and is similar to that found in both Sexton, and Fulton and Giannakas. Sexton examines the situation where farmers differ in their geographical location, while Fulton and Giannakas develop a model where consumers differ in their commitment to the co-op and IOF. Both of these explanations, which focus on relatively homogeneous products that are treated differently by different producers, apply to most supply co-ops. For instance both explanations can be used to examine the willingness of farmers and rural residents to patronize a local co-op or its competitor in the CRS case outlined at the end of the section on cooperative investment activity. Note that the model could also be used to examine situations where the firms supply different varieties of farm inputs (e.g., seeds, chemicals) and where the benefits to farmers of these varieties differ because of differences in land quality, education, or technology adopted.

[7] This is a standard assumption in the literature of horizontal and vertical product differentiation (see Shy).

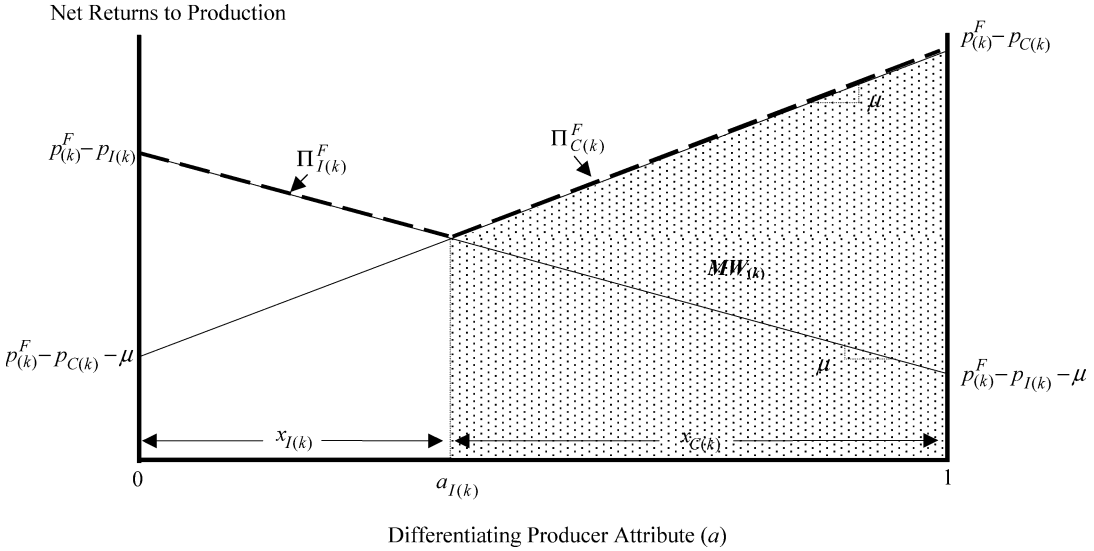


Figure 2. Producer decisions and welfare at the pre- and post-innovation stages

two input suppliers. By normalizing the mass of producers at unity, the market shares give the producer demands faced by Supplier I, $x_{I(k)}$, and Supplier C, $x_{C(k)}$, at the kth stage of the game, respectively. In what follows, the terms "market share" and "demand" will be used interchangeably to denote $x_{I(k)}$ and $x_{C(k)}$. Formally, $x_{I(k)}$ and $x_{C(k)}$ can be written as:

$$(3) \qquad x_{I(k)} = \frac{p_{C(k)} + \mu - p_{I(k)}}{2\mu}$$

$$(4) \qquad x_{C(k)} = \frac{p_{I(k)} + \mu - p_{C(k)}}{2\mu}.$$

Benchmark Case: Innovation and Pricing Decisions in a Pure Oligopoly

Price Competition at the Post-Innovation Stage (3rd Stage of the Game)

Consider now the optimizing decisions of two profit-maximizing IOFs in the post-innovation stage that are involved in a strategic price competition, i.e., they choose their prices simultaneously, with Nash conjectures. The problem of each supplier is to determine the price of the input that maximizes its profits at this stage given the price of the other supplier and the producer demand for its product. Specifically, Supplier i's problem (where $i \in \{I, C\}$) at the 3rd stage of the game can be written as:

$$(5) \qquad \max_{p_{i(3)}} \Pi_{i(3)} = \left(p_{i(3)} - c_{i(3)}\right) x_{i(3)}$$

where $c_{i(3)}$ represents Supplier i's post-innovation marginal cost of producing its product. Recall that $c_{I(3)}$ and $c_{C(3)}$ are determined by the innovation decisions of the two input suppliers at the 2nd stage of the game and are thus fixed when the two IOFs choose their prices at the post-innovation stage.

Solving the input suppliers' problems shows the standard result that profits are maximized at the price-quantity combination determined by the equality of the marginal revenue and the marginal cost of production. Specifically, for any $p_{j(3)}$, Supplier i's best-response function (i.e., the profit-maximizing price of Supplier i) is given by

$$p_{i(3)} = \frac{p_{j(3)} + \mu + c_{i(3)}}{2}$$

where $j \in \{I, C\}$) and $j \neq i$. Solving the best response functions of the two suppliers simultaneously and substituting $p_{I(3)}$ and $p_{C(3)}$ into equations (3) and (4) gives the Nash equilibrium prices and quantities for the two competitors as a function of the post-innovation costs of production and the degree of producer heterogeneity μ, i.e.,

$$(6) \qquad p^*_{i(3)} = \frac{3\mu + 2c_{i(3)} + c_{j(3)}}{3}$$

$$(7) \qquad x^*_{i(3)} = \frac{3\mu - c_{i(3)} + c_{j(3)}}{6\mu}.$$

The equilibrium profits of Supplier i from selling its input at the post-innovation stage are then:

$$(8)\qquad \Pi^*_{i(3)} = \frac{\left(3\mu - c_{i(3)} + c_{j(3)}\right)^2}{18\mu}$$

The equilibrium conditions from the post-innovation pricing competition reveal the significance of the relative costs of production for the market share and profitability of the two rivals. In particular, the analysis shows that the firm with the lower post-innovation costs of production enjoys higher market share and profits relative to its rival.

