Cooperative Formation and Financial Contracting in Agricultural Markets

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Abstract

Cooperative formation in agriculture sometimes occurs in response to the exit of a private firm and typically requires substantial equity investment by participating farmers. What economic rationale can explain why farmers are willing to contribute capital to an activity that (apparently) fails to attract non-farm or "private" investment? We hypothesize that farm capital is high cost, relative to that provided by private entrepreneurs (or in other words, that there is a degree of asset fixity in farm capital) but that it engenders greater organizational commitment—which is particularly important when expected market returns are low—on the part of producers. This commitment arises from the indirect incentive properties associated with at-risk capital. We identify market environments where these incentives are necessary for firm survival and interpret the efficient financial contract in this context as a "cooperative."

Keywords: cooperative, corporate financing, moral hazard, vertical integration.

COOPERATIVE FORMATION AND FINANCIAL CONTRACTING IN AGRICULTURAL MARKETS

Introduction

Although there are many forms of cooperative activity in agriculture, among the most prominent are those that involve the processing and marketing of farmers' output. Perhaps surprisingly, many of the cooperative firms engaged in this activity were at one time investor owned but were subsequently purchased by growers in response to announced plant closings or scaling back of processing activities. For example, American Crystal Sugar, the largest U.S. producer of refined beet sugar, is a producer cooperative that was formed in 1973 with the purchase (by 1,300 beet growers at a price of $86 million) of the combined assets of the investor-owned firm with the same name (American Crystal Sugar Company 2003). Similarly, the recent purchase of an Oscar Meyer meat processing plant by a group of Iowa turkey growers occurred in response to an announced plant closing (West Liberty Foods 2003).

The closing or scaling back of operations by a private firm is presumably an indication of poor profitability. What rationale can be provided for growers to invest equity capital in such a venture? Perhaps growers have fewer opportunities to invest their capital and are willing to accept a lower return on investment than non-farm investors. However, for this to be the case, one would have to explain why the firm cannot simply negotiate a slightly lower payment to growers, sufficient to achieve competitive returns. In this context, Staatz (1987) describes bargaining and informational frictions that may impede renegotiation. For example, growers may not believe claims of the firm's management that market conditions are poor, and verifying these claims may be costly. Cooperative formation is thus a means to achieve a greater degree of transparency in determining the price of farm-level output, and this reduces bargaining costs. However, such a reduction represents a pure efficiency gain. Based on this logic, we should *always* observe the cooperative structure.

Alternatively, Hansmann (2000, p. 124) argues that growers may choose to invest equity in a marginally valuable processing facility if the alternative is one or a small number of oligopsony buyers. That is, the return on investment in such a facility is made up of firm-level profits *plus* any benefit associated with inducing competitive pricing by other buyers. However, in many of the examples in which growers have taken over the activities of a private firm, it has been the threat of *no* buyer that has motivated growers, rather than the threat of a small number of oligopsony buyers.

In this paper, we propose an alternative explanation for cooperative formation that occurs in response to exit. In particular, we assume that cooperative firms are inherently less efficient than investor-owned firms because of the costs associated with governance by majority participation.[1] We further assume that growers are capital constrained and that the cost of raising funds by pledging growers' assets is strictly higher than the cost of capital obtained from non-farm sources. This latter assumption is the simplest possible way of capturing the idea that it is costly to liquidate or redeploy farm assets, or, alternatively, that a particular set of farm assets is more valuable to its current owner than to others. These assumptions seem like reasonable, if somewhat stylized, descriptions of the environment we study and we treat them as maintained hypotheses. Of course, taken together, they essentially rule out cooperative activity as an equilibrium outcome. Thus, we need to consider some beneficial aspect of the cooperative organizational structure in order to rationalize cooperative formation.

For this, we state another pair of maintained hypotheses. First, we assume that there is moral hazard in farm-level production: Farm-level production is stochastic and depends in part on unobserved (by the firm) grower actions. Second, farmers have limited liability, or, equivalently, it is costly for the firm to impose a severe punishment for poor performance. As a result, growers earn an informational rent, and market returns may be inadequate to cover this rent plus a competitive return for non-farm investors. In such an environment, farm assets that are pledged to generate operating or investment capital also provide indirect production incentives to growers by increasing liability for poor performance. When growers pledge sufficient assets, they effectively become firm owners, and the resulting financial structure can be interpreted as a "cooperative."

