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# Licensing in agricultural markets: The role of cooperatives


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## 1. Introduction

Investment in agricultural research and development (R&D) has transformed agriculture and has contributed to the structural change of many economies around the world as technology adoption has been a primary driver of the rapid growth and productivity gains experienced by the sector (see Evenson et al., 1975; Alston et al., 2000; Alston and Pardey, 2021). Due to the increased agricultural input market concentration, the majority of investment in R&D activities is performed by invested-owned firms (IOFs) (Fuglie et al., 2012). While IOFs account for the majority of non-public patented innovations, cooperatives focus primarily on the adoption of external technologies to improve their competitiveness and economic performance (Acosta et al., 2015).

Cooperatives are key actors in the agricultural sector of numerous developed and developing countries around the world (Bijman and Iliopoulos, 2014). These member-owned organizations play a significant role in the supply of inputs for agricultural products and the provision of marketing services to farmers who patronize their activities at lower costs. The ability of cooperatives to provide these benefits is facilitated by the nature of their organizational form, i.e., cooperatives seek to maximize member welfare (Fulton and Giannakas, 2001, 2013), and economies of scale and/or increased bargaining power associated with the larger size of many cooperative organizations (Sexton, 1990; Rogers and Sexton, 1994; Karantininis and Zago, 2001).

Despite the prevalence of mixed markets in which cooperatives compete alongside IOFs, and the involvement of cooperatives in innovation activity (Giannakas and Fulton, 2005; Drivas and Giannakas, 2010; Luo et al. 2017), the impact of cooperative involvement in licensing of innovations has largely been ignored by the relevant literature. The large economic literature on licensing has focused, instead, on pure oligopolies; i.e., markets with a small number of firms making licensing decisions to maximize their profits.

An exception is a recent paper by Chennak and Giannakas (2023) that examines the impacts of cooperative involvement in technology licensing when the cooperative is the innovating firm/owner of a process innovation. Chennak and Giannakas (2023) develop, compare, and contrast sequential game-theoretic models of technology licensing in pure and mixed oligopoly settings that explicitly account for the empirically relevant pre-innovation cost differences between firms and heterogeneity of members and non-members of the cooperative. They show that the organizational form does matter in technology licensing; cooperative behavior differs from that of its investor-owned counterparts yielding significantly different equilibrium outcomes in mixed oligopolies where the cooperative is the licensor of the process innovation involved. In particular, while the optimal licensing contract in the pure oligopoly depends on the pre-innovation cost difference between firms and the degree of agent heterogeneity [the smaller (greater) the degree of agent heterogeneity and/or the greater (smaller) the pre-innovation cost difference between the firms involved, the more likely it is that the IOF will find it optimal to offer a two-part tariff (royalty) licensing contract], the member welfare-maximizing cooperative will always find it optimal to offer a royalty licensing contract as it enables it to maintain its membership while benefiting from the collected licensing revenues. Finally, Chennak and Giannakas (2023) show that both the cooperative in the mixed oligopoly and the IOF in the pure oligopoly prefer a contract that is less socially desirable as total economic welfare is maximized under a fixed fee licensing contract.

As most privately-owned patents are held by IOFs, the objective of this paper is to build on this emerging literature and examine the impact of cooperatives on technology licensing when the cooperative is a licensee, rather than the licensor, of the relevant innovation. In essence, this paper makes two contributions to the literature. The first contribution is the examination and determination of whether the presence of the cooperative as a licensee matters for technology licensing, that is, whether there is a difference in the licensing behavior of the innovating IOF/licensor when licensing to a member welfare maximizing cooperative relative to when licensing to another profit maximizing IOF. The second contribution is the examination and determination of the impact of the nature of cooperative involvement in licensing (the cooperative being the licensor versus being the licensee) on the licensing outcome and technology transfer.