Innovation Competition (2nd Stage of the Game)

At this stage, Supplier I and Supplier C seek to determine the optimal amount of innovation, t_I and t_C, respectively. Expenditures on process innovation at this stage of the game enable the two firms to reduce their marginal cost of production, which has the potential to affect their competitiveness (and profits) when they determine their prices in the post-innovation stage of the game. The relationship between the amount of innovation and the post-innovation marginal costs of producing the input is given by:

$$(9)\qquad c_{i(3)} = c_{i(1)} - \beta t_i$$

where $c_{i(1)}$ is Supplier i's (strictly positive) marginal cost of producing the input at the pre-innovation stage (i.e., prior to process innovation), and $t_i \geq 0$. The parameter β represents the effectiveness of innovation effort, i.e., the rate at which innovation effort is translated into process innovations for the two rivals.[8] For simplicity of exposition, we assume that the two firms have the same pre-innovation cost of production (i.e., $c_{C(1)} = c_{I(1)} = c_{(1)}$) and β is normalized to equal 1. In addition to enhancing tractability, the imposition of symmetry on the pre-innovation costs of production enables the analysis to isolate the impact that the different objective function of the co-op in the mixed duopoly case has on the innovation activity and pricing of the agricultural input. To close the model, we assume that innovation effort is costly for the two suppliers with the innovation costs being an increasing function of the amount of innovation (Shy), i.e.,

$$(10)\qquad I_i(t_i) = \frac{1}{2}\psi t_i^2$$

where ψ is a strictly positive scalar reflecting the size of innovation costs.

The problem of Supplier i at this stage of the game is the determination of innovation effort that maximizes its post-innovation profits from supplying the input, $\Pi^*_{i(3)}$, minus the innovation costs, I_i, i.e.,

$$(11)\qquad \max_{t_i} \Pi_{i(2,3)} = \Pi^*_{i(3)} - I_i = \frac{(3\mu + t_i - t_j)^2}{18\mu} - \frac{1}{2}\psi t_i^2$$

where $\Pi_{i(2,3)}$ denotes the net profits of Supplier i in stages 2 and 3. Solving the optimality conditions for the two suppliers, we derive their best response functions as:

$$(12)\qquad t_i = \frac{3\mu - t_j}{9\mu\psi - 1}.$$

Given that in the real world we do not observe firms having zero (or negative) marginal production costs, we restrict the model parameters so that post-innovation production costs are strictly positive. Specifically, in what follows we assume that ψ and μ are such that $0 \leq t_i < c_{(1)}$ and $c_{i(3)} > 0$.

Solving simultaneously the best response functions of the two input suppliers we derive the Nash equilibrium levels of innovation in the pure oligopoly as:

$$(13)\qquad t_i^* = \frac{1}{3\psi}.$$

Substituting t_i^* into the expressions for innovation costs, I_i, and post-innovation profits, $\Pi^*_{i(3)}$, gives:

$$(14)\qquad \Pi^*_{i(2,3)} = \frac{9\mu\psi - 1}{18\psi}.$$

Price Competition at the Pre-Innovation Stage (1st Stage of the Game)

This section of the article considers the situation prior to the firms engaging in process

[8] While the assumption of deterministic process innovations is adopted in this article, the model can be easily modified to examine the case of stochastic innovations (when innovation effort affects the *probability* that certain production cost reductions will be realized). While consideration of stochastic innovations changes the results quantitatively, the qualitative nature of our results regarding the effect of cooperative involvement in innovation activity remains unaffected.

innovation activity. At the pre-innovation stage, the two input suppliers compete in the market and seek to determine the prices that maximize their profits. Since the payoffs of the two input suppliers in stages 2 and 3 are not a function of the prices charged at the 1st stage of the game (see equation (14)), the two firms at the pre-innovation stage seek to maximize their pre-innovation profits only.

In fact, the problem facing an input supplier in the pre-innovation stage is identical to that expressed in equation (5), with the subscript (3) changed to (1). Consequently, the equilibrium prices, quantities/market shares, and profits at the 1st stage are derived by substituting the pre-innovation costs $c_{(1)}$ for $c_{i(3)}$ in equations (6)–(8) and equal:

$$(15) \quad p^*_{i(1)} = c_{(1)} + \mu$$

$$(16) \quad x^*_{i(1)} = \frac{1}{2}$$

$$(17) \quad \Pi_{i(1)} = \frac{\mu}{2}.$$

Table 1 summarizes the (symmetric) subgame perfect equilibrium in the pure oligopoly. In a pure oligopoly with symmetric pre-innovation costs: (i) the two firms split the market equally and enjoy a price-cost margin of μ at the pre-innovation stage; (ii) each undertakes innovation effort of $1/3\psi$ at the innovation stage of the game; and (iii) similar to the pre-innovation stage, the two firms will charge a price μ above their post-innovation costs of production, and split the market equally at the post-innovation stage of the game. Results (i) and (iii) are well known in the spatial competition literature (see Greenhut, Norman, and Hung).

Innovation and Pricing Decisions in a Mixed Oligopoly

In this scenario, Supplier C is a co-op that competes with a profit-maximizing IOF (Supplier I).

Price Competition at the Post-Innovation Stage in the Mixed Oligopoly

Similar to the pure oligopoly case, the problem of Supplier I in the 3rd stage of the game is to determine the input price that maximizes its profits given the price of the other supplier and the producer demand for its product. Supplier I's problem is thus the same as the one specified in equation (5) and its best-response function is given by

$$p_{I(3)} = \frac{p_{C(3)} + \mu + c_{I(3)}}{2}.$$

Unlike Supplier C in the pure oligopoly case, however, the objective of the co-op in a mixed duopoly is to maximize the welfare of its members. Specifically, the problem of the co-op is to determine the price $p_{C(3)}$ that maximizes the welfare of producers that patronize the co-op at the post-innovation stage of the game (shown by the shadowed area *MW* in figure 2) subject to a non-negative profit constraint, i.e.

$$(18) \quad \begin{aligned} \max_{p_{C(3)}} MW_{(3)} &= \left(p^F_{(3)} - p_{C(3)}\right)x_{C(3)} \\ &\quad - \frac{1}{2}\mu x^2_{C(3)} \\ \text{s.t. } \Pi_{C(3)} &\geq 0 \\ &\Rightarrow p_{C(3)} \geq c_{C(3)} \end{aligned}$$

where all variables are as previously defined. Note that equation (18) captures the open-membership nature of a co-op that takes into

Table 1. Subgame Perfect Equilibrium in the Pure Oligopoly

Pre-innovation stage (1st stage)	$p_{i(1)}$	$c_{(1)} + \mu$
	$x_{i(1)}$	$\frac{1}{2}$
Innovation stage (2nd stage)	t_i	$\frac{1}{3\psi}$
	t_T	$\frac{2}{3\psi}$
Post-innovation stage (3rd stage)	$p_{i(3)}$	$c_{(1)} + \mu - \frac{1}{3\psi}$
	$x_{i(3)}$	$\frac{1}{2}$

account the welfare of all producers that buy its product when determining its optimal strategy at this stage of the game.[9]

Solving the co-op's problem specified above shows that the optimality (Kuhn-Tucker) conditions for a maximum are satisfied when the co-op prices its product at marginal cost, i.e., $MW_{(3)}$ is maximized when $p_{C(3)} = c_{C(3)}$. The lower the post-innovation cost of production, the lower the price charged by the co-op, and the greater the welfare of producers that patronize the co-op at the post-innovation stage. Thus, reduced prices at the post-innovation stage are the source of the producer benefits that occur from the cooperative investment in cost-reducing innovation in the 2nd stage of the game.