In what follows, we make these arguments more precise. We first present a simple model with complete separation between farm-level production and processing. The processing firm buys from growers with a procurement contract whereby there is moral hazard in production and limited liability for growers. Following an approach similar to that of Holmström and Tirole (1997), we then introduce a third party, the "outside investor," who can provide capital to growers wishing to form a cooperative to buy the firm. The final section compares these two organizational structures and demonstrates how the cooperative structure can dominate in a market environment with "low" returns.

Model

We assume that our economy is composed of three types of agents: farmers, private investors, and institutional investors. Farmers grow an essential input used in producing some processed agricultural product. Farmers do not have the managerial skills to run a processing facility but can acquire them at some cost. Private investors possess the ability to run a processing facility and they are not wealth-constrained. We assume, however, that private investors are mobile and can operate in several markets; they can eventually exit the food processing market if the returns on this market are not high enough. A private investor who wants to be active in the processing business must invest an amount of $I > 0$ to acquire the physical capital needed to process the agricultural product. He then procures this input from the farmer whose production technology is described presently. The production lasts for one period and we assume that, at the end of the period, the residual value of the processing plant is 0.[2] Finally, institutional investors are passive risk-neutral investors with no managerial skills. We assume that there exists a competitive fringe of such investors who agree to lend only if they expect to recoup their initial loan.

We assume that there is moral hazard in agricultural production: the quality of final output is uncertain and depends in part on unobservable (to the firm) actions of growers. For simplicity, we assume there are only two possible outcomes. When the farmer is "diligent," farm output is high quality with probability P_h, whereas when the farmer "shirks," output is high quality with probability P_ℓ. We let the difference between these probabilities be denoted by $\Delta P = P_h - P_\ell > 0$. The farmer enjoys a private benefit $B > 0$ in monetary units from shirking (or equivalently, incurs a cost $-B < 0$ from being diligent).

Revenue of the processor is R when the output is high quality and is normalized to 0 when it is low quality.

These revenues are *verifiable*, and to make our problem interesting we assume that the following condition holds throughout the paper:

ASSUMPTION 1 (Diligence is optimal).

$$R > \frac{P_h B}{(\Delta P)^2}.$$

As we will see in what follows, such a condition ensures that it is always efficient to induce farmers' diligence.

The timing of activities is as follows:

(*i*) The private investor decides whether to establish a processing facility. He then makes a take-it-or-leave-it procurement offer to the farmers, who decide whether to accept or reject the offer. If the offer is rejected, the private investor exits the market and obtains his reservation utility.

(*ii*) If the offer of the private investor has been turned down, the farmers decide whether or not to acquire and run a processing facility by eventually borrowing money from institutional investors. The institutional investors decide whether or not to lend money. If the loan to the farmers is refused, the latter get their "outside option" utility and the game ends.

(*iii*) Production takes place and the farmers decide to be diligent or careless. Neither the private investor nor the institutional investor observes the farmers' choice.

(*iv*) Processing is performed and outcomes are realized. Payments are made according to the contracts signed in either step 2 or 3. The game ends.

We now turn to the situation in which private investors decide to be present in the processing market.

Investor Financing

The problem of the processor consists in finding a pair of transfers (T_h; T_l) made to the farmer contingent on the processor's revenue. The objective can be stated as

$$\max_{(T_h, T_l)} P_h(R - T_h) - (1 - P_h)T_l \tag{1}$$

subject to the two following constraints:

$$P_h T_h + (1 - P_h) T_l \geq P_l T_h + (1 - P_l) T_l + B \quad (2)$$

and

$$T_h \geq 0, \ T_l \geq 0. \quad (3)$$

The objective function of the processing firm states that the firm obtains net revenue $R - T_h$ with probability P_h and $-T_l$ with probability $1 - P_h$. The incentives constraint (2) states that the farmer is induced to be diligent and thus produces a high-quality input with probability P_h. The second constraint (3) is a limited liability constraint: the private firm cannot use unlimited punishments to induce the farmer to behave.

The solution to this problem is given below.