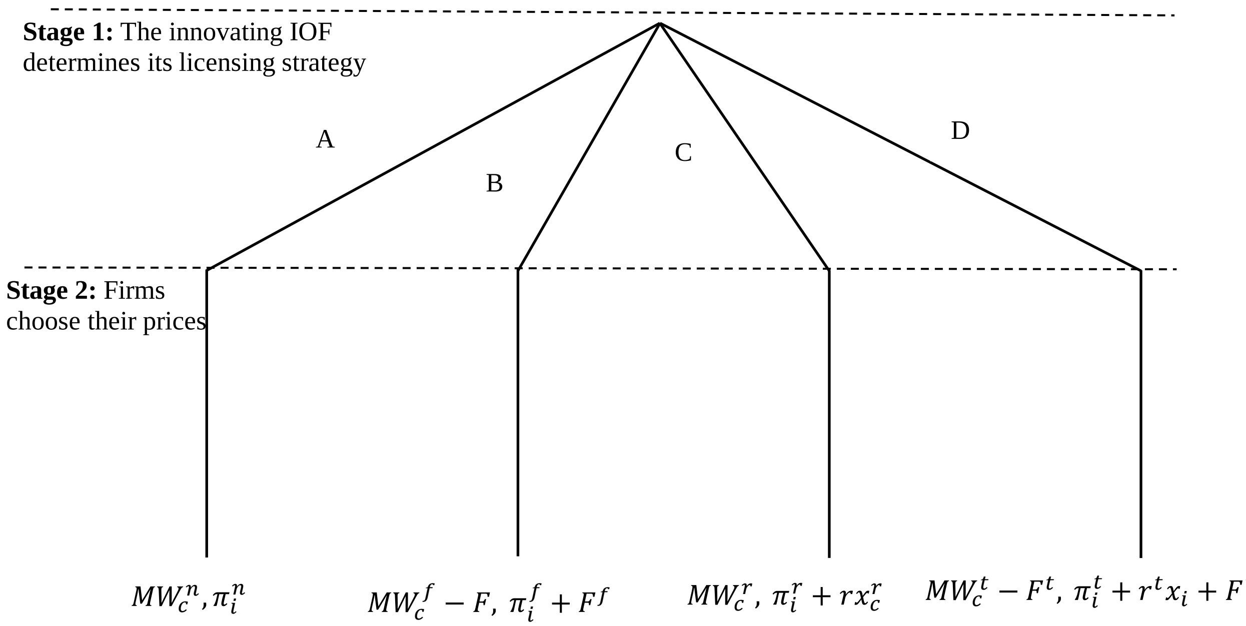
The impacts of the involvement of cooperatives as licensees in technology transfer are determined by comparing our results to the results on licensing in pure and mixed oligopolies derived by Chennak and Giannakas (2023). To facilitate comparability of our results to those of Chennak and Giannakas (2023), our paper adopts a similar structure of the licensing game between the licensor and the licensee and assumptions on the asymmetric cost structure of these firms and the heterogeneity of the members and non-members of the cooperative.

The rest of the paper is organized as follows: Section 2 presents the methodological framework and the main assumptions of our analysis. Section 3 analyses the producer decisions on the firm they will patronize. In sections 4 and 5 the market and welfare impacts of different licensing contracts are derived, and the optimal licensing contract is determined in the mixed oligopoly with the cooperative being the licensee, respectively. The results of these sections are, then, compared with the results of Chennak and Giannakas (2023) to determine the impact of cooperative involvement as a licensee in technology transfer. Section 6 provides two extensions of our analysis. The first examines the implications of licensing for innovation incentives, while the second investigates the impact of the nature of price competition on firms' licensing behavior. Section 7 concludes the paper.

## 2. Methodological framework

We consider two firms, an IOF (firm $I$) and a cooperative (firm $C$) that supply an input to agricultural producers and compete in a horizontally differentiated market. The difference in the organizational form of the cooperative and the IOF is reflected in the difference in their objective functions. The IOF seeks to maximize its profits, while the cooperative seeks to maximize the welfare of its members (i.e., farmers/producers that patronize its activities) without incurring economic losses.

Before the innovation, the cooperative and IOF marginal costs are $c_c$ and $c_i$, respectively, with $\Delta c = c_c - c_i$ denoting the difference between these costs. The IOF owns the process innovation that reduces the marginal cost of production by $\delta$. Thus, in the absence of licensing, the IOF's marginal cost is $c_i - \delta$, while the cooperative's marginal cost is $c_c$. The licensing game between the two firms is modeled as a two-stage sequential game, where, in stage one, the innovating IOF has the choice of licensing its cost-reducing technology to the cooperative via a fixed fee contract, a per-unit royalty contract, a two-part tariff contract, or not licensing at all, and, in stage two, the firms strategically choose their prices to maximize their payoff functions based on the producer demands for their products. Once the producer demands for the agricultural inputs have been derived, the licensing game is solved using backward induction (Gibbons, 1992). The pricing decisions of the input suppliers under different licensing scenarios is analyzed first, followed by the determination of the optimal licensing contract. The licensing game is depicted in Figure 1.




A: No licensing
B: Fixed fee contract
C: Royalty contract
D: Two-part tariff contract

