Agricultural Cooperatives and Quality-Enhancing R&D in the Agri-Food System

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Abstract - *This paper develops a game-theoretic model of heterogeneous consumers to analyze the effect of cooperative involvement on quality-enhancing product innovation activity, the pricing of food products, and the welfare of the groups involved in the context of a mixed duopoly where an open-membership consumer co-op competes with an IOF. Analytical results show that the involvement of the member welfare-maximizing co-op in R&D can be quality and welfare enhancing by increasing the arrival rate of product innovations and reducing the prices of food products. The effectiveness of the co-op is shown to depend on the nature of product differentiation and the relative quality of its products, the degree of consumer heterogeneity, and the size of innovation costs*.

Keywords: Open Membership Cooperatives, Product Innovation, Mixed Oligopoly, Retained Earnings.

1. Introduction

Research and development (R&D) is a critical business strategy affecting the competitiveness of firms, technological progress, and social welfare. Innovation activity has become particularly relevant in the increasingly industrialized agri-food sector where changes in consumer preferences and global competition have resulted in aggressive attempts by agribusiness firms to satisfy market demands for higher quality products through innovation and product differentiation strategies.

The strategic interactions among innovating firms and their effect on innovating behavior have received considerable attention in the economic literature with the main focus being on R&D competition in a pure oligopoly (i.e., a small number of profit-maximizing, investor-owned firms (IOFs)), and the consequence of this competition for the structure of the market and the arrival rate of innovations.[1]

Despite the prevalence of mixed markets where cooperatives (co-ops) compete alongside IOFs,[2] the effect of cooperative organizations on product innovation activity has not been considered previously.[3] The only study considering the effect of cooperatives on

[1] See Fudenberg et al[7], Grossman and Shapiro[11], Aoki[4], Delbono[6], Malueg and Tsutsui[13], and Sutton[18]. For Schumpeterian models of innovation competition see Segerstrom, Avant, and Dinopoulos[14], and Aghion and Howitt[1], [2].

[2] Co-ops account for 25% to 30% of total farm supply and marketing expenditures in the US (USDA[20]).

[3] The literature on mixed oligopolies involving co-ops has focused on the effect of different types of cooperative organizations on the equilibrium conditions of various Cournot and

innovation is Giannakas and Fulton [9] that focused on the effect of input supplying co-ops on cost-reducing, process innovation activity.

Part of the reason for this lack of research is that co-ops have not traditionally played a major role in quality-enhancing, product innovation activity. Indeed, the standard view has been that co-ops are largely concentrated in the vertical stages just before and just after the farm enterprise. While co-ops are still largely concentrated near the farm gate, a number of them are taking steps to position themselves via their innovation activity. Important examples include Limagrain, Cebeco, and Cosun in Europe, while co-ops in the U.S. such as Ocean Spray have had substantial R&D activity.[4]

The objective of this paper is to examine the market and welfare effects of cooperative involvement in quality-enhancing innovation activity in the agri-food system. In particular, the paper analyzes the consequences of cooperative involvement for the arrival rate of (quality-enhancing) product innovations, the pricing behavior of firms, and social welfare in the context of a mixed duopoly where an open-membership consumer co-op competes with an IOF. By focusing on a mixed oligopoly, the study pays particular attention to the impact of replacing a profit-maximizing IOF with a member welfare-maximizing co-op. The case of a pure oligopoly is also analyzed and is used as a benchmark for determining the consequences of cooperative involvement in quality-enhancing R&D. Different scenarios on the type of product differentiation (horizontal versus vertical product differentiation[5]) and the relative quality of the products supplied by the firms in the vertically differentiated mixed and pure duopolies are examined within this framework.

The rest of the paper is organized as follows. Section 2 outlines the methodological framework and the main assumptions of our analysis. The three sections following analyze the cases where: the products supplied by the firms are horizontally differentiated (Section 3), the products are vertically differentiated and the co-op is the high quality firm (Section 4), and the products are vertically differentiated and the co-op is the low quality firm (Section 5). Within each of these three sections, the equilibrium conditions in the pure and mixed oligopolies are derived and compared to determine the effect of cooperative involvement on quality-enhancing product innovation activity, the prices of the food products, firm profits, and consumer welfare. Section 6 concludes the paper.

2. Methodological framework

To analyze the effect of cooperative involvement in quality-enhancing product innovation activity our study follows the approach developed by Giannakas and Fulton [9](G&F, hereafter) when examining the effect of input supplying co-ops on cost-reducing, process innovation activity. In particular, the strategic interaction between the firms in the pure and

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Bertrand market settings (see Sexton and Sexton [16], Cotterill [5], Sexton [15], Tennbakk [19], Albaek and Schultz [3], Fulton and Giannakas [8], Karantininis and Zago [12]). A key result of this literature is that the different objective function of the co-op results in more competitive conduct and increased welfare.

[4] The example of Ocean Spray provides a good illustration of the different types of innovation activity in which firms can engage. Product innovation is reflected in the development of new markets for cranberries – e.g., the mixed cranberry drinks such as Cran Apple and the dried cranberry Craisins. Ocean Spray's Ingredient Technology Group, which works with its customers to develop innovative fruit ingredients, is another example of R&D activity in product innovation.

[5] Products are horizontally differentiated when they are not uniformly ranked by consumers – if offered at the same price, all products will enjoy positive shares of the market. Vertically differentiated products are those that are uniformly quality ranked by consumers – if offered at the same price all consumers will prefer the same (high quality) product.

the mixed duopolies is modeled as a three-stage sequential game where: in stage 1, the firms compete in prices and a new product innovation that can enhance the quality of their offerings is announced; in stage 2, the firms determine their optimal level of investment in the new quality-enhancing innovation; and in stage 3, quality levels are fixed and the firms engage in price competition. In what follows, stage 1 will often be referred to as the "pre-innovation stage," stage 2 as the "innovation stage," and stage 3 as the "post-innovation stage."

To avoid Nash equilibria involving non-credible strategies, the different formulations of the game are solved using backward induction (Gibbons [10]) – the pricing behavior of the firms at the post-innovation stage is considered first, the optimal investment in the quality-enhancing innovation is analyzed next, and the solution to the pre-innovation pricing problem determines the subgame perfect equilibrium amount of R&D, the pricing of the food products, and consumer decisions in the pre- and post-innovation stages.

In addition to being intuitively appealing, this structure of the strategic interaction in the mixed oligopoly enables us to explicitly account for the different objective function of the co-op (member welfare maximization vs. profit maximization pursued by IOFs) as well as for the need of the co-op to rely on earnings raised at the pre-innovation stage to finance its subsequent investment in quality-enhancing innovation (on the difficulties of open membership co-ops to raise investment capital and the role of retained earnings in addressing various property rights problems see G&F[9] and the references therein). Other than facilitating the explicit consideration of these important idiosyncrasies of the cooperative organization, this structure of strategic interactions makes our results directly comparable to those of G&F[9]. Given that both the input-supplying co-op analyzed in G&F[9] and the consumer co-op considered here constitute a backward integration of their members (they are both selling their products to their members), a comparison of our results with those of G&F[9] will enable us to determine whether the type of innovation (i.e., product vs. process innovation) matters when considering the effect of cooperative involvement in innovation activity.

3. Horizontal product differentiation

Before examining the pricing and innovation decisions in the pure and mixed oligopolies, we need to analyze the way consumers make their purchasing decisions. By doing so, we will be able to derive the demands faced by each firm and obtain a measurement of consumer surplus.

3.1. Consumer decisions and welfare

Consider first the case where the products supplied by Firm I and Firm C are horizontally differentiated – i.e., the food products are not uniformly quality ranked by consumers so that, if they were offered at the same price, they would both enjoy positive shares of the market. Consumers buy one unit of either the product supplied by Firm I or the product supplied by Firm C. The purchasing decision represents a small share of their budget and, due to different tastes or location (i.e., physical distance from the two firms), consumers differ in their valuation of these products. We will distinguish between consumer decisions made in stages 1 and 3 since the amount of quality-enhancing innovation affects the consumer utility at the post-innovation stage of the game.

Consumer Decisions and Welfare in Stage 1 (Prior to the Quality-Enhancing Innovation)

As mentioned previously, consumers have to decide between the product of Firm I and the product of Firm C and, due to different tastes or location, they differ in the valuation of these products. Let $\alpha \in [0,1]$ be the attribute that differentiates consumers. A consumer with attribute α has the following utility function at the pre-innovation stage of the game:

$$U_{C(1)} = U_1 - p_{C(1)} + \mu\alpha \qquad \text{If a unit of Firm C's product is consumed}$$
$$U_{I(1)} = U_1 - p_{I(1)} + \mu(1-\alpha) \qquad \text{If a unit of Firm I's product is consumed} \tag{1}$$

where $U_{C(1)}$ and $U_{I(1)}$ is the utility associated with the unit consumption of the product supplied by Firm C and Firm I, respectively; $p_{C(1)}$ and $p_{I(1)}$ are the pre-innovation prices of these products; and U_1 is a base level of utility associated with the unit consumption of these products that is common across consumers. The parameter μ is non-negative and captures the degree of consumer heterogeneity. *Ceteris paribus*, consumers with large values of α prefer the product of Firm C, while consumers with low values of α prefer the product of Firm I. The greater is μ, the greater the differences in consumer valuation of the two products.