PROPOSITION 1 (Procurement Contract). *The solution to the program (1) is given by the following transfers:*

$$T_h^* = \frac{B}{\Delta P}$$

and

$$T_l^* = 0.$$

Proof. See the Appendix.

The farmers derive an expected *informational rent* of $P_h(B / \Delta P)$ from their farming activities.[3] The expected level of equilibrium profit for the private firm is

$$P_h \left(R - \frac{B}{\Delta P} \right) - I.$$

Thus, the processor will undertake the processing activity if the following condition is met:

$$P_h \left(R - \frac{B}{\Delta P} \right) - I \geq 0,$$

and no processing activity is undertaken by a private firm if the returns are too low; that is, if

$$R < \overline{R} = \frac{I}{P_h} + \frac{B}{\Delta P}.$$

We now turn to an organization in which farmers decide to launch a cooperative eventually by pledging their assets.

Cooperative Financing or "Pledging the Farm"

The formation of a cooperative is a costly activity for farmers. Farmers have to select members, elect leaders, and acquire the necessary skills to manage a processing plant on a day-to-day basis, or at least monitor the CEO that they appoint to perform managerial tasks. We thus assume that cooperative formation necessarily entails a monetary cost K > 0. We assume that this cost is independent of the cost of the assets of the food processing plant, I, and that it is borne by our representative farmer during the life of the cooperative.[4]

In this model, farmers do not have cash in advance but rather have some illiquid assets such as farms, machines, and acreages. These assets can be used as collateral by farmers in any loan that the institutional investors issue. We assume that the value of these assets for the farmer is F, whereas it is f for any outside investor. We assume that $F > f > 0$. Such an assumption may be due to the fact that farmers have developed some specific knowledge and know how to operate the collateralized machine. If this machine is transferred to another person, she may have to learn such skills. Other reasons for this discrepancy in asset value include any sentimental attachment that farmers have for their farms. Therefore, there is a strictly positive deadweight loss of $F - f$ if the asset is seized.

The farmers have to invest an amount $I + K$ to form a processing cooperative. There exist several prospective lenders, with no managerial skills, who compete in a Bertrand fashion in issuing a loan to the farmers. The loan contract specifies how the two parties will share the revenue R in case of success (or in case of failure), as well as possible contingent rights for the lenders to seize the assets. Let R_f denote the farmers' share of income in case of success, whereby lenders receive the residual $R - R_f$, and let y_s and y_f denote the probabilities that the farmers will keep their farm in case of success or failure.

The program of the farmer can be stated as

$$\max_{(R_f, y_s, y_f)} P_h(R_f + y_s F) + (1 - P_h)y_f F \tag{4}$$

subject to

$$P_h(R_f + y_s F) + (1 - P_h)y_f F \geq P_l(R_f + y_s F) + (1 - P_l)y_f F + B \tag{5}$$

and

$$P_h(R - R_f + (1 - y_s)f) + (1 - P_h)(1 - y_f)f \geq I + K. \tag{6}$$

The incentive constraint (5) states that the loan contract is structured in such a way that farmers are induced to produce high-quality input. The loan contract must also meet the individual rationality constraint (6) of the lenders; that is, the farmers must at least recoup their investment $I + K$, on average.

The next result gives the solution of program (4) when R is decreased gradually.

PROPOSITION 2 (Financial Contract). *As the return R of the processing activity decreases (equivalently if I+K increase), the financial contract passed with lenders will have several regimes:*

(*i*) (Open Cooperative) *When*

$$R \geq \frac{I+K}{P_h} + \frac{B}{\Delta P},$$

farmers are able to pledge cash for repayment without pledging any physical assets in any state of the world; that is,

$$R_f^* > 0 \text{ and } y_s^* = y_f^* = 1.$$

(*ii*) (Private Cooperative with light pledging) *When*

$$\frac{I+K}{P_h} + \frac{B}{\Delta P} - \frac{P_h F + (1-P_h)f}{P_h} < R < \frac{I+K}{P_h} + \frac{B}{\Delta P},$$

cash pledging is not sufficient to ensure that both (5) and (6) hold, and the farmers will sometimes lose their assets in case of failure; that is,

$$R_f^* \geq 0 \text{ and } y_s^* = 1 \text{ and } y_f^* \leq 1.$$

(*iii*) (Private Cooperative with strong pledging) *For even lower values of R, the farmers will sometimes keep their assets in case of success; that is,*

$$R_f^* = 0 \text{ and } y_s^* \leq 1 \text{ and } y_f^* = 0.$$

(*iv*) *For the lowest values of R, lenders simply decline to lend to farmers.*

Proof. The proof consists of writing the Lagrangian of program (4) and discussing the optimal solution as a function of *R*. This is done in the Appendix.