**Figure 1.** The licensing game in the extensive form

## 3. Producer decisions and welfare

Before analyzing the licensing and the pricing decisions of the input suppliers in the mixed oligopoly, we derive the producer demands faced by the two inputs suppliers by examining the producers' (e.g., farmers) decision when procuring their inputs. In particular, consider a farmer/producer who has the choice between buying one unit of input supplied by the cooperative and the IOF. Due to differences in things like location, agronomic characteristics, education, management skills, land quality, and/or preferences for organizational form (Fulton and Giannakas, 2001), producers differ in the returns they receive from the use of inputs supplied by the different firms. Let the parameter $\alpha \in [0,1]$ capture the attribute that differentiates producers. The producer with differentiating attribute $\alpha$ has the following net returns function:

$$NR_i = p_f - (p_i + \lambda\alpha) \qquad \textit{if a unit of the IOF's input is procured}$$
$$NR_c = p_f - [p_c + \lambda(1-\alpha)] \quad \textit{if a unit of the cooperative's input is procured} \qquad (1)$$

where $NR_i$ and $NR_c$ are the farmer's net returns associated with producing one unit of the output using the input supplied by the IOF and the cooperative, respectively; $p_i$ and $p_c$ are the prices of these inputs; and $p_f$ is the farm price of the output produced by the farmer. The coefficient $\lambda$ is non-negative and captures the degree of producer heterogeneity. The greater is $\lambda$, the greater is the difference in the farmer benefits from the two inputs. Farmers with large values of the differentiating attribute $\alpha$ prefer the input supplier by the cooperative, while farmers with low values of $\alpha$ prefer the input supplied by the IOF.

Each farmer produces one unit of the farm output using one unit of the input in question (i.e., the farmers have a fixed proportions production technology) and the purchasing decision depends on the benefits associated with the use of each input. In particular, the producer with differentiating attribute $\alpha_i$: $NR_c = NR_i$ is indifferent between buying from the IOF and buying from the cooperative. Producers with $\alpha \in [0, \alpha_i)$ are better off buying from the IOF, while producers with $\alpha \in (\alpha_i, 1]$ are better off buying from the cooperative. Formally, the differentiating attribute $\alpha_i$ is given by:

$$\alpha_i : NR_c = NR_i \quad => \quad \alpha_i = \frac{p_c - p_i + \lambda}{2\lambda} \qquad (2)$$

When producers are uniformly distributed with respect to the differentiating attribute $\alpha$ and their mass is normalized to one, the producer demands faced by the IOF and the cooperative, $x_i$ and $x_c$, respectively, are determined by the differentiating attribute of the indifferent producer $\alpha_i$ as:

$$x_i = \alpha_i = \frac{p_c - p_i + \lambda}{2\lambda} \qquad (3)$$

$$x_c = 1 - \alpha_i = \frac{p_i - p_c + \lambda}{2\lambda} \qquad (4)$$

Figure 2 illustrates producers' decisions in the net returns space. The upward sloping curve represents the net returns when the cooperative's input is purchased, while the downward sloping curve graphs the net returns when the IOF's input is purchased. The intersection of the two net return curves gives the differentiating attribute $\alpha_i$ that characterizes the indifferent producer, and the producer demands faced by the IOF and the cooperative are given by $x_i$ and $x_c$, respectively.

As the net returns expressions in equation (1) are direct measures of producer welfare associated with the use of the different inputs, the area under the dashed kinked line in Figure 2 depicts the welfare of the different producer groups. In particular, the welfare of the producers patronizing the cooperative and the IOF are, respectively,

$$PW_c = \int_{\alpha_i}^{1} NR_c d\alpha = \left(p_f - p_c\right) x_c - \frac{\lambda}{2} x_c^2, \qquad PW_i = \int_{0}^{\alpha_i} NR_i d\alpha = \left(p_f - p_i\right) x_i - \frac{\lambda}{2} x_i^2 \tag{5}$$

The total producer welfare is, then, given by:

$$PW = PW_c + PW_i \tag{6}$$

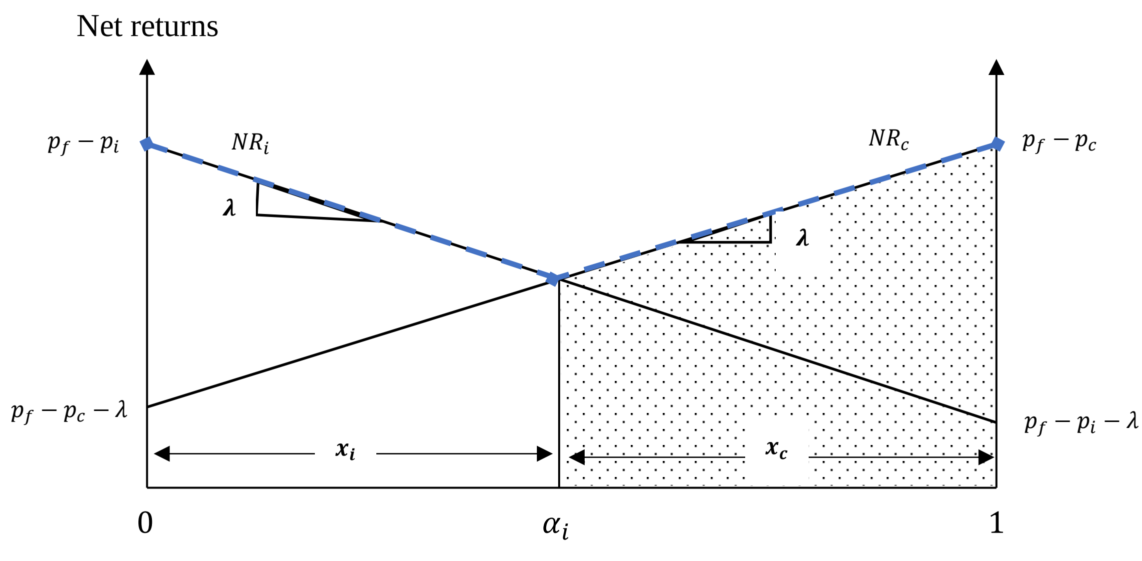



**Figure 2.** Producer decisions and welfare

## 4. Licensing in a mixed oligopoly with the cooperative as the licensee

### 4.1. Benchmark case: No licensing

Under no licensing, the marginal costs of the IOF and the cooperative are $c_i - \delta$ and $c_c$, respectively. In the last stage of the game, the two input suppliers simultaneously choose the price to maximize their objective functions. The IOF seeks to determine the input price $p_i$ that maximizes its profits, i.e.,

$$\max_{p_i} \pi_i(p_c, p_i) = \big(p_i - (c_i - \delta)\big)x_i \quad st \quad x_i = \frac{p_c - p_i + \lambda}{2\lambda} \tag{7}$$

The FOC yields the best response function of the IOF as:

$$p_i = \frac{p_c + \lambda + c_i - \delta}{2} \tag{8}$$

On the other hand, the input-supplying cooperative seeks to determine the input price that maximizes the welfare of its members, subject to the avoidance of economic loss, i.e.,

$$\max_{p_c} MW_c = \big[p_f - \big(p_c + \lambda(1-\alpha)\big)\big]x_c^n - \frac{\lambda}{2}x_c^{n\,2} \quad st \quad \pi_c \geq 0 \quad and \quad x_c = \frac{p_i - p_c + \lambda}{2\lambda} \tag{9}$$

As $MW_c$ increases with a reduction in the price of the cooperative's product, member welfare is maximized when the price of the cooperative is equal to the marginal cost, i.e.,

$$p_c = c_c \tag{10}$$

Solving equations (8) and (10) simultaneously and substituting the input prices into the demands, profits and producer welfare functions gives the equilibrium input prices, quantities/market shares, profits, and member welfare as:

$$p_c^n = c_c, \qquad p_i^n = \frac{\lambda + c_i + c_c - \delta}{2} \tag{11}$$

$$x_c^n = \frac{3\lambda - \Delta c - \delta}{4\lambda}, \qquad x_i^n = \frac{\lambda + \Delta c + \delta}{4\lambda} \tag{12}$$

$$\pi_c^n = 0, \qquad \pi_i^n = \frac{(\lambda + \Delta c + \delta)^2}{8\lambda} \tag{13}$$

$$MW_c^n = \left[p_f - \left(p_c + \lambda(1-\alpha)\right)\right]x_c^n - \frac{\lambda}{2}{x_c^n}^2 \tag{14}$$

The equilibrium prices are increasing in own costs, while the IOF equilibrium price is also increasing in the rival cost and the degree of producer heterogeneity $\lambda$. The cooperative prices its product at marginal cost and its membership $x_c^n$ is decreasing in the effectiveness of the process innovation of the IOF, $\delta$. The higher is $\delta$, the higher are IOF's demand and profits, the smaller is the cooperative membership, and the lower is the cooperative members' welfare. For both suppliers to have a positive share of the market, the inequality $\delta < 3\mu - \Delta\text{c}$ must be satisfied. If $\delta \geq 3\mu - \Delta\text{c}$, the process innovation of the IOF is drastic and the cooperative is driven out of the market (and the IOF becomes a monopolist of the input in question). In what follows, our analysis focuses on the case where the two firms coexist in the market (i.e., the case of the mixed oligopoly/duopoly).

### 4.1. Royalty licensing

Under this contract, the IOF charges the cooperative a royalty rate $r$ per unit of input supplied by the cooperative using the new technology. The input-supplying cooperative's marginal cost is, then, $c_c + r - \delta$. Substituting the relevant costs into equations (11)-(14) gives the market equilibrium conditions under this contract as:

$$p_c^r = c_c + r - \delta, \qquad p_i^r = \frac{\lambda + c_i + c_c + r - 2\delta}{2} \tag{15}$$

$$x_c^r = \frac{3\lambda - \Delta c - r}{4\lambda}, \qquad x_i^r = \frac{\lambda + \Delta c + r}{4\lambda} \tag{16}$$

$$\pi_c^r = 0, \qquad \pi_i^r = \frac{(\lambda + \Delta c + r)^2}{8\lambda} \tag{17}$$

$$MW_c^r = \left(p_f + \delta - c_c - r\right)x_c^r - \frac{\lambda}{2}{x_c^r}^2 \tag{18}$$

The equilibrium prices are increasing in the royalty rate and so are the IOF's equilibrium quantity and profits. The cooperative membership, on the other hand, is decreasing in the royalty rate, as the latter increases the cooperative's cost and price.

