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Contracting with smallholders under joint liability

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Abstract

Although joint liability has been found to work very well in the context of microfinance, surprisingly mixed results have been recorded in other realms. Similarly, contract farming is of interest to policymakers for agriculture in developing countries but is plagued with information asymmetries. This paper examines the optimal design of contract farming when a group of jointly liable farmers contracts with a principal agribusiness to access input credit and can undertake peer monitoring to overcome moral hazard problems.

Under both ex ante moral hazard on production effort and ex post srategic defaulting, the agribusiness takes into account both price incentives on farmers' effort and group's peer monitoring. This entails specific pricing with respect to individual and group characteristics to avoid side-selling and encourage cooperation among farmers. My results suggest that an integrated policy framework comprised of both farmers' groups and price regulation can improve efficiency of contract farming in developing countries.

JEL Codes: D82, L14, 013, Q13

Keywords : Contract Farming, Ex Ante and Ex Post Moral Hazard, Joint Liability, Peer Monitoring, Side-Selling

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1. Introduction

Over the past three decades, contract farming[1] has become one of the major tools for agricultural development in many developing countries.[2] It typically involves an agribusiness which provides quality inputs, a set of extension and other agricultural services, and credit to individual or groups of farmers. In exchange, farmers have a marketing arrangement with a potentially fixed price and an outlet for their output on high-value markets and must follow a particular production method. Reciprocal obligations entail the provision of agricultural services and commitment to purchase prices on the firm's side, and quality requirements and exclusive purchase rights on the farmers' side.

The expansion of contract farming in the developing world has been driven by changes in consumer demand, international trade, technology and policies. Contracting between farmers and agribusinesses has enabled a tightening of the commodity chains (vertical integration), in turn strengthening vertical coordination,[3] which is increasingly required by the supermarket procurement systems or manufacturing/retailing importers.[4] In the course of commodity reforms (see Akiyama et al. 2001), provision of inputs, rural credit, or extension services has become problematic for small-scale farmers facing several market failures. Outgrower schemes are often one of the only channels linking smallholders to input and output markets (Key and Runsten 1999) through market interlinking. This is an efficient solution in an incomplete market environment, as shown by the theoretical literature. Interlinked agreements among rational economic agents arise in a very fragmented and incomplete market environment (Mitra 1983) where agents are isolated by barriers from entry to some markets (Basu 1983). Braverman and Stiglitz (1982) showed that the creation of efficient surplus improves when interlinking occurs. Interlinkages facilitate contract enforcement while saving on information, enforcement and monitoring costs (see also Bell 1989). Nevertheless, the literature has not explored the endogenous mechanisms through which contracts are enforced and production is monitored. In this paper, I consider the interlinked nature of these contracts when the agribusiness contracts with smallholders who have no access to credit or extension services. While outside options for smallholders are assumed to be of limited scope (e.g. access to inputs), because of market incompleteness, I explicitly allow for selling of the crop to a third party (hereafter referred to as side-selling) and thus for ex post contract-enforcement failures. I also account for group mechanisms—namely joint liability[5] and peer monitoring—through which the agribusiness elicits credit repayment of production inputs. There is a natural advantage to relying on peer monitoring and social mechanisms through joint liability in many rural communities of the developing world, where many smallholders lack appropriate collateral to secure a loan. Because of local informal institutions and social ties, joint liability acts as effective social collateral, inducing delegated monitoring among peers that ensures workable credit-repayment rates when the groups are well designed and cohesive.

Such collective credit agreements are widespread in the developing world, as witnessed by the successful Grameen Bank in Bangladesh and other microfinance institutions (see Morduch 1999, for a review). This paper aims to show how group liability may be relevant in the case of contract farming, given the latter's increasing importance for agricultural development and rural welfare. Indeed, collective agreements may enable contractors to decrease transaction costs through such group mechanisms which ease enforcement, reduce moral hazard problems, and provide savings on supervision costs (see Van Bastelaer and Leathers 2006, in the case of seed provision to Zambian farmers). In addition, since credit is linked to the productive output for which the contractor gets exclusive purchase rights, it provides additional physical collateral. Such collective agreements are commonly observed across African and Latin American agro-industries such as in the cotton sector (Tschirley et al. 2009), the rice sector (Madagascar and Senegal), horticulture (Key and Runsten 1999), irrigation schemes, and several high-value commodity chains (see Winter-Nelson and Temu 2002, in the case of Tanzanian coffee growers).

Peer monitoring and joint liability are borrowed from the large body of literature on collective credit agreements and microfinance.[6] Most of the theoretical literature has shown that joint liability in credit agreements is efficient under a variety of circumstances, and that it may generate higher profits for the contractor than individual liability. First, group formation allows positive assortative matching by affinities (Ghatak and Guinnane 1999), thereby reducing ex ante moral hazard (the risk type of the project or individuals' probability of success). According to Besley and Coate (1995), joint liability provides two opposite repayment incentives: a positive incentive stemming from the mutual insurance of the group and a negative incentive because expected marginal profit depends not only on individual effort but also on the effort of others (free-rider effect). This negative effect of joint liability can be mitigated by the use of credible social sanctions if farmers' actions can be observable ex post with a costly monitoring effort from the group. This will enforce cooperative behaviors within groups and will discourage opportunistic ones.[7] Armendariz de Aghion (1999) focuses on ex post moral hazard through the lens of a credit-repayment game with an endogenous peer-monitoring decision-level stage.[8] For a monopolistic lender, it is proven that joint liability brings even more profit than individual creditors, on condition that social sanctions are sufficiently credible and monitoring costs are not too high.

These insights also apply to the case of contract farming in developing countries with smallholders, where collective agreements are widespread (e.g. input credit). This is notably the case for outgrower schemes, in which credit repayment proceeds by deducting its value from the output sales to the contractor. In this literature, however, the probability of the project's success (and hence, of credit repayment) is exogenous and the moral hazard problem is only explored through the project choice or the ex post behavior of agents. Yet peer monitoring must also affect the actions of the agents ex ante through individual and collective incentives for effort and project choice. This is what I address in this paper by accounting for ex ante simultaneous decisions on both effort and peer monitoring when strategic defaulting can also occur ex post, in the form of side-selling (selling the contracted output to another trader makes farmers default on their input credit).

The main contribution of this paper lies in its accounting for group mechanisms in the design of contract farming, thereby bridging the gap between the theoretical literature on interlinkages and that on collective credit agreements. This is done by formally addressing the problem of ex ante moral hazard as endogenous on the one hand, while on the other, I consider contract farming to be an interlinked agreement with groups of smallholders within which strategic interactions occur. I do not examine why and when contract farming with joint liability occurs or what the optimal scale of these arrangements is in agricultural production. Rather, I study the efficiency of such contracts and their optimal design from the agribusiness's perspective.[9] To the best of my knowledge, this paper is the first to examine contract farming as an interlinked agreement with both endogenous effort and peer monitoring of a group of smallholders, and the first to study the role of joint liability and endogenous peer monitoring in overcoming both ex ante and ex post moral hazard problems.

To this end, I solve for a group-repayment game that is linked to a production activity (the project) under the supervision of a Principal. The production activity is undertaken according to an endogenous effort which can only be observable by other peers ex post (at some cost) and that determines the probability of success. Hence, both production effort (and credit-repayment probability) and the level of peer monitoring are endogenous and simultaneously chosen by farmers ex ante. I also allow for ex post strategic defaulting, that is, it is possible for agents to contract or to market their output with another trader ex post. The group-repayment game is linked to a prior contracting stage between a Principal and a group of farmers (the Agent). I show that the level of peer monitoring sufficient to yield a cooperative effort equilibrium is less likely to be undertaken by the group when individual and group production incentives are higher under no side-selling, but becomes more likely for intermediate incentives when side-selling is feasible. However, sufficient peer monitoring is more likely to hold when the group's marginal return on peer monitoring increases. Hence, the Principal may face a trade-off between price incentives on production and peer monitoring. Consequently, the optimal pricing rule is not continuous with respect to either the group's capacity to enforce cooperative behaviors or individual incentives. This has several policy implications in terms of both the design of efficient smallholder groups and the regulation of contract-farming schemes. These results can serve for future studies of contract farming in terms of welfare creation and redistribution on the one hand, and optimal market structure and regulation on the other.

The remainder of this paper is organized as follows. Section 2 presents the conceptual framework with a group of two symmetric farmers (the Agent) and an agribusiness (the Principal) under perfect information on group and individual characteristics, and moral hazard on production effort and ex post repayment decisions. Section 3 analyzes the optimal reaction of farmers in terms of effort, peer monitoring and side-selling under exogenous contract terms. Section 4 explores optimal contracting from the agribusiness Principal's standpoint. Section 5 considers the implications of group size and heterogeneity. Section 6 concludes and discusses the policy implications of the model.

2. The theoretical framework

In the basic framework, a group—the Agent—is composed of two symmetric farmers who contract with a monopsonistic agribusiness (the Principal). First, the Principal sets the terms of the contract by defining the purchase price of the cash crop p and providing one unit of input credit. The cost of one physical unit of input is normalized to unity and the Principal faces a marginal receipt at the farm gate of $\bar{p}$.[10] I assume that all farmers who participate in contract farming are cash-constrained and cannot access rural credit markets, so they have no alternative access to inputs: seeds, fertilizers, and pesticides.

In the basic model, I also assume that the Principal has all of the bargaining power (at least on the local scale), making it a take-it-or-leave-it offer. This assumption does not rule out ex post contractual enforcement problems and the possibility of side-selling. The Principal is assumed to have perfect information on the farmers' and group's characteristics (this assumption is relaxed in the next section). Second, the two farmers play a group credit-repayment game, that is, they are jointly liable for repayment by their peers (each other's repayment). If the group repays its whole credit at the end of the game, then contract farming can be repeated in the future. Otherwise, the group is denied credit access in the repeat stages of the game.