The intuition for this "cascade" of regimes is as follows: it is always more efficient to transfer cash to lenders than to transfer assets, because the latter transfer involves a deadweight loss supported by farmers. When the project does not generate enough cash, however, assets have to be pledged to lenders in the optimal loan contract. The right to seize farmers' physical assets should, however, be contingent on failure rather than on success, because doing so has obvious incentive properties.

This proposition illustrates how farmers are put at risk when they decide to create a private cooperative. In particular, the fact that some assets may be seized when farmers fail in their processing business is a feature that is readily observed in these private cooperatives. This suggests that regimes in which assets are pledged to banks are ones in which farmers are highly motivated and very involved in the managerial activity of the cooperative.

It is not obvious that any farmer would agree to bear the risks involved in the creation of a private cooperative, and it seems likely that the number of outside options available to the farmer would play a crucial role in explaining the existence of private cooperatives. According to this theory, private cooperatives are more likely to occur in regions where outside options such as spot markets are weak.

Proposition 2 may also have some policy implications. When returns are low, the farmer may simply not want to participate in these private cooperatives. Therefore, if maintaining processing activities is valuable for some region, then providing secured loans to farmers can restore regimes in which creating a cooperative is attractive. Formally, in our model, a secured loan to farmers would act like a decrease in $I + K$, and regimes with fewer risks can be reached. However, for incentive purposes, it is important to let the farmers bear *some* of the project's risk.

Comparison of Investor and Cooperative Financing

The aim of this section is to integrate, in the same framework, situations in which we observe private firms and private cooperatives. The next results, which are the main results of the paper, discuss the existence, as an equilibrium outcome, of the different types of processing organizations observed:

PROPOSITION 3 (Private Cooperatives). *When the administrative cost of setting up a private cooperative, K, is strictly smaller than the expected information rent of the farmers,* $P_h(B/\Delta P)$ *, then, as R increases, we observe the following exclusive sequence of processing organizations:*

(*i*) *If* $R < (I+K)/P_h$*, no procurement contract by processors is ever observed; farmers sell their product on the "spot market."*

(*ii*) *If* $(I+K)/P_h \leq R \leq I/P_h + B/\Delta P$*, cooperatives with private membership occur as an exclusive way of processing the input. Their financial structure is described by points (ii) and (iii) in Proposition 2.*

(*iii*) *If* $I/P_h + B/\Delta P \leq R \leq (I+K)/P_h + B/\Delta P$*, processing activities are exclusively performed by private firms. Their procurement contract is described in Proposition 1.*

(*iv*) *If* $R \geq (I+K/P_h) + (B/\Delta P)$*, processing activities are performed by private firms who propose a payment* L^* *(defined as* $L^* = P_h[R - (B/\Delta P)] - (I + K))$ *to the farmers and a procurement contract as described in Proposition 1.*

Proof. First, observe that the expected payoff of the farmers when they form a private cooperative is given by the total expected surplus of the project.[5] Thus, farmers will not become stockholders of the cooperative if $R < (I + K)/P_h$.

Moreover, a private firm's net benefit from owning and managing a processing plant is

$$\Pi_{PF} = P_h\left(R - \frac{B}{\Delta P}\right) - I,$$

and the firm is willing to invest only if R is larger than $I/P_h + B/\Delta P$. This establishes the first point of Proposition 3. When $(I+K)/P_h \leq R \leq I/P_h + B/\Delta P$, only private cooperatives occur; this establishes the second point.