In the first stage of the game, the objective of the IOF is to determine the royalty rate that maximizes the sum of its market profits and the licensing royalties, $\pi_i^r + rx_c^r$, and induces the cooperative's participation, i.e.,

$$\max_r \pi_i^r + rx_c^r \tag{19}$$

$$s.t. \;\; MW_c^r \geq MW_c^n \tag{20}$$

where the inequality (20) is the cooperative's participation constraint (PC). The cooperative's maximum willingness-to-pay (WTP) for licensing the process innovation is $\delta$ and, given that the IOF's objective function increases with $r$, the IOF will find it optimal to charge the cooperative its maximum WTP for its innovation, i.e., $r = \delta$. As the cost structure under this contract is identical to that under no licensing, the equilibrium prices and quantities are also the same. The payoffs of the two input suppliers under royalty licensing are, then:

$$\pi_i^r + rx_c^r = \frac{(\lambda + \Delta c + \delta)^2 + 2\delta(3\lambda - \Delta c - \delta)}{8\lambda}, \qquad MW_c^r = MW_c^n \tag{21}$$

As $\pi_i^r + rx_c^r \geq \pi_i^n$ when $r = \delta$, offering a royalty licensing contract is superior to no licensing from the IOF's perspective.

Result 1: *Relative to no licensing, the IOF will always find it optimal to offer a royalty licensing contract for its process innovation and will charge the cooperative a royalty rate equal to the cost reduction enabled by the process innovation.*

By setting $r = \delta$, firms' marginal costs before and after licensing are the same making the equilibrium prices, quantities and the market profits under royalty licensing the same as those under no licensing. The presence of the licensing revenues $rx_c^r$ makes, then, royalty licensing preferable to no licensing for the innovating IOF.

### 4.2. Fixed fee licensing

Under this contract, the IOF licenses its process innovation to the cooperative at a fixed fee $F$ and the input suppliers' marginal costs are given by $c_i - \delta$ and $c_c - \delta$. Given that the cooperative seeks to maximize the welfare of its members by pricing at marginal cost, its market profits equal to zero. To cover the fixed fee paid to the IOF, the cooperative has to charge its membership a fee $f$, in addition to the input price determined at the second stage of the game. As a result, the effective price paid by farmers who patronize the cooperative is $c_c - \delta + f$. The market equilibrium conditions under this contract are given by:

$$p_c^f = c_c - \delta + f, \qquad p_i^f = \frac{\lambda + c_i + c_c - 2\delta + f}{2} \tag{22}$$

$$x_c^f = \frac{3\lambda - \Delta c - f}{4\mu}, \qquad x_i^f = \frac{\lambda + \Delta c + f}{4\lambda} \tag{23}$$

$$\pi_c^f = 0, \qquad \pi_i^f = \frac{(\lambda + \Delta c + f)^2}{8\lambda} \tag{24}$$

Relative to no licensing, the price of the input supplied by the cooperative decreases by $\delta$ and increases by $f$, while the IOF's input price decreases by $\frac{\delta}{2}$ and increases by $\frac{f}{2}$. The cooperative membership and aggregate member welfare are decreasing in the membership fee and increasing in the size of the cost reduction. The welfare of the cooperative members under this type of licensing is given by:

$$MW_c^f = [p_f - (c_c - \delta + f)]x_c^f - \frac{\lambda}{2}{x_c^f}^2 \tag{25}$$

After determining the market conditions under the fixed fee licensing at the pricing stage of the game, the IOF seeks to determine the fixed fee $F$ that maximizes the sum of its market profits at the second stage and the licensing revenues, $\pi_i^f + F$, while inducing the participation of the cooperative, i.e.,

$$\max_F \pi_i^f + F \tag{26}$$

$$s.t. \;\; MW_c^f - F \geq MW_c^n \tag{27}$$

where the inequality (27) is the cooperative's PC. Given that the IOF's profits are increasing in $F$, the cooperative's PC will be satisfied with equality and the IOF will set a fee that captures all the increase in the cooperative's member welfare from adopting the process innovation, i.e., $F = MW_c^f - MW_c^n$. As noted earlier, as the cooperative marginal cost pricing results in making zero profits, to cover the cost of licensing ($F$), the cooperative will charge each of its members a membership fee $f$, given by the ratio of the licensing fee over the cooperative membership $x_c^f$, i.e., $f = \frac{F}{x_c^f}$. In this context, for the cooperative member welfare to be the same before and after licensing (and the cooperative to find it optimal to license the process innovation of the IOF), the fee has to be equal to the size of the cost reduction, i.e.,

$$f = \delta \tag{28}$$

When $f = \delta$, the input prices and market shares under this contract are identical to those under no licensing. The payoff functions of the IOF and the cooperative under this type of licensing are:

$$\pi_i^f + \delta x_c^F = \frac{(\lambda + \Delta c + \delta)^2}{8\mu} + \frac{\delta(3\lambda - \Delta c - \delta)}{4\lambda}, \qquad MW_c^f = MW_c^n \tag{29}$$