To ensure positive market shares for the two firms, it is assumed that μ is greater than the difference in the prices of the two products (see equations (3) and (4)), while, to retain tractability of the model, the analysis assumes that consumers are uniformly distributed between the polar values of α. Each consumer buys only one product with the purchasing decision being determined by the relationship between $U_{C(1)}$ and $U_{I(1)}$.

Figure 1 shows the decisions and welfare of consumers. The downward sloping curve shows the utility associated with the consumption of the product of Firm I, while the upward sloping curve shows the utility associated with the consumption of the product of Firm C for different values of the differentiating attribute α (i.e., for different consumers). The intersection of the two utility curves determines the level of the differentiating attribute that corresponds to the indifferent consumer. The consumer with differentiating characteristic $\alpha_{I(1)}$ given by:

$$\alpha_{I(1)} : U_{C(1)} = U_{I(1)} \Rightarrow U_1 - p_{C(1)} + \mu\alpha = U_1 - p_{I(1)} + \mu(1-\alpha) \Rightarrow$$
$$\alpha_{I(1)} = \frac{\mu + p_{C(1)} - p_{I(1)}}{2\mu} \tag{2}$$

is indifferent between buying from Firm I and buying from Firm C as the utility associated with the consumption of the two products is the same. Consumers with $\alpha \in [0, \alpha_{I(1)})$ buy from Firm I while consumers with $\alpha \in (\alpha_{I(1)}, 1]$ buy from Firm C. Aggregate consumer surplus is given by the area underneath the effective utility curve shown as the (bold dashed) kink curve in Figure 1.

When consumers are uniformly distributed with respect to their differentiating attribute α, $\alpha_{I(1)}$ also determines the market share of Firm I. The share of Firm C is given by $1-\alpha_{I(1)}$. By normalizing the mass of consumers at unity, the market shares give the consumer demands faced by Firm I, $x_{I(1)}$, and Firm C, $x_{C(1)}$. Formally, $x_{I(1)}$ and $x_{C(1)}$ can be written as:

$$x_{I(1)} = \frac{\mu + p_{C(1)} - p_{I(1)}}{2\mu} \tag{3}$$

$$x_{C(1)} = \frac{\mu + p_{I(1)} - p_{C(1)}}{2\mu} \tag{4}$$

Consumer Decisions and Welfare in Stage 3 (After the Quality-Enhancing Innovation)

The quality-enhancing product innovation undertaken by the two firms in stage 2 affects the quality of the firms' products and, therefore, it affects the utility associated with their consumption. To retain tractability, we assume that the amount of innovation undertaken by Firm *i* ($i \in \{C, I\}$) affects the base level of utility associated with the consumption of its product so that the post-innovation base utility becomes:

$$U_3^i = U_1 + \beta_i t_i \tag{5}$$

where t_i is the amount of innovation effort by Firm *i*. The parameter β_i represents the effectiveness of innovation effort by Firm *i* and it is normalized to one. In addition to simplifying our exposition, imposing symmetry on the effectiveness of firms' innovation efforts allows us to focus on the effect that the different objective function of the co-op has on equilibrium innovation and pricing decisions.

Thus, the consumer utility at the post-innovation stage can be written as:

$$\begin{array}{ll} U_{C(3)} = U_1 - p_{C(3)} + \mu\alpha + t_C & \text{If a unit of Firm C's product is consumed} \\ U_{I(3)} = U_1 - p_{I(3)} + \mu(1-\alpha) + t_I & \text{If a unit of Firm I's product is consumed} \end{array} \tag{6}$$

where $p_{C(3)}$ and $p_{I(3)}$ are the post-innovation prices of Firm C's and Firm I's products, respectively. All other variables are as previously defined.

The post-innovation consumer decisions and welfare are depicted in Figure 2. Similar to the pre-innovation case, the indifferent consumer is identified by the intersection of the utility curves associated with the consumption of the two products, i.e.,

$$\begin{array}{l} \alpha_{I(3)} : U_{C(3)} = U_{I(3)} \Rightarrow U_1 - p_{C(3)} + \mu\alpha + t_C = U_1 - p_{I(3)} + \mu(1-\alpha) + t_I \Rightarrow \\ \alpha_{I(3)} = \dfrac{\mu + p_{C(3)} - p_{I(3)} - t_C + t_I}{2\mu} \end{array} \tag{7}$$

and helps determine the demands faced by Firm I ($x_{I(3)} = \alpha_{I(3)}$) and Firm C ($x_{C(3)} = 1 - \alpha_{I(3)}$)

$$x_{I(3)} = \frac{\mu + p_{C(3)} - p_{I(3)} - t_C + t_I}{2\mu} \tag{8}$$

$$x_{C(3)} = \frac{\mu + p_{I(3)} - p_{C(3)} - t_I + t_C}{2\mu} \tag{9}$$

After determining the demands for the two products at the pre- and post-innovation stages, we will now proceed to deriving the subgame perfect equilibria in the pure and mixed oligopolies.

3.2. Benchmark case: innovation and pricing decisions in a pure oligopoly

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

In the post-innovation stage of the pure duopoly, the two IOFs seek to determine the prices that maximize their profits holding Nash conjectures (i.e., assuming that their decisions will not affect the behavior of their rival).[6] Specifically, the problem of the two IOFs at the 3rd stage of the game can be expressed as:

$$\max_{p_{i(3)}} \Pi_{i(3)} = \left(p_{i(3)} - c \right) x_{i(3)} \tag{10}$$

where c is firms' marginal cost of production.[7] In addition to simplifying our exposition, the imposition of symmetry on the costs of production allows us to isolate the effect of the different objective function of the co-op in the mixed oligopoly case.

Solving the problem of the two IOFs gives their best response functions as:

$$p_{i(3)} = \frac{1}{2}\left(c + \mu + p_{j(3)} + t_i - t_j \right)$$

where $j \in \{C, I\}$ and $i \neq j$. Solving these best response functions simultaneously and substituting $p_{C(3)}$ and $p_{I(3)}$ into equations (9) and (10) gives the Nash equilibrium prices and quantities as:

$$p^*_{i(3)} = c + \mu + \frac{t_i}{3} - \frac{t_j}{3} \tag{11}$$

$$x^*_{i(3)} = \frac{3\mu + t_i - t_j}{6\mu} \tag{12}$$

The equilibrium profits of each IOF are then given by:

$$\Pi^*_{i(3)} = \frac{\left(3\mu + t_i - t_j \right)^2}{18\mu} \tag{13}$$

and are a function of the degree of consumer heterogeneity and the amount of quality-enhancing innovation undertaken by each IOF. *Ceteris paribus*, the greater the innovation effort of a firm, the greater its market share, and the greater its profits at the post-innovation stage of the game.

Innovation Competition (2nd Stage of the Game)

In stage 2, the two IOFs seek to determine their optimal innovation effort. While, as indicated by equation (13), innovation effort has the potential to increase the post-innovation profits of a firm, quality-enhancing innovation requires resources. Without loss of generality, innovation costs are assumed an increasing function of the innovation effort (Shy)[17], i.e.,

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[6] The assumption of Nash conjectures is maintained throughout the analysis.

[7] Note that the costs of production are not affected by the quality-enhancing innovation activity. Product innovation is taking place in stage 2 and is financed through a sunk investment occurring at that stage.

$$I_i = \frac{1}{2}\psi t_i^2 \tag{14}$$

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

Thus, at the innovation stage of the game each IOF seeks to determine the innovation effort that maximizes its post- innovation profits, $\Pi_{i(3)}$, minus the cost of innovation effort, I_i, i.e.,

$$\max_{t_i} \Pi_{i(2,3)} = \frac{\left(3\mu + t_i - t_j\right)^2}{18\mu} - \frac{1}{2}\psi t_i^2 \tag{15}$$

From the first order conditions for each IOF's problem we obtain their best response function as:

$$t_i = \frac{3\mu - t_j}{9\mu\psi - 1} \tag{16}$$

Solving the best response functions simultaneously, we get the Nash equilibrium levels of innovation for each firm as:

$$t_i^* = \frac{1}{3\psi} \tag{17}$$

Substituting the equilibrium levels of innovation in the expressions for innovation costs and post- innovation profits, we get the net profits of each firm in stages 2 and 3 as:

$$\Pi_{i(2,3)}^* = \frac{9\mu\psi - 1}{18\psi} \tag{18}$$

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

In this stage, the two Firms seek to determine the prices that maximize their profits. Since the firms' payoffs in stages 2 and 3 are not dependent on pre- innovation prices or quantities, the objective of the two IOFs in stage 1 is to maximize their pre- innovation profits only, i.e.,

$$\max_{p_{i(1)}} \Pi_{i(1)} = \left(p_{i(1)} - c\right) x_{i(1)} \tag{19}$$

The Nash equilibrium prices, quantities and profits at the pre- innovation stage are then:

$$p_{i(1)}^* = c + \mu \tag{20}$$

$$x_{i(1)}^* = \frac{1}{2} \tag{21}$$

$$\Pi^*_{i(1)} = \frac{\mu}{2} \tag{22}$$

Table 1 summarizes the subgame perfect equilibrium in the pure oligopoly. Since the two IOFs have the same cost structure, the same effectiveness of innovation effort, and their products are horizontally differentiated, the equilibrium is symmetric. Both firms undertake a positive innovation effort, enjoy a per unit profit margin of μ, and split the market equally in both the pre- and post- innovation stages of the game.