When $R \geq I/P_h + B/\Delta P$, both cooperatives with private membership and private firms are profitable. However, farmers prefer the procurement contracts offered by private firms rather than creating their "own" firm. This happens as long as

$$P_h \frac{B}{\Delta P} > P_h R - (I + K);$$

that is, when

$$R \leq \frac{B}{\Delta P} + \frac{(I + K)}{P_h}.$$

When $R > B/\Delta P + (I{+}K)/P_h$, the farmers want to create an open cooperative, as they obtain a greater surplus. However, the investors, who have managerial skills, are able to operate the processing facilities by proposing to pay an upfront payment L to the farmers.[6] Indeed, proposing

$$L^* = P_h \left(R - \frac{B}{\Delta P} \right) - (I + K)$$

will discourage farmers from opening a cooperative and will leave the investors with a net surplus of

$$\Pi_{PF} = P_h \left(R - \frac{B}{\Delta P} \right) - I - L^* = K > 0.$$

We see that proposing L^* is a dominant strategy for the private investor. This establishes the last point.

This proposition gives an explanation of why private cooperatives tend to supplant private firms when the returns to processing activities decrease. When the returns R are high, private investors have to leave some rents to the farmers in order to discourage cooperative formation. The next proposition investigates the case in which the administrative cost of setting up a cooperative is rather high.

PROPOSITION 4 (Private Firms). *When $K > P_h(B/\Delta P)$, then, as R increases, we observe the following sequence of processing organizations:*

(*i*) *If $R < (I+K)P_h$, no procurement contract by processors is ever observed; the farmers can use their outside option.*

(*ii*) *If $I/P_h + B/\Delta P \leq R \leq (I+K)/P_h + B/\Delta P$, private firms will organize the processing activity and the procurement contract is described in Proposition 1.*

(*iii*) *If $R \geq I/P_h + B/\Delta P$, private investors make an offer (that is subsequently accepted) of L^* to farmers, as well as offering a procurement contract.*

This proposition emphasizes the fact that private firms will dominate as long as they are strictly more efficient than cooperatives.

Note that in each of these comparisons, we have ignored the possibility that private investors could fund the project but farmers would still be liable for project failure. That is, in principle, there is no reason why farmers cannot choose to pledge their assets but cede all managerial authority to private investors who provide the cash. In practice, in this case a private processing firm would write a contract with suppliers in which the assets of suppliers could be seized in the event that the firm fails. Though we leave these issues unmodeled, it seems reasonable to suppose that such a contract would be difficult to implement in practice. With so much at stake, growers would be inclined to be involved in managerial decision making, and this necessarily creates a "cooperative" governance structure.

Conclusion

This paper examines the motivation for cooperative formation in agricultural markets. Our principal aim is to provide an explanation for the observation that cooperatives sometimes form in response to the exit of an investor-owned firm. Our explanation relies on three key ingredients that we treat as maintained hypotheses in our analysis. First, there is moral hazard in farming: the quantity and quality of farm output is uncertain and depends to some extent on the unobservable actions of growers. Second, the cooperative organizational form entails a deadweight loss, relative to an investor-owned organization. And finally, there is some degree of fixity in farm-level assets: the value of these assets to the farmers who own them is strictly larger than their value in the next best alternative use.

Moral hazard in production implies that, in addition to the resource costs associated with farm production and processing, an informational cost must be collectively borne by farmers and the processing firm. There is sufficient revenue to cover both forms of cost when market returns associated with the processed output are sufficiently high. In this case, it is efficient for processing to be undertaken in an investor-owned firm, because doing so avoids the deadweight loss associated with the cooperative form.

However, when market returns are sufficiently low, there may be insufficient resources to provide an incentive for growers to work hard. An alternative to rewarding growers for good performance is to punish them for poor performance. One way this can be accomplished is to require that their assets be seized when there is a "project failure." Of course, this is a costly means of providing incentives, because the farmers must bear considerable risk, and in the event assets are actually seized, society bears a deadweight loss associated with the transfer of farmers' assets. Nevertheless, we show how in some market environments this may be the only feasible means of implementing socially efficient actions. When farmers pledge their assets in this way, it is reasonable to suppose that they will exercise some degree of control over managerial decision making within the firm, or, in other words, that the firm will be governed "cooperatively."