When compared to no licensing, the IOF is willing to license its cost-reducing technology to the cooperative if its profits under fixed fee licensing exceed those under no licensing, i.e.,

$$\pi_i^f + F \geq \pi_i^n \tag{30}$$

This inequality is always satisfied, which yields the next result.

<u>Result 2</u>: *Fixed fee licensing to an input-supplying cooperative is superior to no licensing for an innovating IOF. To cover the licensing fee, the cooperative charges each of its members a membership fee that equals the size of the cost reduction. As a result, the fixed fee licensing contract is reduced to a royalty licensing contract.*

By having a cooperative membership fee that is equal to the cost reduction, i.e., $f = \delta$, the marginal costs at the final stage of the game are the same with and without licensing. As a result, the equilibrium prices, quantities, and market profits do not change under to this "fixed fee" licensing. However, the total profits under this contract increase by $\delta x_c^f$, which is captured by the IOF making its total profits under this licensing higher than those under no licensing. In essence, the introduction of a membership fee by the cooperative to cover the fixed fee to the IOF when licensing its process innovation, makes the fixed fee licensing in this mixed oligopoly equivalent to the royalty licensing analyzed above.

### 4.3. Two-part tariff licensing

Under this contract, the IOF uses both a royalty rate $r$ per unit of output and a fixed fee $F$. Since, as shown earlier, the fixed fee licensing to a member welfare maximizing cooperative becomes a royalty licensing (where the cooperative charges its members a membership fee), the two-part tariff contract is reduced to a royalty licensing contract with $F = 0$ and $r = \delta$. The analysis of two-part tariff licensing is, then, identical to that of royalty licensing.

### 4.4. Welfare analysis of licensing in the mixed oligopoly case with the cooperative as the licensee

As both the fixed fee and two-part tariff contracts are reduced to a royalty licensing contract, the analysis in this section focuses only on the welfare impacts of the royalty licensing contract on the IOF, the cooperative, producers, and the subsequent social desirability of this contract. The differences in the cooperative's and the IOF's payoffs between royalty licensing and no licensing are given by:

$$\Delta \mathrm{MW}_c^{\mathrm{rn}} = 0 \tag{31}$$

$$\Delta \pi_i^{rn} = \frac{\delta(3\lambda - \Delta c - \delta)}{4\lambda} > 0 \tag{32}$$

Given that the IOF can, through a take-it-or-leave-it contract, extract all the licensing benefits, the change in the cooperative members' welfare between the royalty licensing and no licensing is equal to zero. The change in the IOF's profits due to royalty licensing, on the other hand, is positive suggesting that royalty licensing is superior to no licensing. As the royalty licensing contract leaves the cost structure unaffected, the difference in total producer welfare between royalty licensing and no licensing is equal to zero, i.e.,

$$\Delta \mathrm{T}PW^{rn} = \Delta \mathrm{M}W_c^{rn} + \Delta PW_i^{rn} = 0 \tag{33}$$

Finally, the change in the total economic welfare is given by the increase in the IOF's profits i.e.,

$$\Delta TEW^{rn} = \Delta\pi_c^{rn} + \Delta\pi_i^{rn} + \Delta TPW^{rn} = \frac{\delta(3\lambda - \Delta c - \delta)}{4\lambda} > 0 \tag{34}$$

and it is positive, suggesting that royalty licensing is preferred to no licensing from a social welfare maximizer's perspective, which yields the next result.

*Result 3: The involvement of the cooperative as a licensee results in the IOF/licensor choosing the socially desirable contract.*

Before concluding this section, we compare our results on the impact of cooperative involvement in technology licensing to the licensing behavior of the IOF when facing another IOF, and to the licensing behavior of an innovating cooperative in a mixed oligopoly. When the IOF is licensing its process innovation to another IOF, Chennak and Giannakas (2023) show that the optimal licensing contract depends on the degree of agent (member and non-member) heterogeneity and the pre-innovation cost difference between the licensor and the licensee. As the degree of consumer heterogeneity decreases (increases) and/or the pre-innovation cost difference between the firms increases (decreases), it becomes more likely that the licensor will find it optimal to offer a two-part tariff (royalty) licensing contract in the pure oligopoly. Regarding licensing in a mixed oligopoly where the cooperative is the licensor of the innovation, Chennak and Giannakas (2023) show that the member welfare-maximizing cooperative will always find it optimal to offer a royalty licensing contract as it enables it to maintain its membership while benefiting from the collected licensing revenues. Our results show that the idiosyncratic nature of the cooperative organization and its objective to maximize member welfare results in both the fixed-fee and the two-part tariff licensing contracts being reduced to a royalty licensing contract. Put in a different way, if a process innovation is to be licensed to an input-supplying cooperative, this will occur through a royalty licensing contract, a result that is consistent with the observed preference of cooperatives for this type of licensing agreements (Krogt et al., 2007).