3.3. Innovation and pricing decisions in a mixed oligopoly

In this case, Firm C is a co-op instead of an IOF. The market structure is, thus, a mixed duopoly consisting of an IOF (Firm I) and a co-op (Firm C).

Price Competition at the Post-Innovation Stage

Similar to the pure oligopoly case, at the 3rd stage the IOF seeks to determine the price that maximizes its profits. Thus, both its objective function and its best response function are identical to those in the post-innovation stage of the pure duopoly.

Unlike Firm C in the pure oligopoly, the co-op seeks to identify the price that maximizes the welfare of its members (i.e., consumers that patronize its activities) subject to not incurring economic losses. Member welfare is given by the shadowed area $MW_{(3)}$ in Figure 2 and the cooperative's problem can be expressed as:

$$\max_{p_{C(3)}} MW_{(3)} = \left(U_1 - p_{C(3)} + t_C + \mu\right) x_{C(3)} - \frac{1}{2}\mu x^2{}_{C(3)}$$

$$\text{s.t. } \Pi_{C(3)} \geq 0 \Rightarrow p_{C(3)} \geq c \tag{23}$$

Note, that this objective function captures the open membership nature of the co-op since the latter seeks to maximize the welfare of all the consumers that patronize its activity.

Solving the optimality conditions of co-op's problem, shows that the co-op will find it optimal to price its product its marginal cost (i.e., $p_{C(3)} = c$).[8] The Nash equilibrium prices and quantities at the post-innovation stage of the mixed oligopoly are:

$$p'_{I(3)} = \frac{1}{2}\left(2c + \mu + t_I - t_C\right) \tag{24}$$

$$x'_{I(3)} = \frac{\mu - t_C + t_I}{4\mu} \tag{25}$$

$$p'_{C(3)} = c \tag{26}$$

$$x'_{C(3)} = \frac{3\mu - t_I + t_C}{4\mu} \tag{27}$$

[8] It should be noted that marginal cost pricing will be the optimal strategy of the co-op at the post-innovation stage no matter if it seeks to maximize the welfare of all consumers that buy its product or the welfare of only a subset of its post-innovation membership. The obvious reason is that the welfare of any consumer group is inversely related to the food product prices.

The profits of the two Firms and the welfare of the group that patronizes the co-op are then:

$$\Pi'_{I(3)} = \frac{\left(\mu - t_C + t_I\right)^2}{8\mu} \tag{28}$$

$$\Pi'_{C(3)} = 0 \tag{29}$$

$$MW'_{(3)} = \left(U_1 - c + t_C + \mu\right) x'_{C(3)} - \frac{1}{2}\mu x'^2_{C(3)} \tag{30}$$

Innovation Competition in the Mixed Oligopoly

In this stage, the two Firms seek to determine their optimal innovation effort. Similar to the pure oligopoly case, the problem of the IOF is to determine the amount of innovation that maximizes its post-innovation profits minus its innovation costs, i.e.,

$$\max_{t_I} \Pi_{\mathrm{I}(2,3)} = \Pi'_{\mathrm{I}(3)} - I_I = \frac{\left(\mu - t_C + t_I\right)^2}{8\mu} - \frac{1}{2}\psi t_I^2 \tag{31}$$

On the other hand, the problem of the co-op is to maximize the welfare of consumers that are members at the time the decision to invest in innovation is being made (this group will be referred to as the "pre-innovation membership"). As will be shown below (in stage 1), the pre-innovation membership is the group that, by paying increased prices at the pre-innovation stage, provides the co-op with earnings that finance its subsequent quality-enhancing innovation effort. Thus, even though the co-op knows that its innovation activity can increase the relative quality of its product and attract new consumers/members to the co-op at the post-innovation stage, when making its innovation decisions it considers only the welfare of consumers that finance its innovation activity (by patronizing the co-op in stage 1).[9]

Algebraically, the problem of the coop can be expressed as:

$$\max_{t_C} MW_{(2,3)} = MW'_{(3/1)} - I_C = \left(U_1 - c + t_C + \mu\right) x_{C(1)} - \frac{1}{2}\mu x_{C(1)}^2 - \frac{1}{2}\psi t_C^2 \tag{32}$$

where $x_{C(1)}$ is the share of the co-op in stage 1, $MW_{(2,3)}$ 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 in stage 3. Solving the problems of the co-op and the IOF, we get their best response functions as:

$$t_C = \frac{x_{C(1)}}{\psi} \tag{33}$$

$$t_I = \frac{\mu - t_C}{4\mu\psi - 1} \tag{34}$$

[9] See G&F[9] for a similar formulation of the input-supplying co-op's objective function when determining its investment in cost-reducing, process innovation activity.

Solving these best response functions simultaneously, we get the Nash equilibrium levels of innovation:

$$t_C^{'} = \frac{x_{C(1)}}{\psi} \qquad (35)$$

$$t_I^{'} = \frac{\mu\psi - x_{C(1)}}{\psi\left(4\mu\psi - 1\right)} \qquad (36)$$

The total innovation in the mixed oligopoly is then:

$$t_T^{'} = t_C^{'} + t_I^{'} = \frac{\left(4\mu\psi - 2\right)x_{C(1)} + \mu\psi}{\psi\left(4\mu\psi - 1\right)} \qquad (37)$$

Plugging $t_C^{'}$ and $t_I^{'}$ in the expressions for innovation costs, post-innovation profits, and member welfare, we get:

$$\Pi_{I(2,3)}^{'} = \frac{\left(\mu\psi - x_{C(1)}\right)^2}{2\psi\left(4\mu\psi - 1\right)} \qquad (38)$$

$$MW_{(2,3)}^{'} = \left(U_1 - c + \frac{x_{C(1)}}{\psi} + \mu\right)x_{C(1)} - \frac{1}{2}\mu x_{C(1)}^2 - \frac{x_{C(1)}^2}{2\psi} \qquad (39)$$

Price Competition at the Pre-Innovation Stage

Unlike the pure oligopoly case, in the mixed duopoly the outcome of price competition in the pre-innovation stage affects firms' optimal decisions and payoffs in subsequent stages (see equations (35), (36), (38) and (39)). Thus, in stage 1 the IOF seeks to determine the price that maximizes its total profits (i.e., its profits at the pre-innovation stage plus its profits at the post-innovation stage minus its innovation costs), i.e.,

$$\max_{p_{I(1)}} \Pi^T{}_{\text{I}} = \Pi_{I(1)} + \Pi_{I(3)} - I_I = (p_{I(1)} - c)x_{I(1)} + \frac{(\mu\psi - x_{C(1)})^2}{2\psi(4\mu\psi - 1)} \qquad (40)$$

The best response function of the IOF is:

$$p_{I(1)} = \frac{\mu\left[8\mu^2\psi^2 + 1 - 4\mu\psi + 2c\psi\left(4\mu\psi - 1\right)\right] + \left(8\mu^2\psi^2 - 2\mu\psi - 1\right)p_{C(1)}}{16\mu^2\psi^2 - 4\mu\psi - 1}$$

Regarding the co-op, its problem at this stage is to determine the price that maximizes the welfare of its pre-innovation membership in both the pre- and post-innovation stages of the game, subject to raising earnings that can be retained to finance its quality-enhancing innovation in stage 2. The capital required for the subsequent investment in innovation is $I_C = \frac{1}{2}\psi t_C^2 = \frac{x^2{}_{C(1)}}{2\psi}$ and the problem of the co-op at the pre-innovation stage can be expressed as:

$$\max_{t_C} MW^T = MW_{(1)} + MW'_{(3/1)} =$$

$$= \left(U_1 - p_{C(1)} + \mu\right) x_{C(1)} - \frac{1}{2}\mu x^2_{C(1)} + \left(U_1 - c + \frac{x_{C(1)}}{\psi} + \mu\right) x_{C(1)} - \frac{1}{2}\mu x^2_{C(1)}$$

$$\text{s.t.} \quad \Pi_{C(1)} - I_C \geq 0 \Rightarrow \left(p_{C(1)} - c\right) x_{C(1)} - \frac{x^2_{C(1)}}{2\psi} \geq 0 \qquad (41)$$

where $MW_{(1)}$ is the welfare of the pre-innovation membership in stage 1. The optimality conditions for the co-op's optimization problem suggest that the co-op will find it optimal to choose its price such that the investment constraint binds, i.e., the co-op will price its product so that it raises exactly the amount of capital needed for its innovation activity in stage 2. The best response function of the co-op is then:

$$p_{C(1)} = \frac{\mu + 4c\mu\psi + p_{I(1)}}{4\mu\psi + 1}$$

The Nash equilibrium prices and quantities at the pre-innovation stage of the mixed oligopoly are given by:

$$p'_{I(1)} = c + \frac{\mu\left(4\mu\psi - 1\right)}{8\mu\psi - 3} \qquad (42)$$

$$x'_{I(1)} = \frac{8\mu^2\psi^2 + 4\mu\psi - 3}{(1 + 4\mu\psi)(8\mu\psi - 3)} \qquad (43)$$

$$p'_{C(1)} = c + \frac{4\mu\left(3\mu\psi - 1\right)}{\left(1 + 4\mu\psi\right)\left(8\mu\psi - 3\right)} \qquad (44)$$

$$x'_{C(1)} = \frac{8\mu\psi\left(3\mu\psi - 1\right)}{\left(1 + 4\mu\psi\right)\left(8\mu\psi - 3\right)} \qquad (45)$$

Substituting the equilibrium pre-innovation membership of the co-op (equation (45)) in equations (35)-(37) gives the subgame perfect equilibrium innovation levels in the mixed duopoly. Substituting the new expressions of t_I and t_C into equations (24)-(30) gives the subgame perfect equilibrium prices and quantities in the post-innovation stage of the game.