The structure of this sub-game is the same as that in Armendariz de Aghion (1999) except that the probability of repayment is endogenous in our model, and depends upon a production effort variable. In addition, there may be strategic defaulting (ex post moral hazard) because a parallel market may exist allowing for possible contract-enforcement failures. In this case, the Principal should envision an efficient pricing so as to render side-selling unprofitable for farmers. While peer monitoring is a device to deter strategic defaulting in Armendariz de Aghion (1999), I also use it here to reduce the scope of ex ante moral hazard. The timing of the game is represented in Fig. 1. Note that this one-shot game can be repeated n times, which will lead to endogenizing the value of contract renewal.

[Fig. 1 here: Principal – group game under joint liability]

After the contracting stage, farmers simultaneously choose a level of individual production effort e and of peer monitoring γ, which are assumed to lie on the interval $[0,1]$. The individual effort is private information but can be observed ex post with probability γ. The equilibrium choice of γ is the minimum desired level of peer monitoring among the group's members. The level of effort represents the labor effort and the quality of the input application (which can be diverted or resold on the black market). Effort is assumed to have a quadratic cost $C(e) = ce^2/2$ and peer monitoring a linear one $C(\gamma) = d\gamma$.

I model effort as a moral hazard variable, that is, the observed production outcome is realized with a probability that increases with effort. For the sake of simplicity, I assume that using one unit of input, farmers can reach two levels of production:

$$\begin{array}{l} \overline{Y} \text{ with probability } e \\ \underline{Y} \text{ with probability } 1-e \end{array} \quad (1)$$

Note that although production outcome is random, there is no exogenous source of risk in the model. Adding exogenous risk would not add much to our analysis, except when considering risk-averse farmers.

The lower production outcome does not allow the Principal to recover the input loan, while the higher production outcome does. In the latter case, the farmer gets a positive profit, while he/she defaults in the former:

$$(\tilde{p} - p)\overline{Y} > 1 > (\tilde{p} - p)\underline{Y} \text{ and } p\overline{Y} > 1 > p\underline{Y} \qquad (2)$$

I assume limited liability of farmers as no more than the produced cash crop can be seized by the Principal. In the case of defaulting, they get zero profit (under no side-selling); I assume that future credit access is lost, and that any produced cash crop is seized (except if farmers practice side-selling). Since I am interested in the case of joint liability, I allow that a group of two symmetric farmers will be able to repay if one of the two farmers defaults, such that:

$$p\overline{Y} + p\underline{Y} > 2 \qquad (3)$$

When playing in groups, farmers can choose their individual maximizing effort, which drives an individual optimum level of effort. However, they can attain a higher level of effort that will allow both farmers to be better off. This cooperative effort, e^c, which they want to induce (maximizing the joint profit of the group), cannot be supported as an equilibrium as such, since both parties have individual incentives to deviate. Deviation involves saving on effort costs while benefitting from the other member's higher efforts (less expected individual and group defaulting). Let us now formally describe how cooperative effort can be enforced through peer monitoring.

With peer monitoring, farmers' efforts and production can now be observable with some probability. Setting the cooperative level of effort as a group objective (or an informal rule or norm), anyone who is observed cheating can be punished. If the group observes ex post that a farmer has not respected his/her commitment and has played his/her individual profit-maximizing level of effort e^{nc} (non-cooperative), he/she will incur a social sanction W. As in Armendariz de Aghion (1999), this will also apply to ex post cheating farmers who choose to side-sell their crops and in turn, avoid repaying their input credit when they were in position to do so. The social sanction may be a loss of reputation in the farmer's community or exclusion from the group, for instance. Incentives to invest in peer monitoring thus depend on its efficiency, that is, the relative level of W compared to d, and on the additional profit in moving from a non-cooperative to a cooperative production effort or from a side-selling to a no side-selling one. I call d/W the group's peer-monitoring cost-to-sanction ratio. Simultaneous monitoring and effort decisions are thus endogenous and related to one another. According to Armendariz de Aghion (1999), full joint liability and implementation of the whole social sanction are always optimal for the group. I then derive the optimal solutions under full joint liability and punishment. However, I consider that the social sanction can be implemented with cheating farmers only if the other farmer(s) are non-cheating: no side-selling, and cooperative effort. That is, W is implemented contingent on the state of farmers' efforts and outcomes.

Once production occurs and farmers choose to deliver their crops to the Principal (or not, i.e. decide to side-sell), farmers learn of their peers' effort and production outcomes with some probability and punish cheaters (i.e. non-cooperative or side-selling). If the group repays its global debt, then it will be funded again in the next period. The exogenous value of accessing credit in the next periods is denoted $V > 0$.[11] All parameters are common knowledge within the group.

3. The two-symmetric credit-repayment game

3.1 The pure ex ante moral hazard problem

Assuming risk neutrality,[12] I can write the objective function of a group of two symmetric farmers under a full joint liability agreement (same effort undertaken by both players). This contains individual and group incentives:

$$E\pi = e^2[p\overline{Y}-1]+e(1-e)[p(\overline{Y}+\underline{Y})-2]+Ve(2-e)-ce^2/2 \qquad (4)$$

where e^2 is the probability that both farmers will repay their credit and $e(1-e)$ is the probability that an individual farmer will repay but will have to finance his/her peer's debt. Finally, $e(2-e)$ is the probability that at least one farmer will repay their credit, so that the group can be refunded in the next period. The first two terms on the RHS are individual profit incentives, and the third one is a group incentive: the whole group repayment and motivation for contract renewal or reputation building.

I solve the game by backward induction. I first compute the cooperative, and then the non-cooperative levels of production effort (maximizing individual objective), then I look at the equilibria according to peer-monitoring decisions. Notably, I define parameter intervals in which cooperative and non-cooperative effort levels are the equilibrium of the credit-repayment game. Second, according to the levels of cooperative and non-cooperative effort, I derive the optimal peer-monitoring investment. Finally, I derive simultaneous effort and peer-monitoring equilibria according to the model's parameters.

To obtain the optimal level of cooperative effort, I maximize eq. (4) with respect to effort under the participation constraint that expected profit is non-negative and treat the peer's effort as endogenous. Note that this is sufficient since the farmers are symmetric. First-order conditions entail:

$$e^c = \frac{p(\overline{Y} + \underline{Y}) - 2 + 2V}{c + 2p\underline{Y} - 2 + 2V} \tag{5}$$

To obtain interior solutions, I assume that

$$c > p\Delta Y = p(\overline{Y} - \underline{Y}) \Rightarrow c/2 > 1 - p\underline{Y} \tag{6}$$

because of eq. (3). To make sure that this assumption is relevant, I hereafter consider the case in which $c/2 < 1$. The non-cooperative effort is the optimal individual effort, treating the peer's effort as exogenous, and solves the following problem:

$$\max_e \; ee'[p\overline{Y} - 1] + e(1 - e')[p(\overline{Y} + \underline{Y}) - 2] + V(e + e'(1-e)) - ce^2/2 \tag{7}$$

where e' stands for the exogenous effort of the other player. First-order conditions yield the best-response function for each farmer:

$$e^{nc}(e') = \frac{p(\overline{Y} + \underline{Y}) - 2 + V}{c} - e'\frac{(p\underline{Y} - 1 + V)}{c} \tag{8}$$

Note that for low values of V, efforts are strategic complements, whereas they become strategic substitutes at higher V.

Now I look at the effort equilibria according to peer-monitoring levels. In the credit-repayment game, there are two pure strategies: play cooperatively or not.

Effort strategies	Cooperative	Non-cooperative
Cooperative	e^c, e^c	$e^c, e^{nc}(e^c)$
Non-cooperative	$e^{nc}(e^c), e^c$	$e^{nc}(e^{nc}), e^{nc}(e^{nc})$

[Table 1: Strategies of the credit – repayment game under no side – selling]

(e^c, e^c) is the equilibrium if the expected profit of playing cooperatively is greater than that of deviating minus the expected social sanction, that is $E\pi(e^c, e^c) > E\pi(e^{nc}(e^c), e^c) - \gamma W$. In addition, $(e^{nc}(e^{nc}), e^{nc}(e^{nc}))$ is an equilibrium because the return from non-cooperative behavior is larger than deviation, and neither non-cooperative player can implement social sanctions on the other: in other terms, $E\pi(e^{nc}(e^{nc}), e^{nc}(e^{nc})) > E\pi(e^c, e^{nc}(e^{nc}))$. After some calculations, I find that the cooperative effort level is a symmetric equilibrium if and only if:

$$\gamma > \gamma^c = \min(\frac{c(\Delta e)^2}{2W}, 1) \qquad (9)$$

where $\Delta e = e^c - e^{nc}(e^c) > 0$ because of eqs. (5) and (8) when efforts are interior solutions, and *Δe* with V. Indeed,

$$\frac{\partial \Delta e}{\partial V} = \frac{(c - p\Delta Y)}{(c + 2p\underline{Y} - 2 + 2V)^2} > 0$$

because of the assumption made in eq. (6). Hence, while effort incentives increase with *V*, the cooperative effort is more and more difficult to enforce and needs higher peer-monitoring levels γ^c. Therefore, there is a trade-off between group incentives on individual effort and the ones on peer monitoring.

Thus only two pure equilibria exist, the symmetric non-cooperative and cooperative ones, and the latter only exists under a sufficient level of peer monitoring. The choice between each equilibrium will then depend on the cost of peer monitoring and the profit differences. From eq. (9), I can discuss the pattern of peer-monitoring thresholds that define the areas of equilibrium occurrence. Note that there is no mixed-strategy equilibria because mixed strategies entail higher peer-monitoring costs and levels than cooperative strategies, with lower expected returns.