In addition to being, in essence, the only way of licensing a process innovation to a member welfare maximizing cooperative, the royalty licensing contract is also the one that maximizes social welfare. Chennak and Giannakas (2023) show that both in pure oligopoly and the mixed oligopoly where the cooperative is the innovating firm, the innovating firms prefer a contract that is less socially desirable than the fixed fee licensing contract. Our results suggest that, unlike the pure oligopoly and the mixed oligopoly case where the cooperative is the licensor, the involvement of the cooperative as a licensee results in the innovating firm choosing the socially desirable contract. These findings are summarized in the next result.

<u>*Result 4*</u>*: Due to the idiosyncratic nature of the cooperative, both the two-part tariff and the fixed fee contracts are reduced to a royalty licensing contract in a mixed oligopoly where the cooperative is the licensee. In addition, unlike the pure oligopoly and the mixed oligopoly where the cooperative is the innovating firm/licensor, the involvement of the cooperative as a licensee results in the IOF/licensor choosing the socially desirable contract.*

## 5. Extensions of the analysis

### 5.1. The incentive to innovate and the incentive to license

This section extends our analysis to examine the implications of licensing for the incentive to innovate. As noted earlier, licensing is a key driver of innovation activity. Firms' incentive to innovate is driven, among other things, by their ability to appropriate the benefits of their R&D investments and licensing is a way of achieving that. In our model, the total benefits from innovation are given by the collected licensing revenues and the impact of process innovation on the innovator's profitability (i.e., market profits). The greater are these benefits, the greater the incentive to innovate.

Research shows that (a) the incentive to innovate is greater under licensing relative to no licensing (Gallini and Winter, 1985; Mukherjee and Mukherjee, 2013; and Colombo, 2020), (b) when either a royalty licensing or a fixed fee licensing is used, an outside inventor has greater incentives to innovate when licensing to a purely competitive industry relative to a monopolistic industry (Arrow, 1962; Kamian and Tauman,1986), and c) the innovating cooperative has greater incentive to innovate relative to the innovating IOF when a royalty licensing contract is optimal in a pure oligopoly, while, when the two-part tariff contract is optimal, the innovating IOF can have greater or lower incentive to innovate relative to the cooperative (Chennak and Giannakas, 2023). This extension contributes to this literature by considering the impact of cooperative involvement as a licensee for both the incentive to license and the incentive to innovate.

The difference in the total benefits from innovation collected by the input-supplying IOF through a royalty licensing contract when facing another IOF ($\mathrm{B}_c^p$) and when facing an input-supplying cooperative ($B_i^m$) is given by:

$$\Delta B_{ci}^{pm} = B_c^p - B_i^m = \frac{\delta[\delta - 4(3\lambda - \Delta c)]}{72\lambda} \quad (35)$$

This difference is negative suggesting that the presence of the cooperative as a licensee gives greater incentives to the IOF to innovate as opposed to when the licensee is another IOF. Note also that the impact of the innovation on the IOF's profitability (i.e., market profits) when facing a cooperative is higher than when facing another IOF.[1] Similarly, when $\Delta c \leq 0$ or $\Delta c > 0$ and $\delta < 3\lambda - 5\Delta c$, the IOF collects higher licensing revenues from a cooperative licensee compared to an IOF licensee. On the other hand, when $\Delta c > 0$ and $\delta \geq 3\lambda - 5\Delta c$, the IOF collects higher licensing revenues when competing with an IOF than when competing with a cooperative.[2]

On the other hand, when the IOF in the pure oligopoly uses a two-part tariff contract, the difference in the total benefits from innovation is:

$$\Delta B_{ci}^{pm} = B_c^p - B_i^m = \frac{(9\lambda - \Delta c)^2 + \delta[5\delta - 8(6\lambda - \Delta c)]}{72\lambda} \quad (36)$$

and it can be positive or negative suggesting that an IOF facing another IOF can have greater or lower incentives to innovate relative to when facing a cooperative as a licensee.