Table 2 summarizes the subgame perfect equilibrium in the mixed oligopoly. Note that, unlike the pure duopoly case, the subgame perfect equilibrium in the mixed oligopoly is asymmetric. The member-welfare maximizing co-op charges lower prices both in the pre- and post-innovation stages of the game and invests more in quality-enhancing innovation than the IOF. The reason is that, due to its objective function, the co-op is better able to internalize the costs and benefits of innovation.

Before concluding this section, it is important to point out that the lower the innovation costs and/or the less heterogeneous the consumers, the greater the market share of the co-op at the post-innovation stage of the game. When $\mu\psi < 0.625$, the IOF will exit the market at the 3rd stage of the game (i.e., $x_{I(3)} = 0$) and the co-op will dominate the market (i.e., $x_{I(3)} = 1$). The exit of the IOF in stage 3 eliminates its incentives to innovate in stage 2 and, therefore, changes the equilibrium conditions in the mixed oligopoly. In this context, before comparing the subgame perfect equilibria in the pure and mixed oligopolies, it is important to consider the case where the co-op ends up being a monopolist at the post-innovation stage of the game.

3.4. Innovation and pricing decisions when the co-op is a monopolist in stage 3

Price Competition at the Post-Innovation Stage

Similar to the case examined previously, the objective of the co-op at the post-innovation stage is to maximize the welfare of its members without incurring financial losses. Since consumer welfare is inversely related to food product prices, the co-op will price its product at marginal cost and will dominate the market since, when $p_{C(3)} = c$ and $\mu\psi < 0.625$, the IOF will find it optimal to exit the market. Thus, the Nash equilibrium prices, quantities, profits, and consumer welfare are:

$$x''_{I(3)} = 0 \quad (46)$$

$$p''_{C(3)} = c \quad (47)$$

$$x''_{C(3)} = 1 \quad (48)$$

$$\Pi''_{I(3)} = 0 \quad (49)$$

$$\Pi''_{C(3)} = 0 \quad (50)$$

$$MW''_{(3)} = \left(U_1 - c + t_C + \mu\right) - \frac{1}{2}\mu \quad (51)$$

Innovation Competition

In this stage the two Firms determine their innovation efforts. Since the IOF's post-innovation profits are zero, its optimization problem is equivalent to minimizing innovation costs. Of course, innovation costs are minimized when $t_I = 0$.

Regarding the co-op, its problem at the innovation stage of the game remains to identify the level of innovation that maximizes the welfare of its pre-innovation membership (i.e., consumers that patronized the co-op at the pre-innovation stage of the game), i.e.,

$$\max_{t_C} MW_{(2,3)} = MW''_{(3/1)} - I_C = \left(U_1 - c + t_C + \mu\right) x_{C(1)} - \frac{1}{2}\mu x^2{}_{C(1)} - \frac{1}{2}\psi t_C^2 \quad (52)$$

Solving the maximization problem of the co-op, we get the Nash equilibrium level of innovation as:

$$t''_C = \frac{x_{C(1)}}{\psi} \quad (53)$$

The profits of the IOF and the welfare of the pre-innovation membership in stages 2 and 3 are:

$$\Pi''_{I(2,3)} = 0 \quad (54)$$

$$MW''_{(2,3)} = \left(U_1 - c + \frac{x_{C(1)}}{\psi} + \mu\right) x_{C(1)} - \frac{1}{2}\mu x^2_{C(1)} - \frac{x^2_{C(1)}}{2\psi} \quad (55)$$

Price Competition at the Pre-Innovation Stage

In this stage the two Firms compete in prices. Since the IOF's profits in stages 2 and 3 are zero (and thus, not dependent on the firm's choices in stage 1), the problem of the IOF in stage 1 is to determine the price that maximizes its profits at the pre-innovation stage of the game, i.e.,

$$\max_{p_{I(1)}} \Pi_I^T = \Pi_{I(1)} = (p_{I(1)} - c)x_{I(1)} \tag{56}$$

Regarding the co-op, its payoff in stages 2 and 3 remains dependent on the size of its pre-innovation membership (i.e., $x_{C(1)}$) and, thus, it remains dependent on the outcome of the strategic interaction in stage 1. Thus, the co-op's problem in stage 1 remains to determine the price that maximizes the welfare of its pre-innovation membership in the pre- and post-innovation stages of the game subject to raising the capital required for the innovation activity in stage 2 (see equation (41)).

The Nash equilibrium prices and quantities at the pre-innovation stage of the game are:

$$p''_{I(1)} = c + \frac{2\mu\left(2\mu\psi + 1\right)}{8\mu\psi + 1} \tag{57}$$

$$x''_{I(1)} = \frac{2\mu\psi + 1}{8\mu\psi + 1} \tag{58}$$

$$p''_{C(1)} = c + \frac{3\mu}{8\mu\psi + 1} \tag{59}$$

$$x''_{C(1)} = \frac{6\mu\psi}{8\mu\psi + 1} \tag{60}$$

Substituting (60) into equation (53), we get the subgame perfect equilibrium level of innovation. Table 3 summarizes the subgame perfect equilibrium when $\mu\psi < 0.625$. The co-op charges lower pre-innovation prices than the IOF, and is the sole player in stages 2 and 3. It is important to note that even though we observe a monopoly in stage 3, the equilibrium pricing is equivalent to the perfectly competitive one as the co-op seeks to maximize member welfare (and not profits).

3.5. The effect of cooperative involvement on innovation activity

Having determined the subgame perfect equilibrium conditions in the pure and mixed oligopolies, we can now examine the ramifications of cooperative involvement for quality-enhancing innovation activity, pre- and post-innovation prices, and the welfare of the groups involved. We begin by considering the case where $\mu\psi > 0.625$.

Figure 3 graphs the innovation reaction function of the Firms in the pure and mixed oligopolies. When compared to the reaction function of Firm C in the pure oligopoly ($RF_{C(2)}$), the reaction function of the co-op ($RF'_{C(2)}$) is shifted outwards and rotated rightwards. The co-op has increased incentives to innovate because, by seeking to maximize member welfare, it is better able to internalize the cost and benefits associated with its investment on innovation.

At the same time, the cooperative involvement reduces the marginal profitability of the IOF's investment on innovation by reducing the equilibrium food product prices.

Graphically, the involvement of the co-op results in the reaction function of Firm I (the IOF in both the mixed and pure oligopolies) shifting inwards in rightward rotation. These changes in the reaction functions result in increased innovation by the co-op relative to Firm C in the pure duopoly and reduced innovation by Firm I in the mixed oligopoly case, i.e.,

$$t_C^{'} > t_C^{*} \text{ and } t_I^{'} < t_I^{*} \qquad (61)$$

Regarding the total quality-enhancing product innovation activity, it can be shown that the effect of cooperative involvement depends on the size of innovation costs and the degree of consumer heterogeneity. In particular, when $\mu\psi > 0.701444$, total innovation in the mixed oligopoly exceeds that in the pure duopoly. Formally:

$$\mu\psi \geq (<) 0.701444 \Rightarrow t_{\mathrm{T}}^{'} \geq (<) t_{\mathrm{T}}^{*} \qquad (62)$$

As pointed out by G&F[9], innovation activity in the mixed oligopoly does not always exceed that in the pure oligopoly because the co-op can only partially internalize the cost and benefits associated with its innovation activity. Recall that, when the co-op determines its innovation effort, it is only concerned with the welfare of its pre-innovation membership (i.e., it does not consider the effect of its choices on the rest of the consumers).

Equation (62) indicates that the greater the innovation costs and/or the great the consumer heterogeneity, the more likely it is that the mixed oligopoly will result in higher total innovation than the pure oligopoly. The increased likelihood that total innovation is greater in the mixed oligopoly under higher innovation costs is the direct outcome of the co-op explicitly considering the effects of innovation activity to (at least some) consumers.

In terms of the effect of the degree of consumer heterogeneity on the total innovation undertaken under the pure and mixed oligopolies, the argument is slightly different. Due to the symmetry of the firms in the pure oligopoly, the degree of consumer heterogeneity does not affect the amount of total innovation in this market structure. This is not the case in the mixed oligopoly, however, since μ affects the innovation effort of both the co-op and the IOF. As pointed out by G&F[9], a high value of μ allows the co-op to increase its earnings in stage 1 (used to finance its innovation activity in stage 2) without drastically reducing the size of its pre-innovation membership. At the same time, a high value of μ provides the IOF with incentives to increase its innovation effort since, under increased consumer heterogeneity, this firm can increase its price (and profits) at the post-innovation stage of the game. Thus, as consumer heterogeneity increases, so does total innovation in the mixed oligopoly.