Solving the best response functions of the IOF and the co-op simultaneously we derive the Nash equilibrium prices for the inputs at the post-innovation stage of the game, $p'_{I(3)}$ and $p'_{C(3)}$. Substituting $p'_{I(3)}$ and $p'_{C(3)}$ into equations (3) and (4) gives the Nash equilibrium quantities for the two competitors as a function of $c_{I(3)}$, $c_{C(3)}$, and μ. Mathematically, the Nash equilibrium prices and quantities at the post-innovation stage of the game are:[10]

$$(19) \qquad p'_{I(3)} = \frac{\mu + c_{C(3)} + c_{I(3)}}{2}$$

$$(20) \qquad x'_{I(3)} = \frac{\mu + c_{C(3)} - c_{I(3)}}{4\mu}$$

$$(21) \qquad p'_{C(3)} = c_{C(3)}$$

$$(22) \qquad x'_{C(3)} = \frac{3\mu - c_{C(3)} + c_{I(3)}}{4\mu}.$$

The profits of the two rivals from selling their inputs and the welfare of producers patronizing the co-op at the post-innovation stage of the game are then equal to:

$$(23) \qquad \Pi'_{I(3)} = \frac{\left(\mu + c_{C(3)} - c_{I(3)}\right)^2}{8\mu}$$

$$(24) \qquad \Pi'_{C(3)} = 0$$

$$(25) \qquad MW'_{(3)} = \left(p^F_{(3)} - c_{C(3)}\right)x'_{C(3)} - \frac{\mu x'^2_{C(3)}}{2}.$$

Before concluding this section, it should be noted that while the analysis assumes that the co-op considers the welfare of all producers that patronize its activities at the post-innovation stage of the game, the same results hold for a co-op that seeks to maximize the welfare of a fixed group of members (e.g., producers who funded the preceding process innovation activity of the co-op). Specifically, even if the co-op considered only the welfare of a fixed group of members when pricing its product at the post-innovation stage of the game, the optimal strategy would still be to price the agricultural input at marginal cost. The reason is that the total welfare of this fixed group of producers is maximized when the input supplied by the co-op is priced at marginal cost.

Innovation Competition in the Mixed Oligopoly

At this stage, the two suppliers seek to determine the optimal amount of cost-reducing process innovation. Maintaining the same assumptions regarding the structure and size of innovation costs, the pre-innovation costs of production, and the relationship between the amount of innovation and the post-innovation costs of producing the input, we can determine the effect of cooperative involvement on innovation activity.

Similar to the pure oligopoly case, the problem of Supplier I (IOF) is to determine the amount of innovation that maximizes its post-innovation profits from supplying the input, $\Pi'_{I(3)}$, minus the innovation costs, I_I, i.e.,

$$(26) \qquad \max_{t_I} \Pi_{I(2,3)} = \Pi'_{I(3)} - I_I = \frac{(\mu - t_C + t_I)^2}{8\mu} - \frac{1}{2}\psi t_I^2.$$

In contrast, the problem of Supplier C (co-op) is to determine the innovation effort that

[9] In an open membership co-op, membership is endogenous in that the decision to join the co-op is up to the producers—the co-op cannot prevent a particular producer from joining. Since the decision to purchase from the co-op is based on the relative returns obtained from purchasing the co-op's product or the IOF's product, a member in this stage is effectively anyone that purchases from the co-op.

[10] It is interesting to note that the member welfare-maximizing pricing strategy of the co-op at the post-innovation stage (i.e., $p_{C(3)} = c_{C(3)}$) does not depend on the pricing strategy of the IOF. An intriguing implication of this result is that the equilibrium conditions presented in equations (19)–(25) *do not* depend on the nature of price competition between the co-op and the IOF at the post-innovation stage. Specifically, it can be shown that the same equilibrium conditions result from a sequential pricing game with the leader being either the IOF or the co-op.

maximizes the welfare of producers that are members of the co-op at the time the investment decisions are being made—this group of members is referred to hereafter as the pre-innovation membership. As will be shown in the next section of the article, the pre-innovation membership is the group of producers who, through their purchasing decisions at the pre-innovation stage of the game, have provided the co-op with the capital for investment in process innovation activity. While the co-op knows that its innovation activity will reduce the production cost (and price) of its product and will attract new members to the co-op, the welfare of producers who find it optimal to patronize the co-op at the post-innovation stage (i.e., after the costly investment decisions have been made) is not accounted for by the co-op. Instead, when the co-op determines its innovation effort, it seeks to maximize only the welfare of its pre-innovation membership—i.e., producers who have patronized the co-op at the pre-innovation stage and funded its subsequent innovation activity.

The assumption that the co-op considers only its pre-innovation membership reflects the problem that open membership co-ops have in getting future members to pay for innovation activities. As a number of authors have pointed out (see, e.g., Cook; Porter and Scully), the poorly defined property rights, e.g., the lack of tradable shares, in an open membership co-op make it difficult for the benefits of future members to be reflected in the decisions made today. The implication is that the future membership cannot be used as a source of funds and consequently their welfare is not considered when innovation decisions are made.