Having found how effort equilibria are related to levels of peer monitoring, now I need to derive the levels of peer-monitoring equilibria according to effort levels and to the parameters of the model. Peer monitoring is profitable when it enables farmers to undertake a cooperative effort instead of a non-cooperative one, when it is Pareto-improving. However, it is costly, and optimal peer monitoring is therefore the minimum level of peer monitoring that can trigger a profitable shift in the effort equilibrium. In our case, the peer-monitoring equilibrium will correspond to γ^c if players expect a cooperative equilibrium in efforts, or to 0 if they expect a non-cooperative equilibrium. Therefore, the joint (e^c, γ^c) is a Pareto-dominating equilibrium if and only if:

$$E\pi(e^c, e^c) - E\pi(e^{nc}(e^{nc}), e^{nc}(e^{nc})) \geq d\gamma^c$$

$$\frac{c(c + 2p\underline{Y} - 2 + 2V)}{(c + p\underline{Y} - 1 + V)^2} \geq \frac{d}{W} \qquad (10)$$

The solutions of the credit-repayment game are stated in the following proposition and are represented in Fig. 2.

Proposition 1 *In the credit-repayment sub-game with two symmetric farmers under ex ante* *moral hazard but without side-selling, the likelihood of cooperative equilibrium first increases and then decreases with respect to the present value of contract farming* V *, and decreases with respect to the group's peer-monitoring cost-to-sanction ratio* d/W *. All effort levels increase with the value of contract farming and output price, and decrease with the effort's marginal cost. Simultaneous individual effort and collective peer-monitoring decisions entail:*

- *Farmers play cooperatively with* $\gamma^* = \gamma^c$ *when* V *and* d/W *are low (such that eq. (10) is satisfied)*
- *Farmers play non-cooperatively with* $\gamma^* = 0$ *when* V *and* d/W *are high*

[Fig. 2 here: Simultaneous effort and peer – monitoring equilibria under no side – selling]

Intuitively, when V becomes large, cooperative and non-cooperative effort levels become so close that it is no longer profitable to peer monitor since the marginal profit is too low. This means that the Principal's trade-off between effort and peer-monitoring incentives is meaningful only for intermediate values of *V* around which farmers can be indifferent between cooperative and non-cooperative strategies (according to *d/W*) while differences in effort levels are still significant

Note that the occurrence of a cooperative equilibrium first increases with V for its lowest values since efforts are strategic complements when V is low (see Fig. 2), but then decreases for larger values since efforts become strategic substitutes. Note also that an increase in p will correspond to a leftward shift of the curves in Fig. 2 (see comparative statics in appendix). In brief, a price change has non-monotonic effects and should be accounted for by the Principal.

3.2 Introducing side-selling (strategic defaulting)

3.2.1 Ex post side-selling decisions

I now introduce the possibility of strategic defaulting ex post, that is, after effort has been applied and production has occurred. Farmers (players) can now decide whether or not to sell their production to the contractor (the agribusiness) or to strategically default, that is, to choose to sell it to another trader and avoid repaying the credit. I assume that the price offered by another trader is the same as the one by the Principal.[13] As in Armendariz de Aghion (1999), I assume that peer monitoring also concerns this ex post moral hazard problem, and strategic defaulting can be revealed with some probability γ, already invested at the beginning of the repayment game together with production effort. Learning both players' decisions in terms of effort as well as strategic defaulting occurs after production and decisions to side-sell have been taken.[14] Under ex post defaulting, a social sanction W can also be imposed on the strategic defaulter if and only if the other player is not a defaulter. And as in the previous section, the social sanction can be implemented only by cooperative farmers. Thus, I make the same assumption as in the case of efforts, i.e. the implementation of W is contingent on the game's outcomes. This, in turn, will make only symmetric equilibria emerge.

I start with the level of peer monitoring required to avoid side-selling. Note that peer monitoring makes sense only if farmers undertake cooperative effort levels; if not, then nobody is able to impose a social sanction, making peer monitoring unprofitable. Under cooperative efforts, a high-outcome player (meaning one having reached $\overline{Y}$) chooses not to default if and only if:

$$e^c(p\overline{Y}-1)+(1-e^c)(p(\overline{Y}+\underline{Y})-2)+V \geq p\overline{Y}-\gamma W$$

and if he/she knows that a low-outcome player will not strategically default either:

$$e^c V \geq p\underline{Y}-\gamma W \tag{11}$$

Thus, there is a symmetric non-side-selling equilibrium whenever

$$\gamma \geq \frac{\max(p\underline{Y}-e^c V, 1-V+(1-e^c)(1-p\underline{Y}))}{W}=\gamma^{SS} \tag{12}$$

If eq. (11) is not satisfied, then no side-selling needs to satisfy:

$$e^c(p\overline{Y}-1)+(1-e^c)(p\overline{Y}-2)+e^c V \geq p\overline{Y}-\gamma e^c W$$

so that:

$$\gamma \geq \frac{2/e^c-1-V}{W} \tag{13}$$

and only high-outcome players choose not to side-sell. If eq. (12) is not satisfied, then a low-outcome player chooses not to side-sell whenever:

$$\gamma \geq \frac{p\underline{Y}}{(1-e^c)W} \tag{14}$$

Then it is possible to show that eq. (11) is always satisfied whenever eq. (13) is, such that NS (no side-selling) by high-outcome players together with SS (side-selling) by low-outcome ones is not an equilibrium.[15] Eq. (11) is also satisfied as soon as eq. (14) is, and the same goes for eq. (12) under the assumptions made in the previous subsection with regard to c.

Therefore, there is no side-selling by either high-outcome or low-outcome players whenever eq. (12) is satisfied; otherwise, both high-outcome and low-outcome players choose to side-sell.

Only symmetric equilibria exist in repayment decisions, similarly to the case of effort decisions,.

Under non-cooperative efforts, farmers are not able to implement a social sanction on others. Therefore, side-selling is avoided by high-outcome players as soon as:

$$e^{nc}(p\overline{Y}-1)+(1-e^{nc})(p(\overline{Y}+\underline{Y})-2)+V \geq p\overline{Y}$$

and
$$e^{nc}V \geq p\underline{Y} \tag{15}$$

hold together, or whenever

$$e^{nc}(p\overline{Y}-1)+(1-e^{nc})(p\overline{Y}-2)+e^{c}V \geq p\overline{Y}$$

This can happen if and only if

$$V \geq \max(\frac{p\underline{Y}}{e^{nc}},1+(1-e^{nc})(1-p\underline{Y}))=V^{SS} \Leftrightarrow V \geq 1+(1-e^{nc})(1-p\underline{Y})) \tag{16}$$

$$\Rightarrow V \geq 2-p\underline{Y}$$

In addition, low-outcome players will always choose to side-sell when high-outcome players do so. So there are only two pure equilibria in side-selling: either both high-outcome and low-outcome players choose not to side-sell whenever peer monitoring is sufficiently high and eq. (12) is satisfied under cooperative efforts, or whenever V is high enough under non-cooperative efforts, or both will side-sell.

3.2.2 Optimal ex ante effort and peer-monitoring decisions

The next issue is then to determine when such peer-monitoring investment, in the case of cooperative effort, will be made, and whether it will be enough to induce cooperative behavior as an equilibrium. For instance, cooperative farmers willing to side-sell cannot use the social sanction ex post and therefore, the cooperative effort cannot be sustained as an equilibrium. The side-selling option will thus change the core results that were derived when assuming no side-selling. Overall, there are basically three equilibria that can emerge: the non-cooperative side-selling one (SS), the cooperative one (without side-selling), and the non-cooperative one (without side-selling) which are still denoted C and NC, respectively. The two latter effort equilibria are the same as in the previous subsection.

I note that under side-selling, the non-cooperative effort becomes (maximizing expected individual returns on effort without incurring the input cost):

$$e^{SS}=\frac{p\Delta Y}{c} \tag{17}$$

which is larger than the non-cooperative effort without side-selling, and even larger than the cooperative one when V is low, i.e. whenever

$$V \leq 1 - p\underline{Y}$$

When eq. (16) is not satisfied, the table of the game's outcome becomes:

Effort strategies	Cooperative	Non-cooperative
Cooperative	e^c, e^c	e^c, e^{SS}
Non-cooperative	e^{SS}, e^c	e^{SS}, e^{SS}

[Table 2: Ex ante effort strategies under ex post side−selling]

Otherwise, it is the same as Table 1.

Since for low V values, the non-cooperative effort under side-selling is higher and yields higher profits than before, the value of γ^c needed to enforce the cooperative effort equilibrium now increases. The new threshold value of peer monitoring is such that:

$$E\pi(e^c, e^c) \geq E\pi(e^{SS}) - \gamma W$$

$$\gamma_{SS}^c = \frac{[e_{SS}^{nc} - e^c][p\Delta Y - c(e_{SS}^{nc} + e^c)/2] + e^c(2 - e^c)(1 - V - p\underline{Y})}{W} \tag{18}$$

noting that $e_{SS}^{nc} - e^c = \dfrac{2(c - p\Delta Y)(1 - V - p\underline{Y})}{c(c + 2p\underline{Y} - 2 + 2V)}$ and is equal to 0 when $V = 1 - p\underline{Y}$, so that non-negative peer monitoring is only needed whenever $V \leq 1 - p\underline{Y}$. For a higher value of V, the cooperative effort is more desirable than the side-selling one, and peer monitoring is not required to prevent from side-selling ex ante. However, it is still possible that players will side-sell ex post. I can show that for any V not satisfying eq. (16), $\gamma_{SS}^c \leq \gamma^{SS}$. I now focus on determining the cases in which γ^{SS} is chosen by the players when the non-cooperative effort is necessarily a side-selling one. For high V values (side-selling does not exist), we are back to the same solution as in the previous subsection.