Consider now the effect of cooperative involvement on prices. It is important to note that the effect of cooperative involvement on prices in the pre-innovation stage also determines the effect of cooperative involvement on consumer welfare. This is not the case in the post-innovation stage, however, since it is the effect of co-op on prices but also on the amount of quality-enhancing innovation that determines the welfare effects of cooperative involvement.

Figure 4 graphs the pre-innovation price reaction functions in the pure and mixed oligopolies and illustrates the changes in equilibrium prices caused by the presence of the member welfare maximizing co-op. When compared to Firm C in the pure oligopoly, the co-op's reaction function ($RF_{C(1)}^{'}$) is shifted inwards in leftward rotation. At the same price, the presence of the co-op causes the reaction function of Firm I (IOF in both the pure and mixed oligopolies) to shift outwards in rightward rotation. The result is that both Firms in the mixed oligopoly charge lower prices than the IOFs in the pure duopoly. Since both prices are reduced in the mixed oligopoly, all consumers, members and non-members of the co-op, benefit from the presence of the co-op in the pre-innovation stage of the game. It is important to note that this result holds irrespectively of the degree of consumer heterogeneity and the size of innovation costs.

Similar to the pre-innovation stage, in the post-innovation stage both Firms in the mixed duopoly will charge lower prices than their IOF counterparts in the pure oligopoly. Even though Firm I will invest less in innovation when it competes with a co-op, $t_I^{'} - p_{I(3)}^{'} > t_I^{*} - p_{I(3)}^{*}$ $\forall$ $\mu\psi$. This is important since it implies that the utility associated with the consumption of the product of Firm I is always higher in the mixed duopoly. Regarding Firm C, since $t_C^{'} > t_C^{*}$ and $p_{C(3)}^{'} < p_{C(3)}^{*}$, $t_C^{'} - p_{C(3)}^{'} > t_C^{*} - p_{C(3)}^{*}$ indicating that the utility associated with the consumption of co-op's product is higher than the utility derived from the product of Firm C in the pure oligopoly. Thus, similar to the pre-innovation stage, the presence of the co-op benefits all consumers, members and non-members of the co-op, and this result is independent of μ and ψ. The effect of cooperative involvement on the welfare of consumers in the post-innovation stage is shown in Figure 5.

For completeness of exposition, consider next the ramifications of cooperative involvement when $\mu\psi < 0.625$ and the co-op becomes a monopolist at the post-innovation stage of the game (Table 3). Relative to the pure oligopoly, total innovation falls in this case because, even though the co-op innovates more than each individual IOF in the pure oligopoly, its innovation effort is less than the aggregate of these IOFs. Thus, when $\mu\psi < 0.625$ the presence of the co-op induces exit of Firm I and results in reduced quality-enhancing innovation activity.

In terms of pre-innovation prices, both firms charge lower prices in the mixed oligopoly than their counterparts in the pure oligopoly indicating that the presence of the co-op benefits all consumers at the pre-innovation stage of the game. This is also true for the post-innovation stage since $t_C^{'} - p_{C(3)}^{'} > t_C^{*} - p_{C(3)}^{*}$ and $t_C^{'} - p_{C(3)}^{'} > \mu + t_I^{*} - p_{I(3)}^{*}$. Thus, even though the presence of the co-op reduces total innovation when $\mu\psi < 0.625$, the price effect is such that the utility associated with the consumption of the co-op's product is greater than the utilities associated with the consumption of the products supplied by the two IOFs in the pure oligopoly. Figure 6 depicts both the dominance of the co-op in the post-innovation stage and the consumer benefits from its presence.

Overall, the analysis in this section reveals that even though the cooperative involvement in quality-enhancing innovation in markets for horizontally differentiated products does not always result in increased innovation activity, it does cause an unambiguous increase in the welfare of all consumers, members and non-members of the co-op. Note that the reduced price-cost margins in the mixed oligopoly indicate that the co-operative involvement in product innovation enhances competition and, thus, it enhances total economic welfare in this market. These findings are consistent with the results of G&F[9] on the effects of the involvement of input-supplying co-ops in process innovation activity.

While both the consumer co-op considered in this study and the input-supplying co-op examined in G&F[9] constitute a backward integration of their members (i.e., they are formed by groups that are part of the demand side of these co-ops (consumers in the case of the consumer co-op and agricultural producers in the case of the input supplying co-op)), the nature of the innovation activity considered in the two cases is different. An important implication of this is that when considering the effect of cooperative involvement in markets for horizontally differentiated products, the nature of innovation activity does not matter. No matter if it is cost-reducing process innovation or quality-enhancing product innovation, the involvement of cooperatives that are a backward integration of their members *can* increase the innovation activity in the market, is welfare enhancing and, thus, socially desirable.

4. Vertical product differentiation: co-op is the high quality firm

After analyzing the effect of cooperative involvement in product innovation activity in markets for horizontally differentiated products, we turn our attention to markets for vertically differentiated products. In particular, adopting the same game-theoretic structure and (relevant) assumptions, we seek to determine the effect of cooperative involvement in quality-enhancing innovation in markets for products that are uniformly quality ranked by consumers.

To begin, consider first the case where the products of the two firms are vertically differentiated with the product supplied by Firm C (co-op in the mixed oligopoly) being the high quality product. Before deriving the subgame perfect equilibria in the pure and mixed oligopolies, we need to derive the consumer demands at the pre- and post-innovations stages of the game.

4.1 Consumer decisions and welfare

Consumer Decisions in Stage 1

Similar to the case of horizontal product differentiation, consumers have the choice between the products of Firm I and Firm C and the purchasing decision represents a small share of their budget. Consumers consume one unit of a product and, even though they uniformly quality rank the two products, they differ in their valuation of the perceived quality differences. To capture these elements, consumer utility is now:

$$U_{C(1)} = U_1 - p_{C(1)} + \mu\alpha \quad \text{If a unit of Firm C's product is consumed}$$
$$U_{I(1)} = U_1 - p_{I(1)} - \mu\alpha \quad \text{If a unit of Firm I's product is consumed} \qquad (63)$$

where all variables are as previously defined. Note that if $p_{C(1)} = p_{I(1)}$, $U_{C(1)} \geq U_{I(1)}$ $\forall\alpha$ and all consumers will buy the product of Firm C. For different prices, the consumer with differentiating attribute $\alpha_{I(1)}$ where:

$$\alpha_{I(1)} : U_{C(1)} = U_{I(1)} \Rightarrow U_1 - p_{C(1)} + \mu\alpha = U_1 - p_{I(1)} - \mu\alpha \Rightarrow$$
$$\alpha_{I(1)} = \frac{p_{C(1)} - p_{I(1)}}{2\mu} \qquad (64)$$

is indifferent between the two products and determines the demands faced by Firm I, $x_{I(1)} = \alpha_{I(1)}$, and Firm C, $x_{C(1)} = 1 - \alpha_{I(1)}$, at the pre-innovation stage:

$$x_{I(1)} = \frac{p_{C(1)} - p_{I(1)}}{2\mu} \qquad (65)$$

$$x_{C(1)} = \frac{2\mu + p_{I(1)} - p_{C(1)}}{2\mu} \qquad (66)$$

Consumer Decisions in Stage 3

The utility function at the post- innovation stage (i.e., after the quality enhancing product innovation) is:

$$U_{C(3)} = U_1 - p_{C(3)} + \mu\alpha + t_C \qquad \text{If a unit of Firm C's product is consumed}$$
$$U_{I(3)} = U_1 - p_{I(3)} - \mu\alpha + t_I \qquad \text{If a unit of Firm I's product is consumed} \qquad (67)$$

where all variables are as previously defined. Following the same procedure established earlier, we derive the demand functions faced by the two firms at the post- innovation stage as:

$$x_{I(3)} = \frac{p_{C(3)} - p_{I(3)} - t_C + t_I}{2\mu} \qquad (68)$$

$$x_{C(3)} = \frac{2\mu + p_{I(3)} - p_{C(3)} - t_I + t_C}{2\mu} \qquad (69)$$

4.2. Benchmark case: innovation and pricing decisions in a pure oligopoly

To determine the effect of cooperative involvement in innovation activity in a vertically differentiated market where the co- op is perceived as the high quality firm, we need to first analyze the benchmark case of the pure oligopoly with Firm C being the high quality firm.

Since the only thing that varies from our previous analysis is the nature of product differentiation, we will omit the derivations and will only present the equilibrium conditions at the different stages of the game. The subgame perfect equilibrium in the pure duopoly is presented in Table 4. Unlike the horizontal product differentiation case, the pure oligopoly equilibrium in this vertical product differentiation case is not symmetric. In particular, the high quality IOF charges higher prices in both the pre- and post- innovation stages of the game, enjoys greater market shares, and invests more in quality- enhancing innovation than its low quality counterpart.

4.3. Innovation and pricing decisions in a mixed oligopoly

Table 5 presents the subgame perfect equilibrium for the case where the high quality Firm C of the pure oligopoly is replaced by a high quality, member welfare maximizing, open membership co- op. A very important result here is that the presence of the high quality co-op results in the low quality IOF not investing in quality- enhancing product innovation and exiting the market at the post- innovation stage of the game. At the pre- innovation stage, the co- op will charge a higher price than the IOF due to its need to raise capital for its subsequent innovation activity. Despite it charging a higher price, the superior quality of its product enables the co- op to enjoy a higher market share than the IOF.