Formally, the problem of the co-op can be expressed as:

$$(27)\quad \max_{t_C} MW_{(2,3)} = MW'_{(3/1)} - I_C = \left(p_C^F - c_{C(3)}\right) x_{C(1)} - \frac{\mu x_{C(1)}^2}{2} - \frac{1}{2}\psi\, t_C^2$$

where $x_{C(1)}$ is the pre-innovation market share of the co-op (i.e., the share of producers that patronize the co-op at the pre-innovation stage of the game), $MW_{(2,3)}$ is the welfare of the pre-innovation membership in stages 2 and 3, and $MW'_{(3/1)}$ is the welfare of the pre-innovation membership at the post-innovation stage of the game. Solving the optimality conditions of the firms we derive their best response functions as:

$$(28)\quad t_I = \frac{\mu - t_C}{4\mu\psi - 1}$$

and

$$(29)\quad t_C = \frac{x_{C(1)}}{\psi}.$$

Solving simultaneously the best response functions of the two suppliers we derive the Nash equilibrium levels of innovation in the mixed oligopoly as:[11]

$$(30)\quad t'_I = \frac{\mu\psi - x_{C(1)}}{\psi(4\mu\psi - 1)}$$

$$(31)\quad t'_C = \frac{x_{C(1)}}{\psi}$$

$$(32)\quad t'_T = t'_I + t'_C = \frac{(4\mu\psi - 2)x_{C(1)} + \mu\psi}{\psi(4\mu\psi - 1)}.$$

Substituting t'_i into the expressions for innovation costs, post-innovation profits, and member welfare, we get:

$$(33)\quad \Pi'_{I(2,3)} = \frac{\left(\mu\psi - x_{C(1)}\right)^2}{2\psi(4\mu\psi - 1)}$$

$$(34)\quad MW'_{(2,3)} = \left(p_C^F - c_{(1)} + \frac{x_{C(1)}}{\psi}\right) x_{C(1)} - \frac{\mu x_{C(1)}^2}{2} - \frac{x_{C(1)}^2}{2\psi}.$$

Price Competition at the Pre-Innovation Stage in the Mixed Oligopoly

The analysis in the previous section reveals that both the optimal innovation effort and the payoff of the two rivals in the mixed oligopoly depend on the share of producers that patronize the co-op at the pre-innovation stage of the game. This section considers the strategic interaction of the two firms at the pre-innovation

[11] Equation (29) indicates that, similar to its optimal pricing strategy at the post-innovation stage, the member welfare-maximizing innovation effort of the co-op does not depend on the innovation effort exerted by the IOF. The implication of this result is that the equilibrium conditions presented in equations (30)–(34) are not dependent upon the nature of the strategic interaction at the innovation stage of the game. Instead, the same equilibrium conditions will also prevail for a sequential innovation game with the leader being either the IOF or the co-op.

stage and determines the equilibrium prices and market shares of the two rivals.

At the pre-innovation stage, the co-op and the IOF are involved in strategic price competition holding Nash conjectures. Unlike the pure oligopoly case where the pricing decisions at the pre-innovation stage have no effect on either the innovation decisions or the pricing equilibrium at the post-innovation stage, equations (30)–(34) indicate that the pricing decisions at the pre-innovation stage in the mixed oligopoly affect the subsequent decisions and payoffs of the two rivals through their effect on the pre-innovation market share of the co-op, $x_{C(1)}$.

Thus, when the IOF is making its decisions at the pre-innovation stage, it has to consider the effects of its choices on *total* profits, Π_I^T, i.e., the profits from selling the input at the pre-innovation stage, $\Pi_{I(1)}$, minus the innovation costs incurred at the innovation stage, I_I, plus the profits from selling the input at the post-innovation stage, $\Pi_{I(3)}$. Formally, the problem of the IOF at the pre-innovation stage can be expressed as:

$$(35)\quad \max_{p_{I(1)}} \Pi_I^T = \Pi_{I(1)} - I_I + \Pi_{I(3)} = \big(p_{I(1)} - c_{(1)}\big)x_{I(1)} + \frac{\big(\mu\psi - x_{C(1)}\big)^2}{2\psi(4\mu\psi - 1)}$$

where all variables are as previously defined. The best response function of the IOF is then

$$p_{I(1)} = \frac{\psi(4\mu\psi - 1)\big(2\mu + c_{(1)}\big) - \mu\psi - 2\mu\psi(4\mu\psi - 1)x_{C(1)} + x_{C(1)}}{\psi(4\mu\psi - 1)}.$$

Similarly, when the co-op determines its price at the pre-innovation stage, it has to take into account the effect of its choices on the welfare of its pre-innovation membership in both the pre- and post-innovation stages of the game. Specifically, at the pre-innovation stage of the game the co-op seeks to determine the price that maximizes total member welfare subject to raising the capital required for its subsequent process innovation activity. The co-op knows the optimal amount of process innovation (equation (31)) and, thus, knows the amount of capital that needs to be raised at the pre-innovation stage for funding this innovation effort ($I_C = \frac{1}{2}\psi t_C^2 = \frac{x_{C(1)}^2}{2\psi}$). Formally, the problem of the co-op at the pre-innovation stage can be written as:

$$(36)\quad \max_{p_{C(1)}} MW^T = MW_{(1)} + MW'_{(3/1)} = \big(p_{(1)}^F - p_{C(1)}\big)x_{C(1)} - \frac{\mu x_{C(1)}^2}{2} + \left(p_{(3)}^F - c_{(1)} + \frac{x_{C(1)}}{\psi}\right)x_{C(1)} - \frac{\mu x_{C(1)}^2}{2}$$

$$\text{s.t.}\quad \Pi_{C(1)} - I_C \geq 0 \Rightarrow \big(p_{C(1)} - c_{(1)}\big)x_{C(1)} - \frac{x_{C(1)}^2}{2\psi} \geq 0$$

where $MW_{(1)}$ is the welfare of the pre-innovation membership in stage 1. All other variables are as previously defined. Note that the innovation costs incurred by the co-op, I_C, are included in the objective function as part of $MW_{(1)}$, since the producers who patronize the co-op at the pre-innovation stage finance the subsequent innovation activity through the higher prices they pay at this stage of the game. Indeed, as equation (36) indicates, the co-op's profits in the pre-innovation stage are constrained to equal or exceed the costs of the innovation activity that will be undertaken in stage 2.

Since the total welfare of producers that patronize the co-op at the pre-innovation stage is inversely related to $p_{C(1)}$ (i.e. $(\partial MW^T/\partial p_{C(1)}) < 0$), the co-op will set its price so that the constraint in its optimization problem binds—the co-op equates its profits at the pre-innovation stage to the capital needed to finance its subsequent innovation activity. Thus, the best response function of the co-op at the pre-innovation stage is given by

$$p_{C(1)} = \frac{x_{C(1)}}{2\psi} + c_{(1)}.$$

Solving simultaneously the best response functions and demands faced by the two firms at the 1st stage of the game (the demands are given by equations (3) and (4) for $k = 1$), we derive the Nash equilibrium prices and quantities (market shares) at the pre-innovation stage as:

$$(37)\quad p'_{I(1)} = c_{(1)} + \mu - \frac{2\mu[2\mu\psi(4\mu\psi - 1) - 1]}{4\mu\psi(8\mu\psi - 1) - 3}$$

$$(38)\quad x'_{I(1)} = \frac{4\mu\psi(2\mu\psi + 1) - 3}{4\mu\psi(8\mu\psi - 1) - 3}$$

$$(39)\quad p'_{C(1)} = c_{(1)} + \frac{4\mu(3\mu\psi - 1)}{4\mu\psi(8\mu\psi - 1) - 3}$$

$$(40)\quad x'_{C(1)} = \frac{8\mu\psi(3\mu\psi - 1)}{4\mu\psi(8\mu\psi - 1) - 3}.$$