Endnotes

1. Alternatively, this (relative) inefficiency can be interpreted as a cost associated with growers needing to learn and invest time in the marketing activities of the "firm."
2. This assumption is made for simplicity; the extension to the case in which the processing has some remaining value is immediate.
3. For simplicity, and without loss of generality, we assume that farm input prices are 0.
4. Another (equivalent for our purposes) interpretation of this cost is that it represents a source of inefficiency in a cooperative organization relative to a private firm.
5. This is due to Bertrand competition between lenders.
6. This could be a bribe for not opening a cooperative or an exclusive procurement contract.

Appendix

Proofs of Propositions 1 and 2

Proof of Proposition 1. A procurement contract is optimal if no other contracts that are incentive compatible exist and if it leaves strictly more surplus to the firm. Suppose that the contract (T_h^*, T_l^*) is optimal and let us denote by Π^* the surplus of the firm when this contract is implemented. First, we have to show that the optimal contract is such that $T_h^* \geq T_l^*$. The proof is by contradiction.

Assume that $T_h^* < T_l^*$ and define another contract $(\tilde{T}_h, \tilde{T}_l)$, such that $\tilde{T}_h = T_h^*$ and $\tilde{T}_l = T_l^* - \varepsilon,$ with $\varepsilon > 0$.

With this new contract, the incentive constraint (IC) is written as

$$P_h\tilde{T}_h + (1-P_h)\tilde{T}_l \geq P_l\tilde{T}_h + (1-P_l)\tilde{T}_l + B;$$

that is,

$$\Delta P(T_h^* - T_l^* \geq B + \varepsilon\Delta P. \qquad (7)$$

Thus, expression (7) shows that $(\tilde{T}_h, \tilde{T}_l)$ is incentive compatible. It leaves surplus $\tilde{\Pi}$ to the firm. Using the definition of $(\tilde{T}_h, \tilde{T}_l)$, this surplus is written as

$$\tilde{\Pi} = P_h(R - \tilde{T}_h) - (1-P_h)\tilde{T}_l$$
$$\tilde{\Pi} = P_h(R - T_h^*) - (1-P_h)T_l^*$$
$$\tilde{\Pi} = \Pi^* + \varepsilon(1-P_h),$$

and, since $\varepsilon(1 - P_h) > 0$, this is a contradiction!

The optimal contract satisfies $T_h^* \geq T_l^*$. The optimal should also satisfy $T_h^* > T_l^* = 0$. Indeed, suppose that $T_h^* > 0$ and $T_l^* > 0$. Then, the solution to program (1) is the same as the solution to the relaxed problem without constraints (3). However, the solution to the relaxed problem has $T_h^* < 0$ and $T_l^* < 0$; this violates (3).

Moreover, if $T_h^* = T_l^* = 0$, then IC cannot hold; thus, the optimal contract has $T_h^* > T_l^* = 0$. Finally, it is easy to show that any contract such that $T_h > B/\Delta P$ is suboptimal for the firm.

Proof of Proposition 2. Taking into account that the probabilities y_s and y_f cannot be negative, the Lagrangian of program (4) can be written as

$$\begin{aligned} L(R_f, y_s, y_f) &= P_h(R_f + y_s F) - (1 - P_h) y_f f \\ &+ \lambda_1 \left(\Delta P(R_f + (y_s - y_f)F) - B \right) \\ &+ \lambda_2 \left(P_h(R - R_f + (1 - y_s)f) + (1 - P_h)(1 - y_f)f - (I + K) \right). \end{aligned}$$

The complete set of first-order conditions is written as

$$\frac{\partial L}{\partial R_f} = P_h + \lambda_1 \Delta P - \lambda_2 P_h, \tag{8}$$

$$\frac{\partial L}{\partial y_s} = P_h(F - f) + \lambda_1 \Delta P F - \lambda_2 P_h f, \tag{9}$$

$$\frac{\partial L}{\partial y_f} = (1 - P_h)(F - f) - \lambda_1 \Delta P F - \lambda_2 (1 - P_h) f, \tag{10}$$

$$\lambda_1(\Delta P(R_f + (y_s - y_f)F) - B) = 0, \tag{11}$$

$$\lambda_2(P_h(R - R_f + (1 - y_s)f) + (1 - P_h)(1 - y_f)f - (I + K)) = 0, \tag{12}$$

$$\Delta P(R_f + (y_s - y_f)F) \geq B, \tag{13}$$

$$P_h(R - R_f + (1 - y_s)f) + (1 - P_h)(1 - y_f)f,\ I + K. \tag{14}$$

Since $\partial L/\partial R_f > 0$ when all the constraints are slack, it follows that at least one of them should be binding. For R big, it is optimal to saturate (IR_l), simply because there is no point in giving more repayment than necessary to the lenders, so that $\lambda_1 = 0$ and $\lambda_2 > 0$: Using the first-order condition (8), we have

$$\frac{\partial L}{\partial R_f} = P_h - \lambda_2 P_h = 0 \Rightarrow \lambda_2 = 1 \Rightarrow R_f^* > 0.$$