4.4. The effect of cooperative involvement on innovation activity

Having determined the subgame perfect equilibrium conditions in the pure and mixed oligopolies, we can now examine the effect of cooperative involvement in vertically differentiated markets when the co- op is the high quality firm. In terms of innovation activity, not only does the co- op innovate more than each individual IOF in the pure duopoly, its innovation activity exceeds the aggregate of the pure oligopolists. Therefore, the presence of a high quality co- op increases the quality- enhancing innovation in a vertically differentiated product market.

In terms of pre- innovation prices, both the co- op and the IOF charge lower prices than their IOF counterparts in the pure duopoly. In addition, the co- op charges lower post-innovation prices than both IOFs in the pure oligopoly which, combined with its increased innovation effort, implies that $t_C^{'} - p_{C(3)}^{'} > t_C^{*} - p_{C(3)}^{*}$ and $t_C^{'} - p_{C(3)}^{'} > t_I^{*} - p_{I(3)}^{*}$. The presence of the co-op is, therefore, consumer welfare enhancing in both the pre- and post-innovation stages of the game.

5. Vertical product differentiation: co-op is the low quality firm

5.1. Consumer decisions and welfare

Consider finally the case where Firm C (the co-op in the mixed oligopoly) is the low quality firm in a vertically differentiated product market. The demands faced by Firm I and Firm C at the pre-innovation stage are (see equations (65) and (66)):

$$x_{I(1)} = \frac{2\mu + p_{C(1)} - p_{I(1)}}{2\mu} \quad (70)$$

$$x_{C(1)} = \frac{p_{I(1)} - p_{C(1)}}{2\mu} \quad (71)$$

while the relevant demands at the post-innovation stage are (see equations (68) and (69)):

$$x_{I(3)} = \frac{2\mu + p_{C(3)} - p_{I(3)} - t_C + t_I}{2\mu} \quad (72)$$

$$x_{C(3)} = \frac{p_{I(3)} - p_{C(3)} - t_I + t_C}{2\mu} \quad (73)$$

5.2. Benchmark case: innovation and pricing decisions in a pure oligopoly

Table 6 presents the subgame perfect equilibrium in the pure duopoly when Firm C is the low quality firm. Note that Table 6 is analogous to Table 4 with the identities of the high and low quality IOFs being switched. Thus, similar to the case where Firm C was the high quality firm, the high quality IOF charges higher prices in both the pre- and post-innovation stage of the game, enjoys greater market shares, and undertakes higher innovation effort than the low quality IOF.

5.3. Innovation and pricing decisions in a mixed oligopoly

Table 7 presents the subgame perfect equilibrium conditions when the low quality Firm C is a co-op instead of an IOF. In this case, the low quality co-op charges lower prices and has lower market shares than the high quality IOF in both the pre- and post-innovation stages. Regarding innovation, like all other cases of vertical product differentiation examined in this paper, the high quality firm (IOF in this case) innovates more than the low quality one (co-op in this case).

It is important to note that, for relatively low innovation costs and/or low degree of consumer heterogeneity (i.e., for $\mu\psi < 0.5$), the co-op will exit the market in stage 3 (and will not invest in innovation in stage 2). Table 8 summarizes the subgame perfect equilibrium for this case. Not needing to raise capital for innovation activity, the co-op prices at marginal cost at the pre-innovation stage and splits the market with the high quality IOF.

5.4. The effect of cooperative involvement on innovation activity

Comparing the subgame perfect equilibrium conditions in the pure and mixed oligopolies, we can determine the effect of cooperative involvement in vertically differentiated markets when the co-op is the low quality firm. In terms of innovation, the presence of the co-op increases the profitability of investment in innovation for the high quality Firm I and, consequently, this firm innovates more in the mixed oligopoly case. Even though the low quality co-op innovates more than its IOF counterpart in the pure oligopoly only when $\mu\psi > 0.6$ (and does not innovate at all when $\mu\psi < 0.5$), total innovation is always higher in the mixed oligopoly, i.e., the presence of the low quality co-op increases the quality-enhancing innovation activity in a vertically differentiated product market.

In terms of pre-innovation prices, both the co-op and the IOF charge lower prices than their IOF counterparts in the pure duopoly, while, in the post innovation stage of the game, it always holds that $t_I^{'} - p_{I(3)}^{'} > t_I^{*} - p_{I(3)}^{*}$ and $t_C^{'} - p_{C(3)}^{'} > t_C^{*} - p_{C(3)}^{*}$ ($t_I^{'} - p_{I(3)}^{'} > t_C^{*} - p_{C(3)}^{*}$ when $\mu\psi < 0.5$). Therefore, the presence of the co-op is welfare enhancing in both the pre- and post-innovation stages of the game.

6. Conclusions

This paper developed a sequential game-theoretic model of heterogeneous consumers to analyze the market and welfare effects of cooperative involvement in quality-enhancing, product innovation activity. The open membership cooperative considered in our analysis seeks to maximize the welfare of its members and addresses its property rights problems by financing its investment activity through retained earnings.

The effect of cooperative involvement in quality-enhancing innovation activity was considered in the context of three differentiated product market settings: a horizontally differentiated product market, a vertically differentiated product market with the co-op being the high quality firm, and a vertically differentiated product market with the co-op being the low quality firm.

Analytical results show that, in all cases, cooperative involvement in quality-enhancing product innovation is welfare enhancing – the presence of the member welfare maximizing co-op is shown to result in reduced food prices and welfare gains for all consumers, members and non-members of the co-op. In terms of innovation, while the presence of the co-op in vertically differentiated product markets results in increased quality-enhancing innovation activity no matter if the co-op is a high or a low quality firm, the effect of the cooperative on the innovation effort in horizontally differentiated product markets depends on the degree of consumer heterogeneity and the size of the innovation costs. Thus, while the nature of product differentiation does not affect the welfare effects of cooperatives, it can influence their effect on total product innovation activity in the market.

Before concluding this paper, it should be pointed out that our findings on the effect of cooperative involvement in product innovation activity in markets for horizontally differentiated products are consistent with the results of G&F[9] on the effects of the involvement of input-supplying co-ops in process innovation activity when the agricultural inputs are horizontally differentiated. While both the consumer co-op considered in this study and the input-supplying co-op examined in G&F[9] constitute a backward integration of their members (i.e., they are formed by groups that are part of the demand side of these co-ops), the nature of the innovation activity considered in the two cases is different. An important implication of this is that when considering the effect of cooperative involvement in markets for horizontally differentiated products, the nature of innovation activity does not matter. No matter if it is cost-reducing process innovation or quality-enhancing product innovation, the involvement of cooperatives that are a backward integration of their members *can* increase the innovation activity in the market, is welfare enhancing and, thus, socially desirable.

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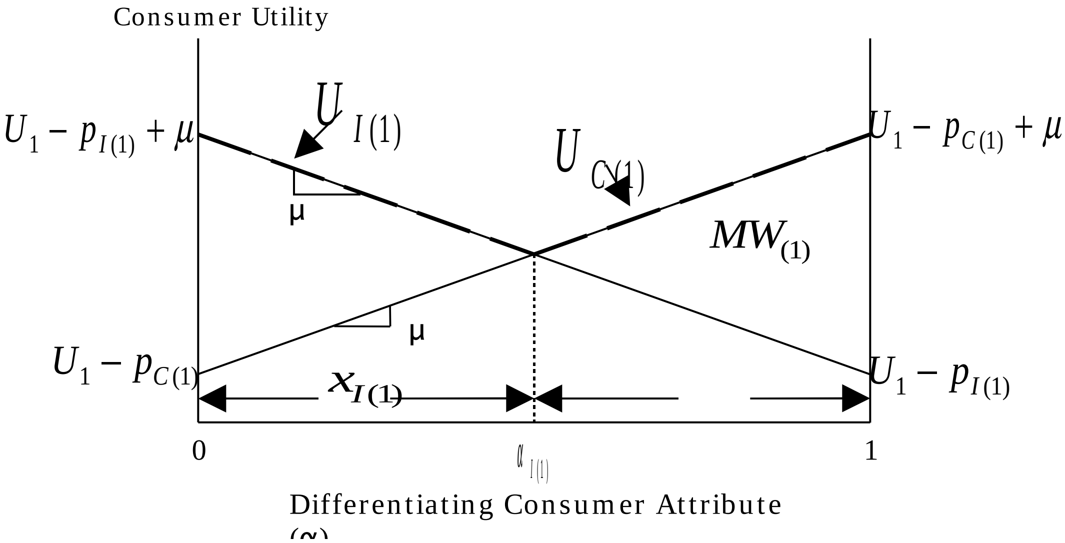