Substituting the equilibrium pre-innovation membership of the co-op (equation (40)) into equations (30)–(32) gives the subgame perfect equilibrium innovation activity in the mixed oligopoly while substituting the ensuing expressions for t_I and t_C into equations (19)–(24) gives the subgame perfect equilibrium at the post-innovation stage of the game expressed in terms of the exogenous parameters (i.e., size of innovation costs, degree of producer heterogeneity, and pre-innovation production costs). Table 2 summarizes the (asymmetric) subgame perfect equilibrium in the mixed oligopoly.

The results reveal that the member welfare maximizing co-op charges lower prices at both the pre- and post-innovation stages of the game and undertakes higher innovation effort than its profit-maximizing rival (i.e., $p'_{C(k)} < p'_{I(k)}$ and $t'_C > t'_I$). The reason is that, unlike the IOF, the co-op internalizes the effect of reduced costs and prices on the welfare of producers that patronize its activities. The magnitude of the difference in the equilibrium strategies of the two rivals depends on the size of the innovation costs and the degree of producer heterogeneity. In particular, the lower are the innovation costs, the greater is the difference in the innovation effort of the two firms, and the greater is the total innovation activity in the market. Similarly, the less homogeneous are the producers, the smaller is the difference in innovation expenses of the two rivals, and the greater is the total innovation effort in the market.

Before concluding this section, recall that the analysis assumes $x_{i(k)} \geq 0$ and $t_i \geq 0$. Using the equilibrium conditions derived earlier, it can be shown that both of these conditions are met when the parameters μ and ψ are such that $\mu\psi \geq 5/8$. In this case, $x'_{C(1)} \leq \mu\psi$, $t_i \geq 0$ and $x_{i(3)} \geq 0$. When, on the other hand, $\mu\psi < 5/8$, the IOF finds it optimal to not invest in process innovation activity and exits the market in the post-innovation stage of the game.

The Effect of Cooperative Involvement on Innovation Activity

Having determined the subgame perfect equilibrium conditions in the pure and mixed

Table 2. Subgame Perfect Equilibrium in the Mixed Oligopoly

Pre-innovation stage (1st stage)	$p_{C(1)}$	$c_{(1)} + \frac{4\mu(3\mu\psi - 1)}{4\mu\psi(8\mu\psi - 1) - 3}$
	$p_{I(1)}$	$c_{(1)} + \mu - \frac{2\mu[2\mu\psi(4\mu\psi - 1) - 1]}{4\mu\psi(8\mu\psi - 1) - 3}$
	$x_{C(1)}$	$\frac{8\mu\psi(3\mu\psi - 1)}{4\mu\psi(8\mu\psi - 1) - 3}$
	$x_{I(1)}$	$\frac{4\mu\psi(2\mu\psi + 1) - 3}{4\mu\psi(8\mu\psi - 1) - 3}$
Innovation stage (2nd stage)	t_C	$\frac{x_{C(1)}}{\psi}$
	t_I	$\frac{\mu\psi - x_{C(1)}}{\psi(4\mu\psi - 1)}$
	t_T	$\frac{(4\mu\psi - 2)x_{C(1)} + \mu\psi}{\psi(4\mu\psi - 1)}$
Post-innovation stage (3rd stage)	$p_{C(3)}$	$c_{(1)} - \frac{x_{C(1)}}{\psi}$
	$p_{I(3)}$	$c_{(1)} + \mu - \frac{\mu + t_T}{2}$
	$x_{C(3)}$	$\frac{3\mu\psi - 1 + x_{C(1)}}{4\mu\psi - 1}$
	$x_{I(3)}$	$\frac{\mu\psi - x_{C(1)}}{4\mu\psi - 1}$

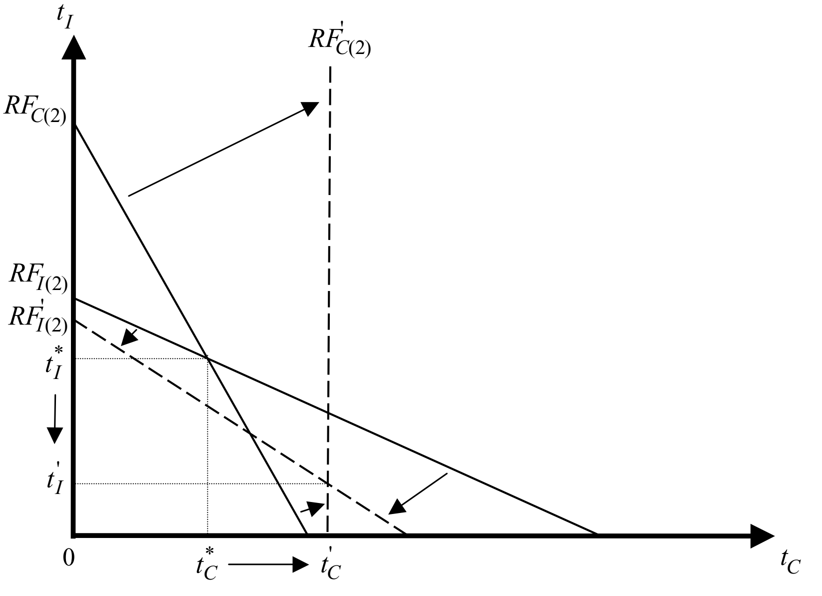


Figure 3. Effect of cooperative involvement on innovation activity

oligopolies, we can now examine the effect of cooperative involvement on innovation activity, the pricing of the agricultural input at the pre- and post-innovation stages, and the welfare of the groups involved (i.e., agricultural producers and input suppliers). The effect of co-op involvement on the equilibrium amounts of innovation undertaken by the agricultural input suppliers is shown graphically in figure 3.

Figure 3 depicts the innovation reaction functions (best response functions) of the input suppliers in the pure and mixed oligopoly cases (equations (12), (28), and (29)). It is shown that, when compared to the reaction function of the profit-maximizing Supplier C in the pure oligopoly ($RF_{C(2)}$), the reaction function of the co-op ($RF'_{C(2)}$) is shifted outwards while rotating rightwards so that it becomes vertical at

$$\frac{x'_{C(1)}}{\psi} = \frac{8\mu(3\mu\psi - 1)}{4\mu\psi(8\mu\psi - 1) - 3}.$$

The incentives to innovate are greater for the co-op because it internalizes the effect of reduced costs and prices (due to process innovation) on the welfare of its members. This internalization occurs because the co-op maximizes member welfare rather than profits.