Then, replacing in (9) implies that

$$\frac{\partial L}{\partial y_s} = P_h(F - f) > 0 \Rightarrow y_s^* = 1,$$

which also implies, by replacing in (10), that

$$\frac{\partial L}{\partial y_f} = (1 - P_h)(F - f) > 0$$

and, hence, $y_f^* = 1$ by equation (10). We thus have a regime in which $R_f > 0$ and $y_f^* = y_s^* = 1$.

In this setting, and because of the complementary slackness condition (12), we know that

$$P_h R_f = P_h R - (I + K). \tag{15}$$

Taking into account (11), we also have

$$P_h R_f > P_h \frac{B}{\Delta P} \Leftrightarrow P_h(R - R_f) > P_h \frac{B}{\Delta P}. \tag{16}$$

Using (15) and replacing in (16) yields

$$R > \frac{I + K}{P_h} + \frac{B}{\Delta P},$$

as given in the first point of Proposition 2.

Now assume that (IR_l) and (IC_f) are both binding (that is $R \leq (I+K)/P_h + B/\Delta P$) so that $\lambda_1 > 0$ and $\lambda_2 > 0$. We have

$$\frac{\partial L}{\partial R_f} = P_h + \lambda_1 \Delta P - \lambda_2 P_h = 0 \Rightarrow \lambda_2 = 1 + \lambda_1 \frac{\Delta P}{P_h} > 1. \tag{17}$$

Thus, using (17) and replacing in (9) implies that

$$\frac{\partial L}{\partial y_s} = P_h(F - f) + \lambda_1 \Delta P F - \left(1 + \lambda_1 \frac{\Delta P}{P_h}\right) P_h f = (P_h + \lambda_1 \Delta P)(F - f) > 0$$

and $y_s^* = 1$. Replacing (17) into (10), we obtain

$$\frac{\partial L}{\partial y_f} = (1 - P_h)F - \lambda_1 \Delta PF - \left(1 + \lambda_1 \frac{\Delta P}{P_h}\right)(1 - P_h)f = 0.$$

This is true if

$$\lambda_1 = \frac{(1 - P_h)(F - f)f}{P_h F + (1 - P_h)f} > 0 \Rightarrow y_f^* \leq 1.$$

We thus have a regime in which $R_f \geq 0$, $y_s^* = 1$ and $y_f^* \cdot \leq 1$. It is easy to verify that when $y_f^* = 0$, the maximum pledgeable value of the farmers is greater than the amount of the loan if

$$P_h\left(R - \frac{B}{\Delta P}\right) + P_h(F - f) + f \geq I + K;$$

that is, if

$$R \geq \frac{I + K}{P_h} + \frac{B}{\Delta P} - \frac{P_h F + (1 + P_h)f}{P_h}.$$

Finally, when $R < (I+K)/P_h + B/\Delta P - [P_hF+(1+Ph)f]/P_h$, we can have

$$\frac{\partial L}{\partial y_s} = 0 \Leftrightarrow y_s^* \leq 1 \text{ and } \lambda_2 = \frac{F}{f} + \lambda_1 \frac{\Delta PF}{P_h f}. \tag{18}$$

We can replace (18) in (10) to obtain

$$\frac{\partial L}{\partial y_f} = -\lambda_1 \Delta PF\left(1 + \frac{1 - P_h}{P_h}\right) < 0 \Rightarrow y_f^* = 0.$$

Doing the same with (8), it is easily shown that at this optimum, we have

$$\frac{\partial L}{\partial y_f} = -(P_h + \lambda_1 \Delta P)\left(\frac{F}{f} - 1\right) < 0 \text{ and } R_f^* = 0$$

as given in the proposition.

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