Players choose to invest γ^{SS} whenever:

$$E\pi(e^c, e^c) - d\gamma^{SS} \geq E\pi(e^{SS})$$

$$\frac{d}{W} \leq -\frac{\gamma_{SS}^c}{\gamma^{SS}} \tag{19}$$

which is possible only when $V \geq 1 - p\underline{Y}$ and whenever $\gamma^{SS} \geq 0 \Leftrightarrow V \leq V^C$. Therefore, there exists intermediate levels of V lying on the interval $[1 - p\underline{Y}, V^C]$ for which the cooperative effort is an equilibrium and requires a (strictly positive) peer-monitoring investment of γ^{SS}. There also exists an interval $[V^{C}, V^{SS}]$ where the cooperative effort is an equilibrium without any peer-monitoring investment. Those particular values of V are:

$$V^{C} = \max\{\frac{2(2-p\underline{Y})-c+\sqrt{(c+2(2-p\underline{Y}))^{2}-8(2+p\Delta Y)(1-p\underline{Y})}}{4}, \frac{2-p\Delta Y+\sqrt{(2-p\Delta Y)^{2}+8p\underline{Y}(c-2(1-p\underline{Y})}}{4}\}$$

$$V^{SS} = \max\{\frac{2-p\underline{Y}-c+\sqrt{(c+(2-p\underline{Y}))^{2}-4p\underline{Y}(1-p\underline{Y})}}{2}, \frac{2-p\overline{Y}+\sqrt{(2-p\overline{Y})^{2}+4p\underline{Y}(c-(1-p\underline{Y}))}}{2}\}$$

The equilibrium area is thus defined by an area of side-selling equilibrium for low V values, an increasing area of cooperative equilibrium over the side-selling one for intermediate V, and a decreasing area of cooperative equilibrium over the non-cooperative one (without side-selling) for the highest V. Compared to the case of no side-selling, there will be an area of inefficient contracting where side-selling is occurring but for intermediate V values, the cooperative equilibrium may become more likely. This can be explained by the fact that even if the non-cooperative effort is more profitable than the cooperative one in this region of parameters, players know ex ante that the non-cooperative effort will turn into side-selling ex post, while the cooperative effort is enforceable as an equilibrium over the side-selling one and yields additional profits. So for intermediate V values, the threat of side-selling results in bringing more effort and peer-monitoring incentives to farmers, in a complementary way, which contrasts with the case of no side-selling.

[Fig. 3 here: Effort and peer – monitoring equilibria under side – selling]

Proposition 2 *Introducing side-selling in the two symmetric players' repayment game with ex ante moral hazard on effort affects Proposition 1 in the following way:*

- *When V is low, side-selling is a certain ex post outcome, which corresponds to inefficient contracting*
- *When V is intermediate, the likelihood of a cooperative equilibrium increases with V and may become certain*
- *When V is high, then the likelihood of cooperative equilibrium decreases with V, as for the case of no side-selling, and the non-cooperative equilibrium becomes more likely (certain if $d/W \geq 1$)*

The main change with respect to Proposition 1 is that peer monitoring and effort incentives may go in the same direction when V is of intermediate value because of the threat of side-selling ex post. The area of equilibrium occurence as a function of our parameters V and d/W is shown in Fig. 3. Fig. 4 displays effort equilibria and their related levels along V and according to d/W.

[Fig. 4 here: Sequence of effort equilibria along V]

4. Contracting

4.1 Optimal pricing rule

Assuming that the Principal has market power and perfect information on farmers' characteristics, it will optimize its own profit by accounting for the farmers' reactions within their group, as solved for the credit-repayment game. In a first step, the Principal maximizes its own profit, according to effort levels. I first solve this optimization problem for both effort levels—cooperative and non-cooperative—while accounting for possible side-selling (in this case, the Principal incurs a loss). Then, I look at the output price for which farmers are indifferent between playing cooperatively or not. Comparing the indifferent price $\bar{p}$ to the optimal pricing under farmers' cooperative and non-cooperative behavior enables us to define an optimal pricing rule for the Principal. I directly take into account the possibility of side-selling.

According to the effort reaction of farmers e^x, then the Principal solves:

$$\max_{p} \Pi^x(p) = (\bar{p} - p)(\underline{Y} + e^x \Delta Y) - 1 + (e^2 + 2e(1-e)) \tag{20}$$

where the x superscript represents the type of effort equilibrium [$x = C$ (cooperative), or $x = NC$ (non-cooperative)], assuming that the price given to farmers will not induce side-selling. I assume that the participation constraint of farmers is not binding at optimum ($\bar{p}$ is sufficiently high) and that optimal pricing is efficient (no side-selling). I obtain the following first-order condition:

$$[\frac{\bar{p} - p^*}{p^*}]^x = \frac{1}{\varepsilon_{EY^x/p}} - \frac{2(1-e^x)}{p^* \Delta Y} \tag{21}$$

which is the optimal margin for the Principal, and where EY^x is the expected production level when effort is x and $\varepsilon_{EY^x/p}$ is the individual price elasticity of supply. Note that this optimal margin falls under the standard Ramsey rule since the Principal internalizes farmers' credit repayment and the associated complementarity between interlinked input and output markets. When V is not too small, the optimal margin is unambiguously higher under cooperative effort since this effort is less reactive to price. Then, under lower price elasticity and higher effort, the Principal can propose a lower price to cooperative farmers' groups compared to non-cooperative ones. For low V, the above expression is also lower under the cooperative effort reaction, although $\frac{\partial e^{c}}{\partial p} > \frac{\partial e^{nc}}{\partial p}$. Note that both optimal cooperative and non-cooperative prices decrease when V increases, according to eq. (21). But when pricing is too low, it induces farmers to side-sell.

I then look at the indifferent price level $\tilde{p}$ at which farmers are indifferent between cooperative and non-cooperative strategies. According to our calculations in the previous subsection, this means that the inequality in eq. (10) should be equalized, which yields:

$$(c+\tilde{p}\underline{Y}-1+V)^2 \frac{d}{W} = c(c+2(\tilde{p}\underline{Y}-1+V)) \tag{22}$$

$$\text{such that } 1 > c/2 > 1-\tilde{p}\underline{Y} > 0 \tag{23}$$

Eq. (22) admits at least one solution when $\frac{d}{W}<1$. This is a necessary condition for having a non-zero probability of playing cooperatively among farmers, as already derived in the previous subsection. These solutions are such that:

$$1-\tilde{p}\underline{Y} = V - \frac{c}{d/W}[1-d/W \pm \sqrt{1-d/W}] = \{V-V_2, V-V_1\} = \{1-\bar{p}\underline{Y}, 1-\underline{p}\underline{Y}\} \tag{24}$$

where $V_1 = 1-d/W-\sqrt{1-d/W} \le V_2 = 1-d/W+\sqrt{1-d/W}$. For the two solutions to be feasible, eq. (24) must satisfy the constraints stated in eq. (23) if $\{V-V_1, V-V_2\} \subset [0, c/2]^2$. For at least one solution to exist, one of the two elements of $\{V-V_1, V-V_2\}$ must be contained in $[0, c/2]$. I then derive the ranges of parameters $(V, d/W)$ for which solutions exist. This can be represented in the Fig. 5.

I now look at the indifferent price p^{SS} for which farmers are indifferent between side-selling and cooperative behavior, that is, whenever inequality (19) is equalized. According to our first results, such an indifferent price only exists when V belongs to $[1-p\underline{Y}, V^{C}]$, but exists for all positive d/W. I also look at the price p^{NS} for which side-selling is deterred. This price should be such that $V = V^{SS}$. These two prices exist in particular regions of the $(V, d/W)$ diagram, displayed in Fig. 5. It can be seen that since side-selling will always emerge for low V, then the existence of $\underline{p}$ does not matter, since it will induce a cooperative effort that is not sustainable as an equilibrium. I note that for intermediate V values, there exist intervals of prices p^{SS} for which the cooperative effort can be sustained as an equilibrium over side-selling, which is beneficial for the Principal as soon as some positive profit can be made. There also exist an interval of prices p^{NS} that ensure cooperative equilibrium over the non-cooperative one, irrespective of the value of d/W, and for the highest V, then $\overline{p}$ exists for the low values of d/W.

[Fig.5 here: Existence of indifferent prices and farmers′ behavior]

The optimal solution for the Principal would then account for the change in the effort type of producers, x, according to the parameters of the group d/W and V and the price incentives not to side-sell. The decision set can be illustrated in Fig. 5. I denote $\underline{p^c} < \overline{p^c}$, the two bounds on the Principal's profit curve under cooperative effort such that:

$$\max \Pi^{nc}(p) = \Pi^{nc}(p^{nc*}) = \Pi^{c}(\underline{p^c}) = \Pi^{c}(\overline{p^c}) \tag{25}$$

Since Π^{nc} is always lower than Π^{c} for every p, then $\underline{p^c} < p^{c*} < p^{nc*} < \overline{p^c}$. From Fig. 5 and our previous calculations, I know that the optimal pricing rule for the Principal will follow a particular sequence as a function of V, and depending on d/W. Cooperative and non-cooperative optimal pricing will be applied when their respective effort and peer-monitoring levels can be sustained as equilibria. Otherwise, indifferent prices should be proposed to farmers in order to encourage them not to side-sell or rather, to adopt cooperative instead of non-cooperative behavior when it is profitable for the Principal. However, proposing p^{SS} may still lead to deficits for the Principal. I thus define a price area of efficient contracting where side-selling will not be sustained as an equilibrium and where the Principal can derive positive profits. The overall optimal pricing rule is displayed in Fig. 6.