At the same time, cooperative involvement reduces the marginal profitability of investment in process innovation by the IOF and crowds out IOF investment. In particular, the presence of the co-op shifts the reaction function of Supplier I ($RF'_{I(2)}$) inwards along the t_C axis while rotating it rightwards relative to the reaction function of this same supplier when it competes with another profit-maximizing IOF (i.e., $RF_{I(2)}$ in figure 3). The outcome of these changes in the reaction functions is increased innovation activity of the co-op relative to Supplier C in the pure oligopoly and reduced innovation activity of the IOF when it competes with a co-op relative to when it competes with another profit-maximizing firm, i.e.

$$(41) \quad t'_C > t_C^* \quad \text{and} \quad t'_I < t_I^*.$$

In terms of *total* innovation activity, it can be shown that the effect of cooperative involvement on t_T depends on the size of the innovation costs, ψ, and the degree of producer heterogeneity, μ. Specifically, when $\mu\psi$ exceeds a critical value of 0.701444, total innovation activity in the mixed oligopoly exceeds that in the pure oligopoly, indicating that cooperative involvement increases the total innovation effort in the market, i.e.

$$(42) \quad \mu\psi \geq (<)\, 0.701444 \Rightarrow t'_T \geq (<)\ t_T^*.$$

One reason that an increase in total innovation activity does not always occur in the mixed oligopoly is because the open membership co-op can only partially internalize the costs and benefits of innovation, thus underscoring the importance of modeling this specific organizational structure. This partial internalization occurs because the membership that funds the innovation activity is less than the group of producers that benefit from the innovation.[12]

Equation (42) indicates that the greater are ψ and μ, the more likely it is that cooperative involvement will increase total innovation activity in the market. The reasoning in the case of ψ is linked to the objective function of the co-op. While an increase in innovation costs reduces total innovation activity in both the pure and mixed oligopolies, it reduces innovation activity in the market with a co-op by relatively less. As discussed above, a co-op that maximizes member welfare better internalizes the benefits of innovation than does a profit-maximizing IOF. The effect of this internalization is strengthened with an increase in ψ making the impact of an increase in innovation costs on innovation activity less distortionary in the mixed duopoly case. The result is that, as ψ increases, the more likely it is that cooperative involvement will result in greater innovation activity in the mixed duopoly relative to the pure duopoly.

In the case of producer heterogeneity, the argument is slightly different. As table 1 shows, the parameter μ has no impact on innovation activity in the symmetric pure oligopoly equilibrium. In the mixed oligopoly, however, an increase in producer heterogeneity causes total innovation to rise. For the co-op, a small value of μ provides a major constraint on raising money in the pre-innovation stage, since any attempt to raise its price will result in a significant loss of market share. As well, for the IOF, a small value of μ provides little incentive to undertake innovation since low producer heterogeneity means a limited ability to raise price in the post-innovation stage and, hence, a limited ability to capture the rents from innovation activity (see table 2). As μ rises, the co-op can increase its price in the pre-innovation stage without a significant loss in market share, and is thus better able to raise capital for investment in process innovation; the result is cooperative innovation activity is likely to rise. For the IOF, a larger μ means an increased ability to capture the rents associated with its process innovation, thus leading to an increase in its innovation activity. The overall result is that co-operative involvement in the sector increases total innovation activity as producer heterogeneity rises.

It is important to note that, while cooperative involvement *can* increase the amount of innovation undertaken by the input suppliers, total innovation does not necessarily have to increase in order for farmers to benefit from the presence of the co-op—even if the total innovation effort falls in the mixed oligopoly, producer welfare can still increase in the presence of the co-op. In particular, comparing the equilibrium conditions in the pure and mixed oligopolies, it can be shown that the prices charged by Supplier I in the pre- and post-innovation stages always fall in the mixed oligopoly (i.e., $p'_{I(k)} < p^*_{I(k)}$); given that p_C is also reduced (i.e., $p'_{C(k)} < p^*_{C(k)}$), all producers (members and non-members of the co-op) realize an increase in their welfare.

The effect of cooperative involvement on the pricing of the agricultural input at the post-innovation stage is shown graphically in figure 4, which depicts the price reaction functions of the input suppliers and the determination of the Nash equilibrium post-innovation prices in the pure and mixed oligopoly cases. Specifically, when Supplier C is a co-op instead of an IOF, its best response function ($RF'_{C(3)}$) is constant at c_C (i.e., it is not a function of the price charged by Supplier I). For Supplier I, the reduction in innovation effort in the mixed oligopoly case (see equation (41)) increases its post-innovation production cost and causes a parallel upward shift of its best response function in the 3rd stage of the game (compare $RF_{I(3)}$ and $RF'_{I(3)}$ in figure 4). The outcome is the reduced price of *both* inputs.

The reduction in the input prices in the presence of the co-op increases producer welfare at the pre- and post-innovation stages by the shaded area $\Delta PW_{(k)}$ in figure 5. Since the reduction in $p_{C(k)}$ exceeds the reduction in $p_{I(k)}$, the result is a reduced market share of Supplier I (IOF) at both the pre- and the post-innovation stages in the mixed oligopoly case. Note that, due to the pricing strategy of the co-op and the reduced price-cost margin of the IOF in the mixed oligopoly, the increase

---

[12] Poyago-Theotoky finds that the introduction of a public firm always leads to a reversal of the underinvestment in R&D that can occur in a pure oligopoly. This result occurs because the public firm is able to fully internalize the costs and benefits of R&D. In Poyago-Theotoky's model, the underinvestment in R&D in the pure duopoly results because each firm can easily imitate innovations discovered by the other firm. When innovations are not easily imitated and firms engage in a patent race, the pure duopoly results in over investment. Under these circumstances, Delbono and Denicolò show that a public firm can result in reduced R&D expenditures, again because the public firm more fully internalizes the costs and benefits. See Beath, Katsoulacos and Ulph for a general model of the pure duopoly.

