# Risk Reduction and Cooperatives' Revenue Pooling in the Presence of 

Adverse Selection

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#### Abstract

This paper extends recent work by Saitone and Sexton (2009) on the implications of revenue pooling by cooperatives. They showed that pooling may insure farmers against risks due to stochastic product quality and counteract competitive farmers' tendency to over produce high-quality product. Saitone and Sexton, however, avoided addressing the adverse selection problem that is a central issue for revenue pooling. We extend the Saitone-Sexton model to incorporate ex ante heterogeneous farmers and adverse selection and investigate whether the revenue pooling benefits of cooperation may be sufficient to cause ex ante highquality producers to join in a cooperative and pool revenues at least partially with lower-quality producers.


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## Risk Reduction and Cooperatives' Revenue Pooling in the Presence of Adverse Selection

 Product quality in all of its dimensions is critical in modern food markets. Many studies have demonstrated that consumers are willing to pay premiums for foods that satisfy the product quality attributes that are important to them. Moreover, the dimensions of product quality that matter to at least some consumers have expanded considerably in recent years. Traditional attributes such as a product's taste, appearance, convenience, brand appeal, and healthfulness remain important, but nowadays so do characteristics of the production process (e.g., usage of chemicals, presence of genetic modifications, physical location, or treatment of animals) and implications of production and consumption of the product for the environment.The increasing importance of quality in the food system has not been lost on farmers and their cooperatives. New cooperatives have appeared to exploit quality-based market niches, often in areas of the market where investor-owned firms do not exist (Fulton and Sanderson 2002), and incumbent cooperatives have attempted to reposition themselves to compete for the business of quality-conscious U.S. consumers (Saperstein 2006; Hirsch 2007).

However, despite cooperatives' efforts to position themselves favorably on the quality spectrum, various traditional cooperative business practices are not conducive to success in meeting the market's demands for quality. For example, the horizon problem leads cooperatives to pursue short-term goals at the expense of long-term investments that can enhance objective or perceived quality, such as development of differentiated and branded products. The traditional principle that cooperatives accept all member production, i.e., represent a "home" for it, is problematic both with respect to managing product quality and avoiding negative price impacts in niche markets due to oversupply.

Nearly all cooperatives and some related types of organizations use some form of revenue pooling wherein product from multiple suppliers is agglomerated and sold. Members are then
paid a "pooled" price equal to the average sales revenue from the pooled product less expenses assigned to the pool. When product entering the pool is heterogeneous in its quality and value, pooling will undervalue high-quality production, potentially causing producers of the highest quality products to either lower the quality they produce or exit the cooperative if the opportunity presents itself-a classic adverse selection problem.

These factors, when viewed through the prism of an evolving food and agriculture sector, have led to pessimism on the part of various analysts regarding the ability of traditional producer marketing cooperatives to compete and survive in this market climate (e.g., Coffey 1993, Fulton 1995, and Cook 1995). However, rigorous investigation of cooperatives' performance and behavior in quality-differentiated markets is limited because, with a few notable exceptions, most theory on marketing cooperative behavior has assumed that a single, homogeneous product is produced and sold. Among the exceptions is a treatment by Zago (1999), who modeled a producer organization, such as a cooperative, where heterogeneous farmers' production differs in quality based upon their ability. Depending upon which producer type (e.g., high or low ability) constitutes the majority, different remuneration schemes will be chosen by producers and higher or lower than the first-best level of quality will be provided.

Hoffman (2005) considered a mixed-duopoly market, where a cooperative and investorowned firm (IOF) first compete in choice of product quality and then in price in a vertically differentiated market. Because the cooperative vertically integrates the farm and processing sectors, its objective function differs from the IOF's, leading to different market equilibria than when only IOFs compete. The model, however, is able to make no predictions as to which organizational form emerges in the preferred role of the high-quality seller.

This paper extends recent work by Saitone and Sexton (2009), who focused on the implications of revenue pooling by cooperatives. They identified and analyzed two positive
dimensions of cooperative revenue pooling: (a) pooling can counteract the tendency of competitive farmers to overproduce high-quality product relative to the amount that maximizes industry profits, and (b) in the presence of stochastic quality, pooling insures risk-averse farmers against quality risk.

Because stochastic product quality is important for most types of agricultural production, pooling risks of stochastic quality is a prospectively important benefit. Saitone and Sexton, however, avoided addressing directly the adverse selection problem that is a central issue for revenue pooling. In their models either the cooperative was the sole marketing option, so producer defection was not an issue, or producers were homogeneous ex ante. In this latter case the quality of each producer's production was stochastic ex post due to random shocks, but enforceable decisions among marketing options were made ex ante, meaning that adverse selection was not a consideration.

We extend the Saitone-Sexton model to incorporate ex ante heterogeneous farmers and adverse selection. We ask specifically whether the revenue pooling benefits of cooperation may be sufficient to cause ex ante high-quality producers to join in a cooperative and pool revenues at least partially with lower-quality producers. Simulation results reveal a number of plausible market settings wherein cooperation and at least partial revenue pooling represent stable equilibria.

## The Model

There is a set $\mathrm{N}=\{1,2, \ldots, \mathrm{n}\}$ of farmers. Each farmer's crop is fixed at one unit, and can be of either low or high quality. Crop quality is assumed to be stochastic. There are two farmer types, H and L , characterized by the probabilities that the crop is of low quality, pH and $p L$, with $p L>$ $p H$. Farmers are assumed to be equally risk averse. Each farmer, $f$, is characterized by his low-
quality probability, $p^{f} \in\{p L, p H\}$ and a concave von Neumann-Morgenstern utility function $u^{f}$, the same for all farmers. The family of probabilities is common knowledge.