First (for the lowest V values), and as soon as it becomes profitable for the Principal, the price offered to farmers will be p^{SS} in order to deter side-selling and induce farmers to undertake cooperative efforts and peer monitoring; then, optimal cooperative pricing p^{c*} will be offered to farmers. Cooperative pricing cannot be sustained when it becomes higher than $\max(p^{NS}, \overline{p})$.

When d/W is high, optimal pricing will be p^{NS} in order to ensure farmers' cooperative behavior when it is profitable for the Principal, i.e., when $p^{NS} \geq \underline{p}^c$. When d/W is low, optimal pricing will be $\overline{p}$ for the same reasons and also higher than $\underline{p}^c$. For the highest value of V, only non-cooperative pricing will be offered. Note that cooperative, non-cooperative, and $\underline{p}^c$ prices will shift upward under an increase in $\tilde{p}$, and the area of no contracting will shrink. While cooperative pricing can be implemented for lower V, this will also hold for the non-cooperative pricing which will also start to be implemented earlier.

I see that the sequence of optimal prices is discontinuous with respect to V, decreasing by parts but non-monotonic. The following proposition can then be stated:

Proposition 3 *The optimal price offered to farmers' groups decreases with respect to the present value of contract farming and increases with respect to the group's peer-monitoring cost/sanction ratio.*

- *When V is very low, there is no efficient contracting because it is too costly for the Principal to deter side-selling*
- *When V increases, optimal pricing follows the sequence p^{SS} (side-selling deterrence), p^{c*} (cooperative pricing), $\overline{p}$ or p^{NS} (according to d/W), and p^{nc*} (non-cooperative pricing)*
- *p^{c*} and p^{nc*} decrease with increasing V and increase with increasing $\tilde{p}$*

[Fig. 6 here: Optimal pricing rule sequence along V]

Hence, according to parameters related to farmer and group characteristics, optimal pricing can change and will induce different effort equilibria in the credit-repayment game. Note that the Principal can achieve optimal profits along the interval $[\Pi^{nc}(p^{nc*});\Pi^{c}(p^{c*})]$ after having deterred side-selling. Last, note that a change in d/W from 0 to 1 will decrease the range of V values for which $p^* = p^{c*}$ since the area of cooperative pricing and equilibrium will shrink, as shown in Fig. 6.

4.2 Endogenizing *V*

If the credit-repayment game is repeated n times, then it is possible to endogenize the value of V, allowing further implications to be derived. The probability of getting to play the nth time is

$[e(2-e)]^n$. It should be stated that the value of contracting and accessing credit is the present value of expected profit minus an opportunity cost Z, which is the value of the alternative option, assumed to be less valuable than contracting. Hence, if the conditions (parameters) of the game do not change over time,

$$V = \sum_{k=1}^{n} \frac{1}{1+\delta^k}[e(2-e)]^k \{e^2[p\overline{Y}-1] + e(1-e)[p(\overline{Y}+\underline{Y})-2] - ce^2/2 - Z\} \tag{26}$$

where e is the cooperative effort and δ stands for a discount factor. In the case of a non-cooperative effort:

$$V = \sum_{k=1}^{n} \frac{1}{1+\delta^k}[e+e'(1-e)]^k \{ee'[p\overline{Y}-1] + e(1-e')[p(\overline{Y}+\underline{Y})-2] - ce^2/2 - Z\} \tag{27}$$

where e is the non-cooperative effort reaction as a function of e', the other farmer's effort. Note that these two functions depend on price. Since I have already derived the optimal pricing rule as a function of V, and I know that V, as valued by farmers, is a function of prices that farmers receive, then it is possible to find price equilibrium (may be multiple equilibria). Drawing $V^c(p)$ and $V^{nc}(p)$ on the graph in Fig. 6 will enable us to find the final price equilibria. I note that $V^c(p) \geq V^{nc}(p)$ for a given p and that both are convex functions. Drawing their inverse functions in Fig. 6 yields the price equilibrium.

Fig. 7 displays the case in which both inverse V-curves cross optimal pricing rules of the Principal in the side-selling-deterrence region. Another case is shown in which the V^c curve crosses the optimal price curve in the cooperative region when d/W is low (in black), while the V^{nc} curve crosses the optimal price curve in the non-cooperative region when d/W is higher (in gray). Note that cooperative and non-cooperative prices can also coexist as equilibria, but the Principal may find one (most likely the cooperative pricing equilibrium) to be Pareto-dominating over the other.

The location of the crossing points depends on the value of exogenous parameters, c, $\overline{Y}$, and $\underline{Y}$. For instance, if c increases, cooperative and non-cooperative optimal pricing curves will shift upward to provide more effort incentives to farmers (and because of higher price elasticity), and in the meantime, the $V(p)$ curves will shift downward. Taken together, this means that the cooperative and non-cooperative price equilibria, when they exist, will increase with c, while cooperative pricing becomes more likely (and may be the case for side-selling deterrence) than non-cooperative pricing and efforts. Last, endogenous V enables us to find at least one price equilibrium, although under some parameter values, the optimal price equilibrium may still locate in the no-contracting case. All comparative statics with respect to exogenous parameters are provided in the appendix, and displayed for the repayment and contracting stages (with endogenous *V*).

[Fig. 7: Endogenous V and price equilibria]

5. Extensions

5.1 Group size

An increase in group size will change the incentives for effort as the outcome largely depends on the behavior of others, although not in the cooperative case as everybody endogenizes the same behavior. There are more people to share the deficit of defaulting farmers, but there may be more defaulting farmers. One's own contribution to the likelihood of accessing future credit is reduced. Size changes the probability distribution of ex ante expected profits.

I first look at the effect of size on cooperative and non-cooperative effort levels, then I discuss the effect on peer monitoring. I assume that groups are formed by an even number of members. With n symmetric risk-neutral farmers, the cooperative effort (joint-profit maximizing) is solved for:

$$\max_{e} \sum_{k=0}^{k=n/2} \binom{n-1}{k} [e^{n-k}(1-e)^{k}][p\overline{Y} - 1 + \frac{nV - k(1-p\underline{Y})}{n-k}] - ce^{2}/2 \tag{28}$$

An intuitive route to identifying the way in which size influences effort incentive is to look at the cumulative probability distribution of profits according to e, holding e constant. Then, effort incentives will be higher if the cumulative distribution exhibits first-order stochastic dominance. In Fig. 8, I see that the answer is not obvious and that there is no first-order stochastic dominance. However, according to our parameters, there are distributions (for intermediate sizes) that may second-order stochastically dominate the others and provide the optimal incentives.

[Fig. 8 here: Cumulative probability distribution of profits under cooperative effort]

When farmers play non-cooperatively, larger groups not only decrease the incentive to get V [16] but also that for individual profits, since the cumulative distribution of profits is less affected by own actions. Strategic effort substitutability and complementarity are of smaller scopes. As a consequence, the level of non-cooperative effort decreases with group size.

Thus I can conjecture upon the changes in terms of peer-monitoring incentives. There exists a range of group sizes for which cooperative effort incentives are higher, meaning that γ^{c} takes on higher values, while γ^{SS} and γ_{SS}^{c} are lower. This has several implications with regard to Proposition 2. First, for such group sizes, the occurrence of side-selling is less likely (the left area in Fig. 3 will shrink), while cooperative equilibrium becomes more likely for intermediate V. For high V however, while γ^{c} increases, the difference between cooperative and non-cooperative farmers' profit also increases, so that the effect of group size on the likelihood of cooperative equilibrium is ambiguous.

For specific parameter values of V and d/W, there exists an optimal size for which effort and farmers' profits are largest, that is, under cooperative behavior (intermediate group size). However, when the group has a low ability to enforce the cooperative equilibrium (i.e. when d/W and V are high), smaller groups are desirable. So optimal group size is sensitive to group and individual characteristics.

Regarding optimal pricing by the Principal, this should be adjusted accordingly (reflected by changes in the curves displayed in Fig. 7). Cooperative pricing should be adjusted downward when group size is optimal while non-cooperative pricing should be increased when group size increases (as functions of V). The area of inefficient contracting will shrink because of less likely side-selling when the group is of intermediate size. Together with endogenous V, it is, however, unclear whether cooperative or non-cooperative price equilibria will become more likely (which has to do with the above-mentioned ambiguity for high V), but the cooperative price equilibrium will be a lower price under optimal group size, while non-cooperative pricing should be increased if group size increases. This is because the inverse V^{c}-curve will shift downward under optimal group size while the inverse V^{nc}-curve will shift upward when group size increases.

Taken together, there may exist an optimal group size for which effort and peer-monitoring incentives, as well as the Principal's profit, are maximized whenever the parameters are such that the cooperative equilibrium is ensured—meaning that the price equilibrium will be achieved when V is from low to intermediate values, for instance when c is not too low. However, small groups are more desirable when the parameters are such that non-cooperative pricing will be the only equilibrium—meaning that the price equilibrium will be reached at a sufficiently high value,for instance, when c is low and/or d/W is high.