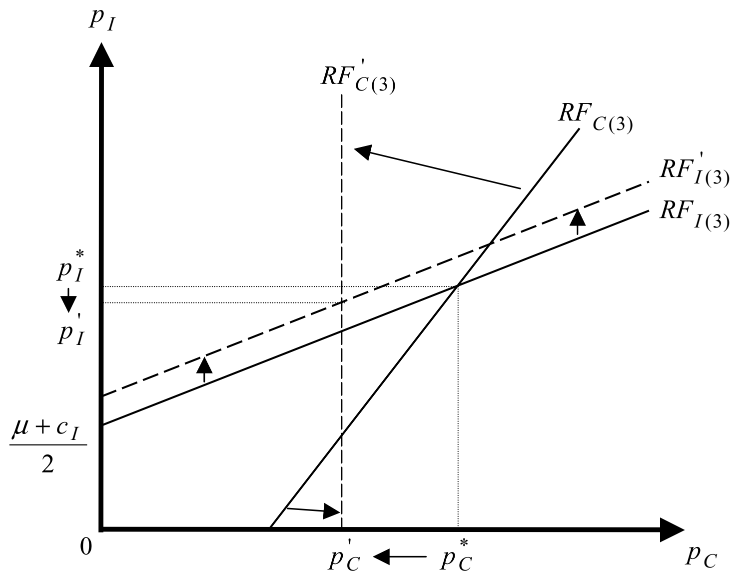


Figure 4. Effect of cooperative involvement on input pricing at the post-innovation stage of the game

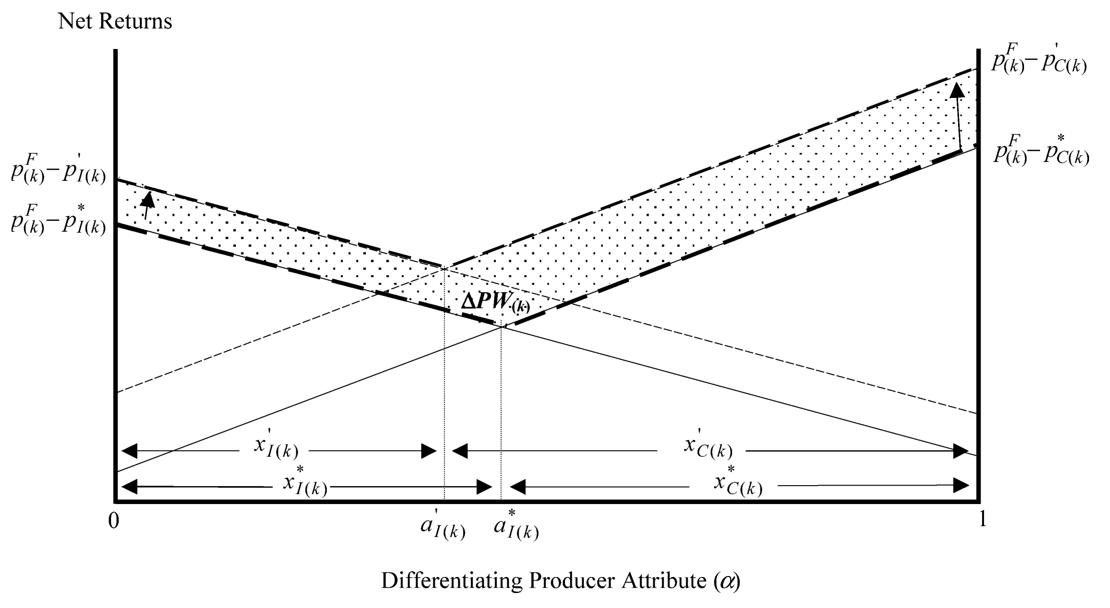


Figure 5. Market and welfare effects of cooperative involvement in innovation at the pre- and post-innovation stages

in producer welfare exceeds the reduction in suppliers' profits, indicating that the presence of the co-op increases total economic welfare in this market.

Discussion and Conclusion

The purpose of this article was to examine the impact of an open membership input supply co-op on the innovation activity in the agricultural input-supplying sector, taking into account the unique manner in which this co-op raises capital. The model that was developed featured two elements that distinguish it from the standard analysis of innovation activity in a pure oligopoly—the introduction of a different objective function, i.e., the maximization of member welfare by the co-op, and the requirement that the co-op finance its innovation through retained earnings.

To address this question, the article developed a sequential game theoretic model with heterogeneous producers and used this model to examine the consequences of cooperative involvement for the arrival rate of innovations, the pricing of agricultural inputs, and the welfare of the groups involved in the industry. Analytical results show that presence of the member welfare-maximizing co-op—which replaces a profit-maximizing IOF—can increase the arrival rate of innovations while reducing the prices of agricultural inputs. Cooperative involvement in innovation activity *can* be thus welfare enhancing and socially desirable with its effectiveness being determined by the degree of producer heterogeneity and the size of the innovation costs.

While this article shows very stark results, e.g., total welfare is always enhanced with the introduction of the co-op, and the co-op's market share exceeds that of its IOF counterpart, these results are dependent on the maintained assumptions of the article. Of course, these assumptions do not always hold. First, the results are predicated on the assumption that the co-op maximizes member welfare. It is well known that co-ops do not always behave in this manner. Agency problems, for instance, can result in co-op managers pursuing different objectives than those desired by their members (Cook; Fulton; Sexton and Iskow). These agency problems can also affect the degree of member commitment, which will have a further impact on the co-ops' ability to raise capital (Fulton and Giannakas).

Second, while the use of retained earnings to finance innovation investment is one way of addressing the property rights problems in co-ops, the persistence of portfolio, horizon and/or equity redemption problems could further constrain the ability of the co-op to raise capital from what is modeled in this article and would need to be accounted for in an analysis of cooperative performance. Of course, the cooperative organization has features that may provide it with an advantage over IOFs—these features include exemptions from antitrust laws, different taxation rules and access to a specialized source of debt capital from the co-operative financial system—and which have also not been considered in our analysis.

While it is the interaction of this complex set of factors and features that will determine the performance and impact of co-ops, the analysis in this article shows that co-ops do posses some potential organizational advantages, not just with respect to pricing as has been previously shown in the literature, but also with respect to investment in innovation activity. Since this investment in innovation affects the prices charged by both the co-op and the IOF, and consequently the profits of the IOF and the welfare of all agricultural producers, the factors affecting co-op innovation activity are of interest to all players in the agricultural industry.

[Received August 2002;
accepted September 2004.]

References

Aghion, P., and P. Howitt. "A Model of Growth through Creative Destruction." *Econometrica* 60(1992):323–51.

——. *Endogenous Growth Theory*. Cambridge MA: The MIT Press, 1998.

Aoki, R. "R&D Competition for Product Innovation: An Endless Race." *American Economic Review* (Papers and Proceedings) 81(1991):252–6.