Finally, to determine the impact of the nature of cooperative involvement (i.e., the cooperative being the licensor versus being the licensee) on the incentive to innovate and the incentive to license, we derive the difference in the total benefits from innovation enjoyed by the cooperative ($B_c^m$) and the IOF ($B_i^m$) when facing a cooperative as:

$$\Delta B_{ci}^{mm} = B_c^m - B_i^m = \frac{\delta[8(U - c_c) + 2(\lambda + \Delta c) + 3\delta]}{32\lambda} \quad (37)$$

[1] The difference in profitability is determined by the difference in profits (without accounting for the licensing revenues). In particular, the difference in the IOF's profitability (i.e., market profits) when facing a cooperative (equation (17) in this paper) and when facing another IOF (equation (25) in Chennak and Giannakas (2023).

[2] The difference in the licensing revenues is $\Delta B_{ci}^{pm} = B_c^p - B_i^m = \frac{\delta[\delta-(3\lambda-5\Delta c)]}{12\lambda}$.

This difference is positive suggesting that, in a mixed oligopoly, a cooperative will have greater incentives to undertake innovation activity relative to an IOF facing a cooperative as potential licensee. Regardless of whether the licensing revenues collected by the cooperative are higher (when $\lambda < \Delta c$) or lower (when $\lambda \geq \Delta c$) than those collected by the IOF, the benefits of the reduced cost for the cooperative members are higher than the increased profitability of the IOF in the mixed oligopoly, making the total benefits of the innovation enjoyed by the cooperative members higher than those gained by the IOF.[3] As a result, the cooperative will have greater incentive to innovate relative to an IOF in a mixed oligopoly suggesting that the nature of cooperative involvement in licensing (being a licensor versus being a licensee) affects both the incentive to innovate and the incentive to license.

Result 5: *While the involvement of the cooperative as a licensee can result in greater or lower incentive to innovate for the IOF relative to when it licenses its innovation to another IOF in a pure oligopoly, it results in lower incentive to innovate relative to the case where the cooperative is the owner of the innovation (and licensor) in a mixed oligopoly.*

## 5.2. Nature of price competition

In this section we examine how the nature of the price competition between the input supplying firms in the last stage of the game affects the licensing equilibria. This analysis is relevant for industries with an innovating firm acting as a price leader in the relevant product/input market.

Chennak and Giannakas (2023) show that the licensing outcomes in the pure oligopoly model are sensitive to the assumed nature of the price competition. Specifically, in a sequential price competition between IOFs, the results are both quantitatively and qualitatively different

[3] The difference in the licensing revenues between the IOF in the mixed oligopoly and the cooperative is $\frac{\delta(\lambda-\Delta c)}{2\mu}$.

than when firms choose prices simultaneously as different equilibrium prices, quantities, and profits lead to different licensing equilibria. Due to the cooperative's marginal cost pricing, on the other hand, its best response function is independent of the price charged by the IOF. As a result, the equilibrium market conditions and the licensing analysis provided in the main part of our manuscript are robust to/hold for different price competition scenarios (e.g., sequential price game with the leader being either the cooperative or the IOF).

## 6. Concluding remarks

This paper develops a sequential game theoretic model of heterogenous firms and producers to examine the impact of cooperative involvement as a licensee in the transfer of process innovations. Our results support previous findings that the different structure of the cooperative organization and its objective to maximize the welfare of its members (rather than profits) do matter in technology licensing. For instance, a key result in the literature is that, to maximize the welfare of its members, cooperatives that constitute a backward integration of their members find it optimal to offer these members the lowest possible price, subject to not making economic losses (Fulton and Giannakas, 2001, 2013). A ramification of this when it comes to innovation licensing is that, to cover the fixed fee in a fixed-fee licensing contract offered by the innovating IOF/patent holder, the cooperative has to charge its membership a fee, in addition to the product price, which, ends up making the fixed-fee and the royalty licensing contracts, in essence, identical. In fact, the idiosyncratic nature of the cooperative organization and its objective to maximize member welfare results in both the (well-utilized in pure oligopolies) fixed-fee and the two-part tariff licensing contracts being reduced to a royalty licensing contract. Put in a different way, if a process innovation is to be licensed to an input-supplying cooperative, this will occur through a royalty licensing contract, a result that is consistent with the observed preference of cooperatives for this type of licensing agreements (Krogt et al., 2007).

In addition to being, in essence, the only way of licensing a process innovation to a member welfare maximizing cooperative, the royalty licensing contract is also the one that maximizes social welfare. Thus, unlike the cases of the pure oligopoly and the mixed oligopoly where the cooperative is the innovating firm/licensor where the optimal contract for the innovating firm is different than the one maximizing social welfare, the involvement of the cooperative as a licensee results in the innovating firm choosing the socially desirable contract.

Finally, our analysis reveals that the presence of the cooperative as a licensee increases the licensing revenues and can increase the incentives to innovate relative to when the licensee is another IOF. While the involvement of the cooperative as a licensee can increase or reduce the incentives to innovate relative to a pure oligopoly, it results in lower innovation incentives relative to the case where the cooperative is the innovating firm in a mixed oligopoly.

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