5.2 Group heterogeneity

Consider one homogeneous credit group in which the two farmers have the same $\hat{c}$. To account for heterogeneity in our model, I now study the two-player game with two asymmetric farmers, endowed with two different c values such that:

$$\hat{c} = \frac{\underline{c} + \overline{c}}{2} \text{ and } \Delta c = \overline{c} - \underline{c} \tag{29}$$

I aim to compare effort and peer-monitoring incentives in the homogeneous group with those in the heterogeneous one. The cooperative effort remains the same because the credit group maximizes the farmers' joint profit, i.e. $e^c(\hat{c})$. When farmers maximize their own profit, then each farmer will exert $e^{nc}(\underline{c})$ and $e^{nc}(\overline{c})$. One obtains:

$$e^{nc}(\overline{c}) = \frac{(p(\overline{Y} + \underline{Y}) - 2 + V)(\underline{c} - (p\underline{Y} - 1 + V))}{\overline{c}\underline{c} - (p\underline{Y} - 1 + V)^2} \le e^{nc}(\hat{c}) \tag{30}$$

$$e^{nc}(\underline{c}) = \frac{(p(\overline{Y} + \underline{Y}) - 2 + V)(\overline{c} - (p\underline{Y} - 1 + V))}{\overline{c}\underline{c} - (p\underline{Y} - 1 + V)^2} \ge e^{nc}(\hat{c}) \tag{31}$$

The average non-cooperative effort in a heterogeneous group is always above the level of a homogeneous one if and only if $\frac{e^{nc}(\overline{c}) + e^{nc}(\underline{c})}{2} \ge e^{nc}(\hat{c})$, which is equivalent (after calculations) to:

$$\hat{c}^2 \ge \overline{c}\underline{c} \Leftrightarrow \Delta c \ge 0 \tag{32}$$

which is always true. Heterogeneity thus has a positive aggregate impact on the average group's effort in the case of a non-cooperative equilibrium.

Since farmers have heterogeneous preferences, their incentives to peer monitor each other are different. The rule of the game is that the chosen peer-monitoring level will be the lowest among the farmers' choices. Meanwhile, the level of peer monitoring needed to enforce cooperative equilibrium is different among farmers. The first consequence is that the cooperative equilibrium will be less likely to occur for low V and side-selling will be more likely since more costly peer monitoring is required to deter side-selling. Second, the cooperative equilibrium will also be less likely for higher V since it is more costly to enforce the cooperative equilibrium than the non-cooperative one. This would be represented in Fig. 3 (not displayed here) by a shrunk cooperative equilibrium area. So heterogeneity entails two opposite effects: the (desirable) cooperative outcome is less likely but the non-cooperative one is of higher average effort value within the group.

Overall, increasing heterogeneity can be efficient for the group in order to improve the average incentive for non-cooperative effort, but only in cases in which non-cooperative effort is to be the equilibrium. In other cases, homogeneity is preferable since it will make cooperative equilibrium more likely. Note also that the higher the heterogeneity, the more likely it is that farmers will be located in different areas of Fig. 3, meaning that this also makes the cooperative equilibrium less likely.

Knowing that size and heterogeneity are positively correlated, several implications can be derived. When the group has high d/W and V, then small groups are desirable; however, heterogeneity can improve effort incentives, so there is a trade-off between size and heterogeneity for effort incentives, meaning that the group should not be too small and should be somewhat heterogeneous. When d/W or V are lower, intermediate-size (homogeneous) groups are desirable since cooperative equilibrium can be enforced under higher effort levels and low heterogeneity is consistent with a higher likelihood of cooperative equilibrium. However, the optimal size—accounting for the positive correlation between size and heterogeneity—may entail inability to enforce the higher cooperative effort equilibrium since heterogeneity might be too high and may thus lead to side-selling or non-cooperative equilibria. Hence, the optimal size must be consistent with some level of heterogeneity which allows farmers to play cooperatively with a higher level of cooperative effort (according to the probability distribution of profits in the group). That is why larger groups exhibit more free-riding and less cooperative behavior.

If the group is formed under a free-adhesion principle, then farmers will accept new members up until the point that they no longer contribute to increasing the farmers' individual profits. Matching by affinities will induce the most highly performing and motivated farmers to get together, while groups of lower-performing farmers will prefer to be more heterogeneous, so that better incentives and expected profits will be provided to the members. As a result, groups can be too small or too large. Hence, free association of members is not likely to lead to the Pareto-optimal group size and heterogeneity.

Starting from the optimal group size and composition, the structure might not be coalition-proof, i.e., the best-performing farmers may exhibit a desire to establish their own group. The final matching outcome will depend on the initial distribution of individual types. It is then likely that the optimal group design is just a framework that is not sustainable as equilibrium of a matching process. However, any regulation of cooperative formation may be worse, because it will define membership through rigid exogenous parameters (such as origin, geographical location, village residence, etc.). Many outgrower schemes have occurred with village groups in which low incentives for production were observed. Allowing free association of members could clearly be an avenue for welfare improvement, and has already been demonstrated as one of the key determinants in the improvement of contract-farming schemes (see Kaminski et al. 2011, for the case of cotton outgrower schemes in Burkina Faso).

6. Policy implications and conclusions

In this paper, I explored the design of contract farming with groups of smallholders under joint liability, addressing the problem of both ex ante and ex post moral hazard issues through both endogenous production effort and peer monitoring. I showed that effort and peer-monitoring incentives may move in opposite directions with respect to the Agent's individual and group parameters. Hence, the optimal contract for a Principal with market power entails specific pricing rules which can be discontinuous as a function of these parameters. While side-selling makes contracting inefficient when the value of contract farming is low, it renders cooperative behavior more likely for intermediate values.

There are several implications for agricultural development. First, the efficiency of contracting with smallholders relies on both individual and group characteristics through incentives on individual production and collective monitoring. There is thus a need to collect data on individuals and their related groups, which means information on individual incentives and social dynamics. Second, information problems are double-sided and have direct consequences on contract design. While contract terms are set to overcome moral hazard problems through appropriate incentives on individual effort and collective monitoring, regulatory policies may enable increasing social welfare by enhancing farmers' incentives and regulating agribusiness profits, which will be limited by adverse selection problems from the regulator's side. Last, the efficiency and design of such contracts is affected by group design (size and composition), but optimal group design from the agribusiness's standpoint does not necessarily emerge from an endogenous process of free matching by affinities.

This provides several policy implications. First, any regulation policy should be established according to the available information on both individuals and groups (cooperatives) of smallholders in order to encourage welfare creation and cooperative levels of peer monitoring within smallholders' groups, while also taking into account information on agribusinesses' costs and profits. Second, group design will affect both individual and group incentives, and regulation of cooperative formation should then enable farmers to match by affinity through free association and co-option so as to ensure Pareto-improving matching. Where such regulations have occured and have been well implemented, smallholders' repayment rates have increased and outgrower schemes have been much more efficient, as evidenced by the successful experience of cotton groups in Burkina Faso (Kaminski et al. 2011). While joint liability is now being challenged in the literature as a successful element of microcredit schemes (Karlan and Morduch 2009), this may nevertheless be a crucial element for smallholders' access to rural credit and contract-farming design in developing countries, notably in cases where joint liability prevents side-selling and fosters cooperative behavior. Finally, since optimal group design will be affected by contract design, both cooperative and contract regulatory policies should be related to one another. The formal analysis of contract-farming regulation under joint liability is left for future research and must incorporate endogenous matching into the analysis.

Another issue to examine in future research is endogenous side-selling. In this paper, I only analyzed farmers' incentives with or without side-selling, assuming market power of the Principal and the existence of an opportunistic trader who can propose the same price as the one of the Principal. In reality, the scope and associated costs and profits of side-selling depend directly on the agro-industrial market structure. Farmers' opportunities for side-selling will likely increase under a more competitive structure. As shown by Delpierre (2008), more competition will lead to a decrease in input or credit provision, thereby justifying the competition-coordination trade-off observed in the empirical literature (see Poulton et al. 2004 for the case of African cotton sectors). Several solutions exist from a social welfare standpoint. The first is to regulate the market structure so as to mitigate side-selling while promoting a certain degree of competition. The second is to promote capacity-building for farmers' associations so as to provide them with significant bargaining power when facing a monopsonistic or duopsonistic downstream industrial structure and more capacity to access inputs. My results suggest that the welfare effects of competition and regulation of contract farming should also be appraised through an examination of the cooperative monitoring response of smallholders.

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A. Appendix

A.1 Comparative Statics

	Parameters of the credit-repayment sub-game				
Endogenous variables	***p***	***c***	***ΔY***	***V***	***d/W***
Cooperative effort	+	-	+	+	No effect
Non-cooperative effort	+	-	+	+	No effect
Side-selling effort	+	-	+	No effect	No effect
Δe	+	+ (low *V*) /-	-	+	No effect
Prob. (coop. effort) under no SS	+ (low *V*) /-	- (low *V*) /+	+ (low *V*) /-	+/-	-
Prob. (coop. effort) under SS	+ (low *V*) /-	- (low *V*) /+	+ (low *V*) /-	+/-	-
Prob. (non-coop. effort) under no SS	- (low *V*) /+	+ (low *V*) /-	- (low *V*) /+	-/+	+
Prob. (non-coop. effort) under SS	+	-	+	+	+
Prob. (side-selling)	-	+	-	-	+
	Parameters of the contracting stage under SS				
	p	***c***	***ΔY***	***V***	***d/W***
Prob. (side-selling deterrence pricing)		-	+	-	-
Prob. (cooperative pricing)	Endogenous	+ (low *V*) /-	-	-	-
Prob. (non-cooperative pricing)	outcome	+	+	-	+
Price equilibrium level		+	-	- (discont.)	No effect
	Optimal contracting under SS with endogenous *V*				
		c	***ΔY***	***V***	***d/W***
V(p)		-	+		No effect
Prob. (side-selling deterrence pricing)		?	?		-
Prob. (cooperative pricing)		+	-	Endogenous	-
Prob. (non-cooperative pricing)		-	+		+
Price equilibrium level		+ (discont.)	- (discont.)		?