Beath, J., Y. Katsoulacos, and D. Ulph. "Strategic R&D Policy." *The Economic Journal* 99(1989):74–83.

Chaddad, F.R., and M.L. Cook. "Testing for the Presence of Financial Constraints in U.S. Agricultural Cooperatives." Working paper AEWP 2002–5, Dept. Agr. Econ., University of Missouri, Columbia, 2002.

Chesnick, D.S. "Asset Growth for Largest Co-ops Shows Resilience to Declining Revenues." *Rural Cooperatives*, January/February (2000), pp. 28–31.

Cook, M.L. "The Future of U.S. Agricultural Cooperatives: A Neo-Institutional Approach." *American Journal of Agricultural Economics* 77(1995):1153–9.

Cotterill, R.W. "Agricultural Cooperatives: A Unified Theory of Pricing, Finance, and Investment." In J.S. Royer, ed. *Cooperative Theory: New Approaches*. Washington DC: U.S. Department of Agriculture, Agricultural Cooperative Service, 1987, pp. 171–258.

Delbono, F. "Market Leadership with a Sequence of History Dependent Patent Races." *Journal of Industrial Economics* 38(1989):95–101.

Delbono, F., and V. Denicolò. "Regulating Innovative Activity: The Role of a Public Firm." *International Journal of Industrial Organization* 11(1993):35–48.

Fairbairn, B. *Living the Dream: Membership and Marketing in the Co-operative Retailing*

System. Saskatoon: Centre for the Study of Co-operatives, 2003.

Fudenberg, D., R. Gilbert, J. Stiglitz, and J. Tirole. "Preemption, Leapfrogging and Competition in Patent Races." *European Economic Review* 22(1983):3–31.

Fulton, M.E. "Co-operatives in Oligopolistic Industries: The Western Canadian Fertilizer Industry." *Journal of Agricultural Cooperation* 4(1989):1–19.

Fulton, M.E., and K. Giannakas. "Organizational Commitment in a Mixed Oligopoly: Agricultural Cooperatives and Investor-Owned Firms." *American Journal of Agricultural Economics* 83(2001):1258–65.

Gibbons, R. *Game Theory for Applied Economists*. Princeton NJ: Princeton University Press, 1992.

Greenhut, M.L., G. Norman, and C. Hung. *The Economics of Imperfect Competition: A Spatial Approach*. New York: Cambridge University Press, 1987.

Grossman, G., and C. Shapiro. "Dynamic R&D Competition." *The Economic Journal* 97(1987):372–87.

Gruber, J.L., R.T. Rogers, and R.J. Sexton. "Do Agricultural Marketing Cooperatives Advertise Less Intensively Than Investor-Owned Food Processing Firms?" *Journal of Cooperation* 15(2000):31–46.

Hansmann, H. *The Ownership of Enterprise*. Cambridge MA: Harvard University Press, 1996.

Harris, A., B. Stefanson, and M.E. Fulton. "New Generation Cooperatives and Cooperative Theory." *Journal of Co-operatives* 11(1996):15–28.

Karantininis, K., and A. Zago. "Cooperatives and Membership Commitment: Endogenous Membership in Mixed Duopsonies." *American Journal of Agricultural Economics* 83(2001):1266–72.

Knoeber, C.R., and D.L. Baumer. "Understanding Retained Patronage Refunds in Agricultural Cooperatives." *American Journal of Agricultural Economics* 65(1983):30–37.

Malueg, D., and S. Tsutsui. "Dynamic R&D Competition with Learning." *Rand Journal of Economics* 28(1997):751–72.

Neary, H.M., and D. Ulph. "Strategic Investment and the Co-existence of Labour-Managed and Profit-Maximizing Firms." *Canadian Journal of Economics* 30(1997):308–28.

Okuguchi, K. "Comparative Statics for Profit-Maximizing and Labor-Managed Cournot Oligopolies." *Managerial and Decision Economics* 14(1993):433–44.

Porter, P., and G. Scully. "Economic Efficiency in Cooperatives." *Journal of Law and Economics* 30(1987):489–512.

Poyago-Theotoky, J. "R&D Competition in a Mixed Duopoly under Uncertainty and Easy Imitation." *Journal of Comparative Economics* 26(1998):415–28.

Rey, P., and J. Tirole. "Financing and Access in Cooperatives." Working paper, L'Institut d'Economie Industrielle, University of Toulouse, France, 2001. Available at http://www.idei.asso.fr/Commun/Articles/Tirole/Financing-Access.pdf.

Rogers, R.T., and B.W. Marion. "Food Manufacturing Activities of the Largest Agricultural Co-operatives: Market Power and Strategic Behavior Implications." *Journal of Agricultural Co-operation* 5(1990):59–73.

Rogers, R.T., and R.J. Sexton. "Assessing the Importance of Oligopsony Power in Agricultural Markets." *American Journal of Agricultural Economics* 76(1994):1143–50.

Segerstrom, P., T. Avant, and E. Dinopoulos. "A Schumpeterian Model of the Product Life Cycle." *American Economic Review* 80(1990):1077–91.

Sexton, R.J. "Imperfect Competition in Agricultural Markets and the Role of Cooperatives: A Spatial Analysis." *American Journal of Agricultural Economics* 72(1990):709–20.

Sexton, R.J., and J. Iskow. "What Do We Know about the Economic Efficiency of Co-operatives?: An Evaluative Survey." *Journal of Agricultural Cooperation* 8(1993):15–27.

Sexton, R.J., and T.A. Sexton. "Cooperatives as Entrants." *Rand Journal of Economics* 18(1987):581–95.

Shy, O. *Industrial Organization*. Cambridge MA: The MIT Press, 1995.

Sutton, J. *Technology and Market Structure*. Cambridge MA: The MIT Press, 1998.

Tennbakk, B. "Marketing Cooperatives in Mixed Duopolies." *Journal of Agricultural Economics* 46(1995):33–45.

U.S. Department of Agriculture (USDA). *What is a Cooperative*? Rural Business and Cooperative Development Service, Cooperative Information Report 50, Washington DC, March 1995.

——. *Cooperative Historical Statistics*. Rural Business Cooperative Service, Cooperative Information Report 1, Section 26, Washington DC, March 1998.

——. *Farmer Cooperative Statistics 2001*. Rural Business Cooperative Service, Report 61, Washington DC, March 2003.

Vitaliano, P. "Cooperative Enterprise: Alternative Conceptual Basis for Analyzing a Complex Institution." *American Journal of Agricultural Economics* 65(1983):1078–83.