Figure 1. Consumer decisions and welfare at the pre- innovation stage

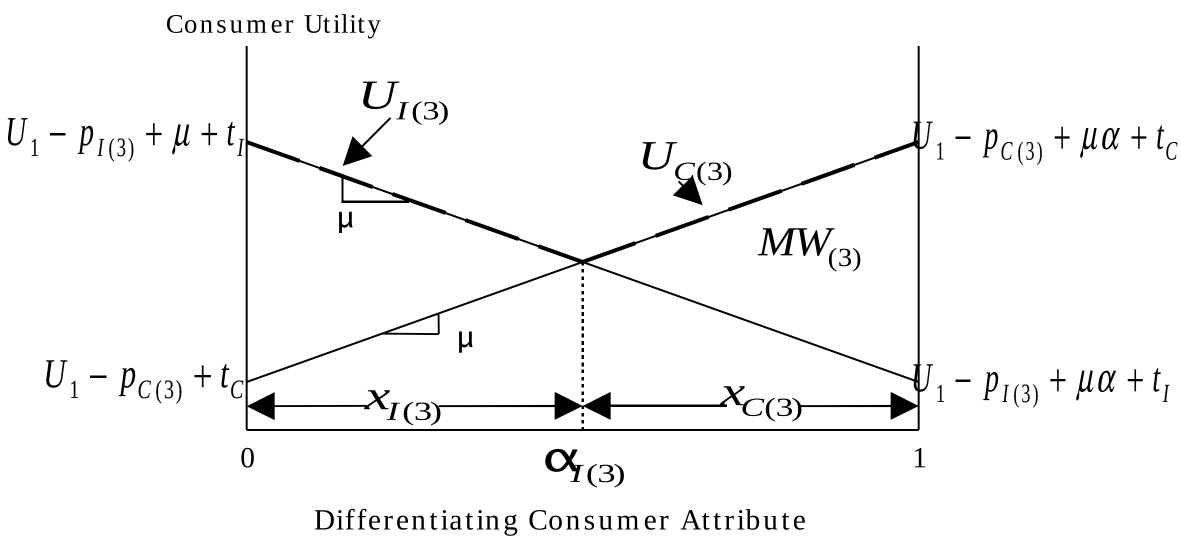

Figure 2. Consumer decisions and welfare at the post- innovation stage

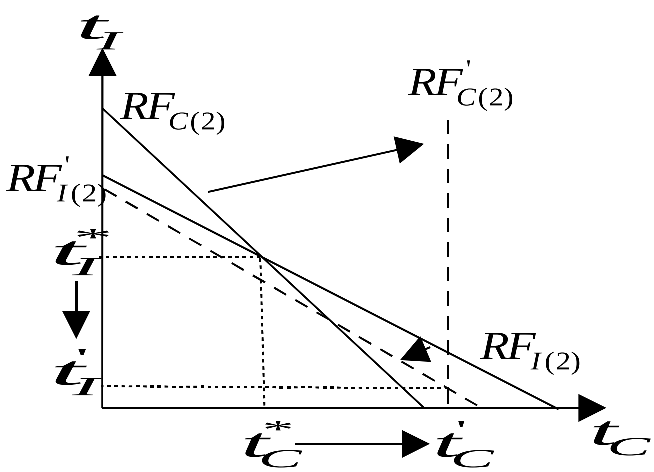

Figure 3. Effect of Cooperative Involvement on Innovation Activity

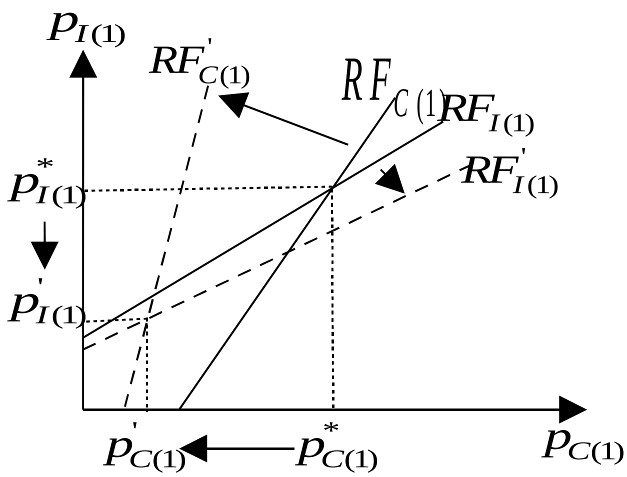

Figure 4. Effect of Cooperative Involvement on Pre-Innovation Prices

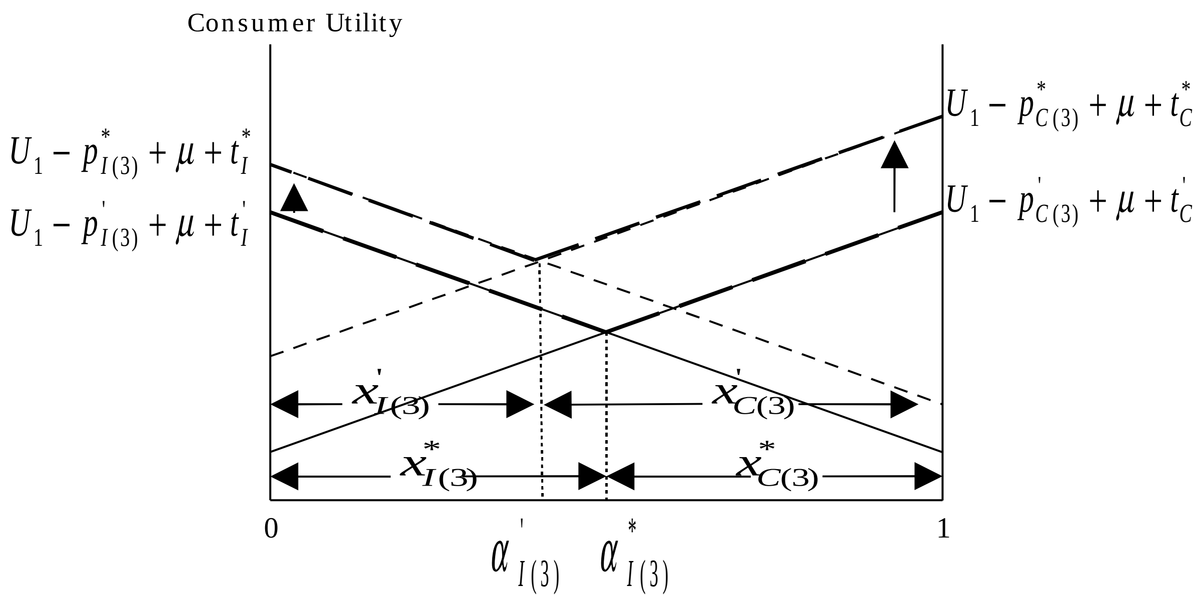

Figure 5. Market and Welfare Effects of Cooperative Involvement (Post-Innovation Stage)

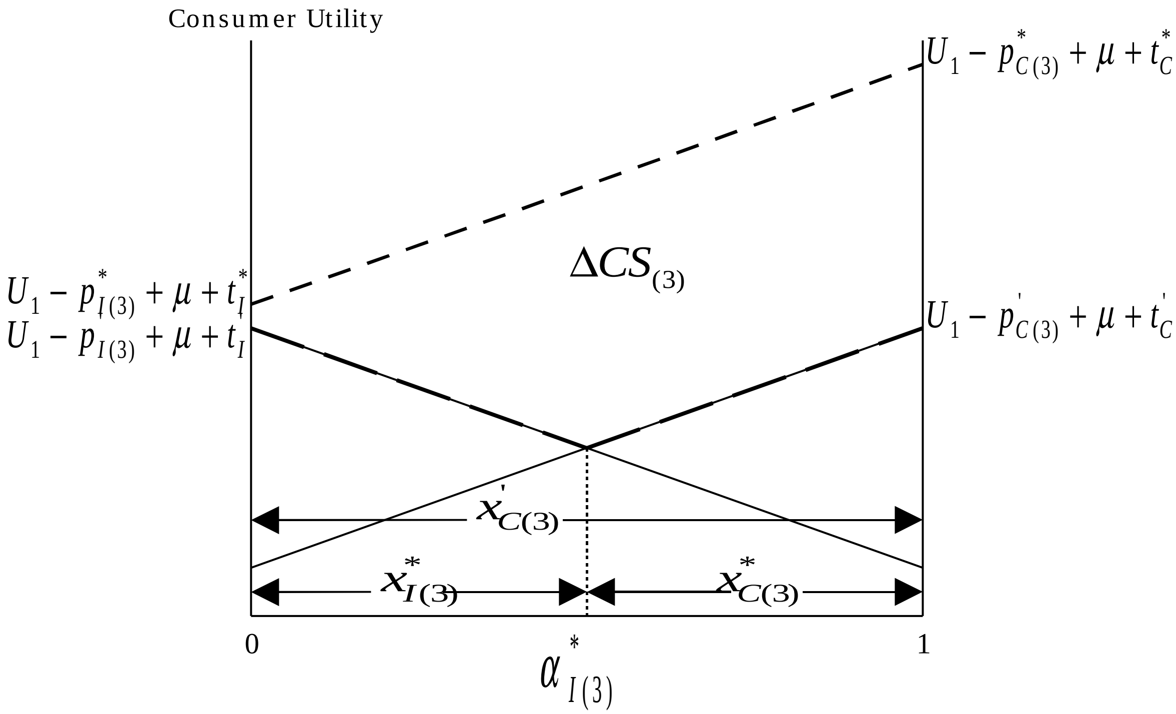

Figure 6. Market and Welfare Effects of Cooperative Involvement when Co-op is a Monopolist at the Post-Innovation Stage

Table 1. Horizontal Product Differentiation: Subgame Perfect Equilibrium in the Pure Oligopoly