Note: SS stands for side-selling

Figures

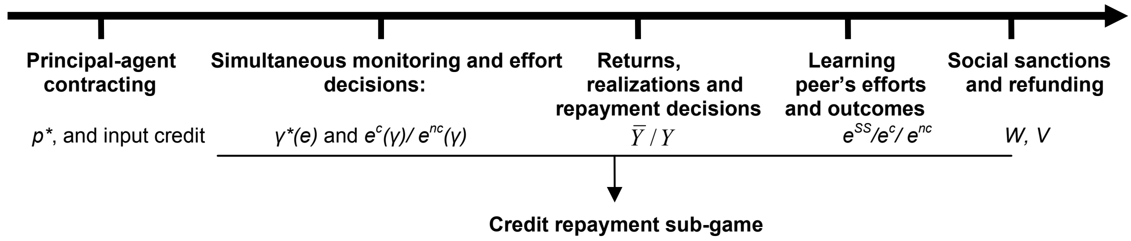


Fig. 1

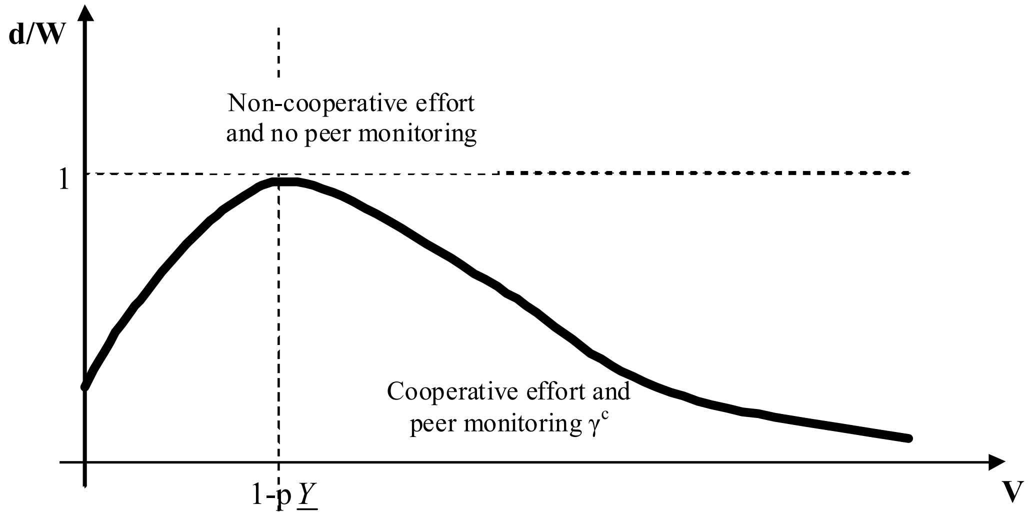


Fig. 2

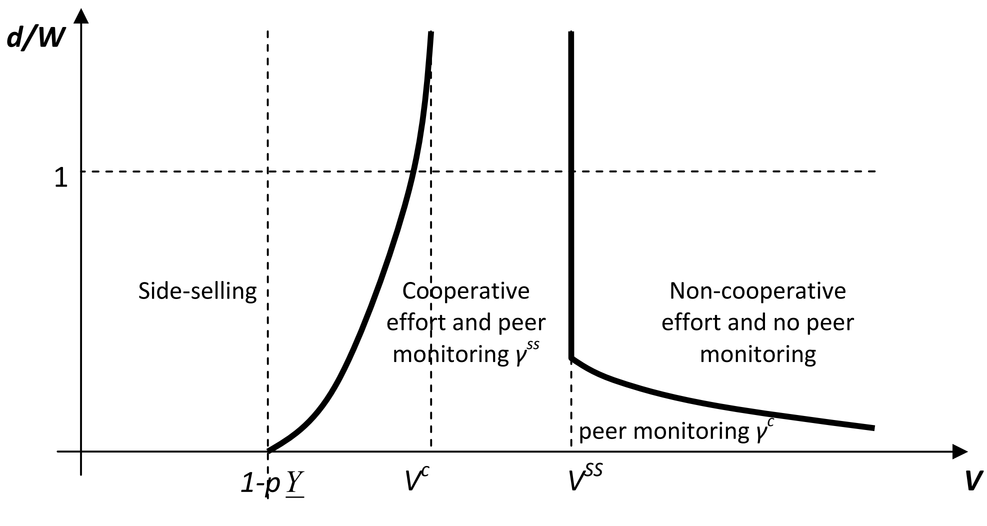
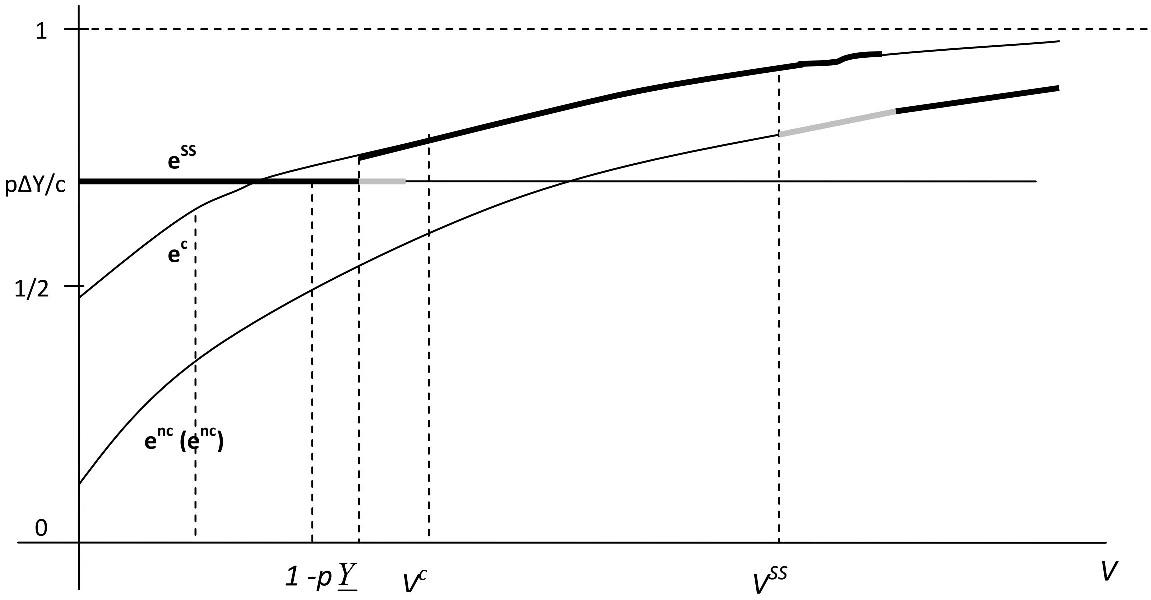


Fig. 3



Note: The bold line is the effort equilibrium when the value of *d/W* is low and necessarily below 1. This trajectory is partly replaced by the gray portions when *d/W* is above 1.

Fig. 4

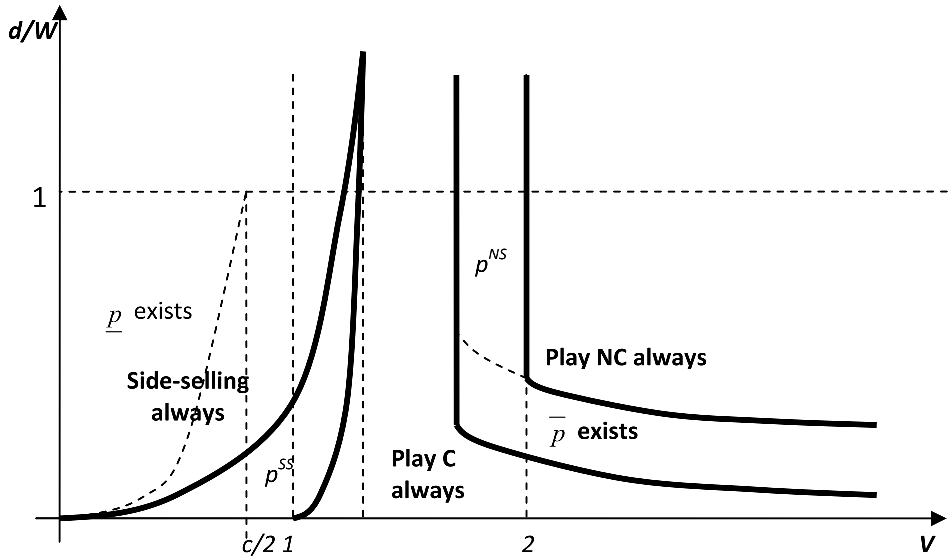
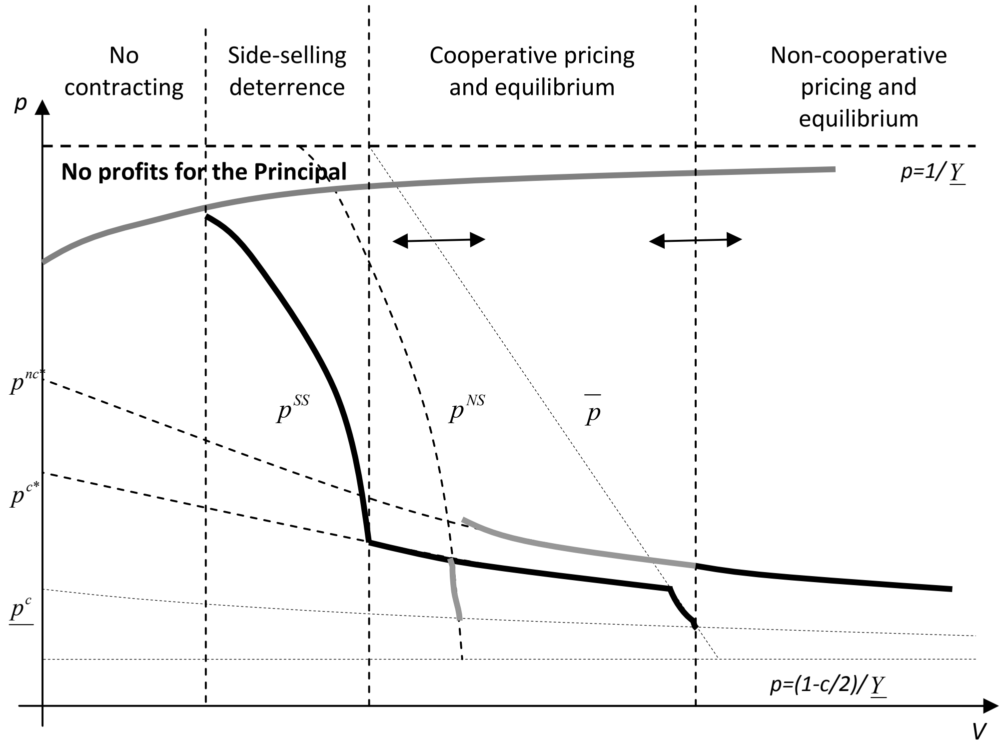


Fig. 5



Note: The trajectory in black represents the case of low *d/W*. When this cost/sanction ratio increases, the $\overline{p}$ line shifts leftward, and the area of cooperative pricing shrinks until $\overline{p}$ becomes lower than p^{NS}, after which the trajectory in black is partly replaced by the gray one.