Pre-innovation Stage (Stage 1)	$p_{i(1)}$	$c+\mu$
	$x_{i(1)}$	$\frac{1}{2}$
	$\Pi_{i(1)}$	$\frac{\mu}{2}$
Innovation Stage (Stage 2)	t_i	$\frac{1}{3\psi}$
	t_{T}	$\frac{2}{3\psi}$
Post-innovation Stage (Stage 3)	$p_{i(3)}$	$c+\mu$
	$x_{i(3)}$	$\frac{1}{2}$
	$\Pi_{i(2,3)}$	$\frac{9\mu\psi-1}{18\psi}$

Table 2. Horizontal Product Differentiation: Subgame Perfect Equilibrium in the Mixed Oligopoly ($\mu\psi > 0.625$)

Pre-innovation Stage (Stage 1)	$p_{C(1)}$	$c+\dfrac{4\mu(3\mu\psi-1)}{(1+4\mu\psi)(8\mu\psi-3)}$
	$p_{I(1)}$	$c+\dfrac{\mu(4\mu\psi-1)}{8\mu\psi-3}$
	$x_{C(1)}$	$\dfrac{8\mu\psi(3\mu\psi-1)}{(1+4\mu\psi)(8\mu\psi-3)}$
	$x_{I(1)}$	$\dfrac{8\mu^2\psi^2+4\mu\psi-3}{(1+4\mu\psi)(8\mu\psi-3)}$
Innovation Stage (Stage 2)	t_C	$\dfrac{8\mu(3\mu\psi-1)}{(1+4\mu\psi)(8\mu\psi-3)}$
	t_I	$\dfrac{\mu(8\mu\psi-5)}{(1+4\mu\psi)(8\mu\psi-3)}$
	t_T	$\dfrac{\mu(32\mu\psi-13)}{(1+4\mu\psi)(8\mu\psi-3)}$
Post-innovation Stage (Stage 3)	$p_{C(3)}$	c
	$p_{I(3)}$	$c+\dfrac{2\mu^2\psi(8\mu\psi-5)}{(1+4\mu\psi)(8\mu\psi-3)}$
	$x_{C(3)}$	$\dfrac{24\mu^2\psi^2+\mu\psi-3}{(1+4\mu\psi)(8\mu\psi-3)}$
	$x_{I(3)}$	$\dfrac{\mu\psi(8\mu\psi-5)}{(1+4\mu\psi)(8\mu\psi-3)}$

Table 3. Horizontal Product Differentiation: Subgame Perfect Equilibrium in the Mixed Oligopoly ($\mu\psi < 0.625$)

Pre- innovation Stage (Stage 1)	$p_{C(1)}$	$c+\dfrac{3\mu}{8\mu\psi+1}$
	$p_{I(1)}$	$c+\dfrac{2\mu(2\mu\psi+1)}{8\mu\psi+1}$
	$x_{C(1)}$	$\dfrac{6\mu\psi}{8\mu\psi+1}$
	$x_{I(1)}$	$\dfrac{2\mu\psi+1}{8\mu\psi+1}$
Innovation Stage (Stage 2)	t_C	$\dfrac{6\mu}{8\mu\psi+1}$
	t_I	0
	t_T	$\dfrac{6\mu}{8\mu\psi+1}$
Post- innovation Stage (Stage 3)	$p_{C(3)}$	c
	$p_{I(3)}$	–
	$x_{C(3)}$	1
	$x_{I(3)}$	0

Table 4. Vertical Product Differentiation with Firm C being the High Quality Firm: Subgame Perfect Equilibrium in the Pure Oligopoly.

Pre-innovation Stage (Stage 1)	$p_{C(1)}$	$c+\frac{4\mu}{3}$
	$p_{I(1)}$	$c+\frac{2\mu}{3}$
	$x_{C(1)}$	$\frac{2}{3}$
	$x_{I(1)}$	$\frac{1}{3}$
Innovation Stage (Stage 2)	t_C	$\frac{12\mu\psi-2}{\psi(27\mu\psi-6)}$
	t_I	$\frac{6\mu\psi-2}{\psi(27\mu\psi-6)}$
	t_T	$\frac{2}{3\psi}$
Post-innovation Stage (Stage 3)	$p_{C(3)}$	$c+\frac{2\mu(6\mu\psi-1)}{9\mu\psi-2}$
	$p_{I(3)}$	$c+\frac{2\mu(3\mu\psi-1)}{9\mu\psi-2}$
	$x_{C(3)}$	$\frac{6\mu\psi-1}{9\mu\psi-2}$
	$x_{I(3)}$	$\frac{3\mu\psi-1}{9\mu\psi-2}$

Table 5. Vertical Product Differentiation with the Co-op being the High Quality Firm: Subgame Perfect Equilibrium in the Mixed Oligopoly.

Pre-innovation Stage (Stage 1)	$p_{C(1)}$	$c+\frac{4\mu}{8\mu\psi+1}$
	$p_{I(1)}$	$c+\frac{2\mu}{8\mu\psi+1}$
	$x_{C(1)}$	$\frac{8\mu\psi}{8\mu\psi+1}$
	$x_{I(1)}$	$\frac{1}{8\mu\psi+1}$
Innovation Stage (Stage 2)	t_C	$\frac{8\mu}{8\mu\psi+1}$
	t_I	0
	t_T	$\frac{8\mu}{8\mu\psi+1}$
Post-innovation Stage (Stage 3)	$p_{C(3)}$	c
	$p_{I(3)}$	–
	$x_{C(3)}$	1
	$x_{I(3)}$	0

Table 6. Vertical Product Differentiation with Firm C being the Low Quality Firm: Subgame Perfect Equilibrium in the Pure Oligopoly.

Pre-innovation Stage (Stage 1)	$p_{C(1)}$	$c+\frac{2\mu}{3}$
	$p_{I(1)}$	$c+\frac{4\mu}{3}$
	$x_{C(1)}$	$\frac{1}{3}$
	$x_{I(1)}$	$\frac{2}{3}$
Innovation Stage (Stage 2)	t_C	$\frac{6\mu\psi-2}{\psi(27\mu\psi-6)}$
	t_I	$\frac{12\mu\psi-2}{\psi(27\mu\psi-6)}$
	t_T	$\frac{2}{3\psi}$
Post-innovation Stage (Stage 3)	$p_{C(3)}$	$c+\frac{2\mu(3\mu\psi-1)}{9\mu\psi-2}$
	$p_{I(3)}$	$c+\frac{2\mu(6\mu\psi-1)}{9\mu\psi-2}$
	$x_{C(3)}$	$\frac{3\mu\psi-1}{9\mu\psi-2}$
	$x_{I(3)}$	$\frac{6\mu\psi-1}{9\mu\psi-2}$

Table 7. Vertical Product Differentiation with the Co-op being the Low Quality Firm: Subgame Perfect Equilibrium in the Mixed Oligopoly ($\mu\psi > 0.5$).

Pre-innovation Stage (Stage 1)	$p_{C(1)}$	$c+\frac{4\mu(2\mu\psi-1)}{(4\mu\psi+1)(8\mu\psi-3)}$
	$p_{I(1)}$	$c+\frac{2\mu(4\mu\psi-2)}{8\mu\psi-3}$
	$x_{C(1)}$	$\frac{8\mu\psi(2\mu\psi-1)}{(4\mu\psi+1)(8\mu\psi-3)}$
	$x_{I(1)}$	$\frac{16\mu^2\psi^2+4\mu\psi-3}{(4\mu\psi+1)(8\mu\psi-3)}$
Innovation Stage (Stage 2)	t_C	$\frac{2\mu(8\mu\psi-4)}{(4\mu\psi+1)(8\mu\psi-3)}$
	t_I	$\frac{2\mu(8\mu\psi-1)}{(4\mu\psi+1)(8\mu\psi-3)}$
	t_T	$\frac{2\mu(16\mu\psi-5)}{(4\mu\psi+1)(8\mu\psi-3)}$
Post-innovation Stage (Stage 3)	$p_{C(3)}$	c
	$p_{I(3)}$	$c+\frac{4\mu^2\psi(8\mu\psi-1)}{(4\mu\psi+1)(8\mu\psi-3)}$
	$x_{C(3)}$	$\frac{16\mu^2\psi^2-2\mu\psi-3}{(4\mu\psi+1)(8\mu\psi-3)}$
	$x_{I(3)}$	$\frac{2\mu\psi(8\mu\psi-1)}{(4\mu\psi+1)(8\mu\psi-3)}$

Table 8. Vertical Product Differentiation with Co-op being the Low Quality Firm: Subgame Perfect Equilibrium in the Mixed Oligopoly ($\mu\psi < 0.5$).

Pre-innovation Stage (Stage 1)	$p_{C(1)}$	c
	$p_{I(1)}$	$c+\mu$
	$x_{C(1)}$	$\frac{1}{2}$
	$x_{I(1)}$	$\frac{1}{2}$
Innovation Stage (Stage 2)	t_C	0
	t_I	$\frac{1}{\psi}$
	t_T	$\frac{1}{\psi}$
Post-innovation Stage (Stage 3)	$p_{C(3)}$	$-$
	$p_{I(3)}$	$c+\frac{1}{\psi}$
	$x_{C(3)}$	0
	$x_{I(3)}$	1