Fig. 6

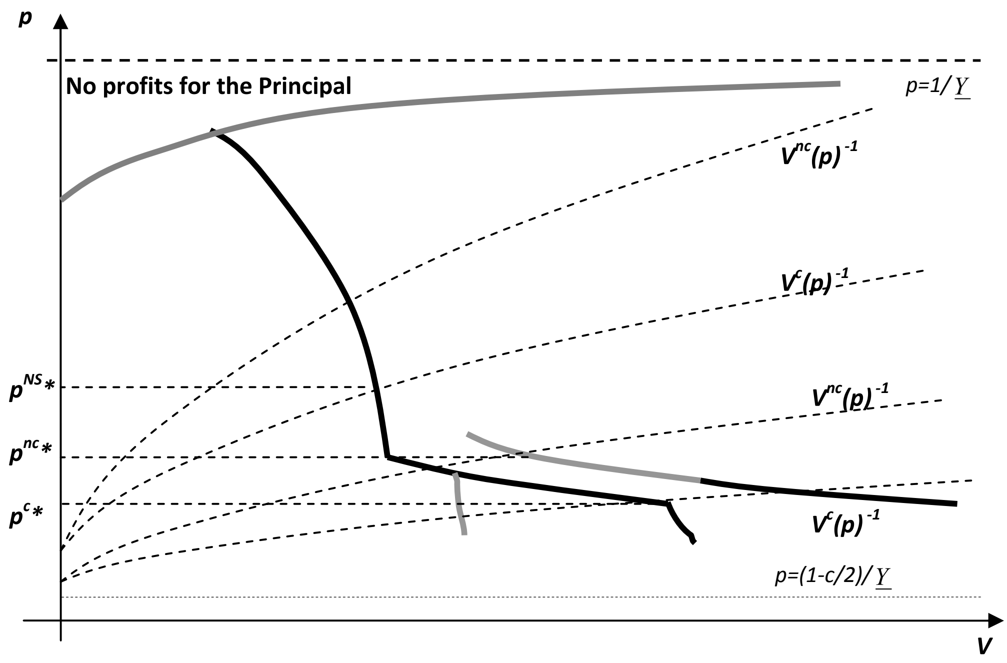
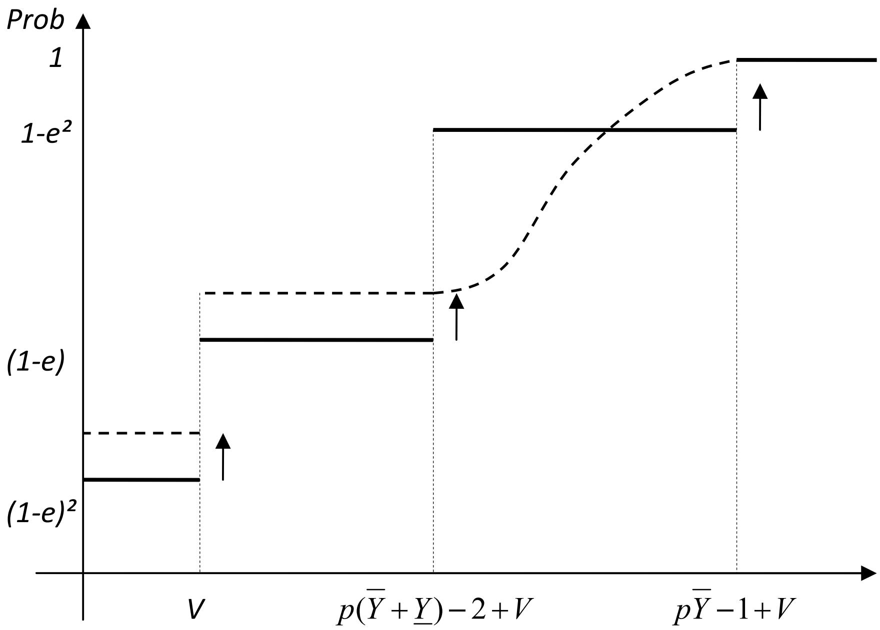


Fig. 7



Note: The cumulative distribution in bold represents farmers' profits when *n=2* and the one delineated by a dashed line represents profits when *n* is large.

Fig. 8

End Notes

[1]I use the terms "contract farming" and "outgrower schemes" interchangeably.

[2]For a review and a complete list of references, see Bijman (2008). Little and Watts (1994) provide a historical survey of contract farming in Sub-Saharan Africa. Glover (1984) focuses on outgrower schemes in poor countries. Most of the works in the development literature aim to assess the impacts of contract farming on smallholders' welfare and on when contract farming takes place. They provide an appraisal of advantages and drawbacks for contractors and farmers. Recent evidence shows that contract farming is beneficial to rural households' welfare (see, for instance, Warning and Key 2002; Bellemare and Stifel 2009), reduces income volatility, and has significant spillovers on other income sources, while the picture was more ambiguous a decade ago (Porter and Phillips-Howard 1997). This article does not tackle any of these positive issues. Rather, I am interested in efficiency and normative concerns.

[3]Vertical coordination is the process through which each stage in the supply chain is ensured to be appropriately managed and tied to the next one. This is particularly relevant in the food industry and other agricultural commodity chains where products are perishable and require a set of complex activities (production, processing, research, extension, quality-grading and certification, transport, marketing, and so on) carried out by a large number of players.

[4]Contracts reduce transaction costs through repeated interaction and provide better control of the production process (for instance see Winter-Nelson and Temu 2002). They also provide better risk allocation for farmers and lower coordination costs for contractors. The latter can better aligned with their customers' demands via a greater regularity of agricultural product supply and quality (with technical assistance), bargain for more profitable prices for farmers, benefit from the low production costs of family farms, and more easily access credit and subsidies (vertical differentiation).

[5]If one member defaults, each member of the group repays that member's share of the debt. Otherwise, the group will be denied access to credit in the future, or the contract will not be renewed.

[6]In the recent literature, a distinction is made between joint liability—which refers to repayment obligations—and group lending—which simply reflects meetings being held with several customers at the same time. On the one hand, and because of moral hazard problems, the former is being abandoned in microfinance. On the other, the latter has become pervasive due to lower transaction costs. Notwithstanding, joint liability remains a crucial component of several outgrower schemes, notably in Sub-Saharan Africa. This might be due to the nature of contract farming (input credit only and linked to a production crop), more monopolistic market structures, and the efficiency of peer monitoring within farmers' group (compared to credit unions). Therefore, I only consider the issue of joint liability hereafter.

[7]The latter involve strategic defaulting due to ex post moral hazard (after the project's outcome is realized), that is, the strategy leading a borrower to default on credit repayment while being able to reimburse. Besley and Coate (1995) show that joint liability may help decrease the scope of strategic defaulting without fully eliminating it.

[8]This is the only paper that treats peer monitoring endogenously in order to prevent strategic defaulting.

[9]I assume that joint liability is favored by the Principal. Indeed, I consider those cases in which the Principal faces a dissuasive contract-supervision cost, and farmers are endowed with no physical (or verifiable) collateral. Contract farming with jointly liable smallholders is then socially efficient since it is welfare-enhancing for smallholder participants and the agribusiness faces a low risk of strategic defaulting.

[10] This corresponds to the equivalent unit value of farm production accounting for marketing and processing costs.

[11] V can be interpreted as a reputational loss for the farmer with respect to the Principal, but also as earnings losses from not accessing future credits. In the latter case, V can be endogenized in a repeated-game framework, as mentioned earlier. However, an endogenous V is robust to our results (see later) and can be specified as a function of the price offered by the Principal to the group of farmers.

[12]Contract farming is usually a secondary source of livelihood for smallholders, who derive the main part of their livelihood from subsistence crops. Focusing on production under contract, I can reasonably assume risk neutrality.

[13] The alternative price can differ according to the agricultural market structure and the scope of parallel markets. This analysis is outside the scope of this paper and is left for future research. Homogeneous pricing is a reasonable assumption since opportunistic traders face less profitable markets but do not incur the cost of input provision.

[14]Changing the ex post timing of the game—learning occurring before strategic defaulting decisions—will not affect the qualitative nature of our results. See Armendariz de Aghion (1999) for the case of joint liability in microfinance.

[15]Calculations are available from the author upon request.

[16] If cheating (side-selling or non-cooperative effort), a farmer may also lose V since an obvious sanction could be exclusion. But this requires that the cheating be observed, with some investment in peer monitoring, which is not optimal for side-sellers or non-cooperative farmers' groups. The cost of exclusion can be represented by $W=V$.

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