Type L farmers, therefore, have a higher chance of producing a crop of low quality than type H farmers. Ex ante heterogeneity among farmers in terms of ability to produce H product is problematic for pooling arrangements due to adverse selection because type H farmers in expectation anticipate transferring farmers to L farmers under any form of revenue pooling. Farmers and marketing firms, whether cooperative or not, are price takers. The high-quality crop is valued at a price normalized to one, while the low-quality crop is valued at a price $\phi<1$. ${ }^{1}$ The difference $p L-p H$ and the value of $\phi$ jointly determine the importance of the adverse-selection problem.

We denote by $\psi(\mathrm{N})$ the set of parts of N , and for any subset $S \subseteq N$ we denote as ( $\mathrm{S}, \delta$ ) the cooperative agreement by which all farmers in S commit to giving a share $1-\delta$ of their crop to the cooperative, and retaining the share $\delta$ to be marketed independently of the cooperative. An equivalent condition following the morphology of Saitone and Sexton is that the farmers in cooperative S agree to a marketing arrangement whereby $1-\delta$ share of each farmer's crop is commingled into a common pool, while the remaining share is sold by the cooperative on the farmer's behalf without pooling. The cooperative is able to sort the product it receives into low and high quality, and therefore sells the high-quality product at a price of one, and the lowquality product at the price $\phi$. The revenue from the participants' pooled crops is then shared equally between cooperative members. ${ }^{2}$

For any partition $F_{k}$ of N and corresponding set of pooling parameters $\boldsymbol{\delta}_{\boldsymbol{k}}$, we call the

[^1]family of cooperative agreements a cooperative partition of N . We write the ex ante utility of a typical farmer f in cooperative S as $u^{f}\left(\mathrm{~S}, \delta_{S}\right)$.

Definition 1: A cooperative partition $F_{k}$ of $N$ is stable if and only if there does not exist an element $T \in \psi(N)$ and an element $\delta \epsilon[0,1]$ such that (i) for all $f \in T u^{f}(T, \delta) \geq u^{f}\left(F_{k}\right)$ and (ii) for at least one $f \in T u^{f}(T, \delta)>u^{f}\left(F_{k}\right)$.

This definition reflects the fact that members can freely secede from a cooperative if they find a more profitable outside option; a given member does not need the approval of other members to leave the cooperative agreement. If no coalition of farmers, including one-member coalitions, can find it profitable to regroup under a new cooperative agreement, the cooperative partition is stable. Note that this definition implies that, if the cooperative-partition is stable, not only will no new coalition form, but existing coalitions will not be able to alter their pooling rates under a unanimity voting rule.

This definition does not say anything about the process by which a stable cooperativepartition $F_{k}$ emerges, only that once it is formed, no alternative coalition arrangement will be preferred. However, since one-member coalitions are not preferred to a stable cooperativepartition, one could think of the initial state as the partition consisting of one-person "coalitions." The above definition then implies that starting from that initial state, every farmer has an incentive to move to the stable cooperative-partition $F_{k}$.

## Some General Results

Lemma 1: $u^{f}$ is concave in $\delta$.
Proof (sketch): The derivative $\partial^{2} u^{f}(\delta) / \partial \delta^{2}$ is straightforward, although tedious, to compute, and it then can be established that this derivative is negative as a consequence of $u^{f^{\prime \prime}}(\cdot)<0$,
owing to the assumption that all farmers are risk averse.
For any farmer $f$, therefore, there are three possible cases regarding the optimal $\delta$, which we will denote $\delta^{f}$ : (i) $\delta^{f}<0$, (ii) $0 \leq \delta^{f} \leq 1$, or (iii) $\delta^{f}>1$. In case (i) the farmer prefers full pulling, whereas in case (iii) farmer $f$ does not want to participate in the cooperative agreement since he would be better off in a one-member cooperative, that is, by himself.

Lemma 2: If $p^{f}=p L$ and there is at least one H-type farmer in the cooperative, then $\partial u^{f} / \partial \delta(\delta=0)<0$.

Lemma 3: If $p^{f}=p H$ and there is at least one L-type farmer in the cooperative, then $\partial u^{f} / \partial \delta(\delta=0)>0$.

Lemma 4 If all members of the cooperative are of the same type, then $\partial u^{f} / \partial \delta(\delta=0)=0$.
Lemma 2 implies that a L-type farmer always prefers full pooling ( $\delta=0$ ) in any cooperative agreement. In particular, he prefers to be in any cooperative than by himself whereby $\delta=1$. Full pooling maximizes the insurance value of the pool, and on expectation enables a Ltype farmer to receive a share of revenues earned by H-type farmers in the cooperative. Lemma 3 establishes that H-type farmers will not prefer a full pooling arrangement if they are in a cooperative partition with L-type farmers. Although full pooling maximizes the insurance value of the pool, H types will always prefer to sacrifice some insurance value in order to share on expectation less revenue with L-type producers. Finally, Lemma 4 establishes the basic result that, absent adverse selection considerations, full pooling yields the maximum benefit to riskaverse farmers because it maximizes the insurance value of the pool.

Analytical on the existence of stable cooperative partitions seem to be unavailable except for special cases. We therefore turn to simulation analyses, examining first a two-person cooperative involving a H-type producer and a L-type producer and then a three-person
cooperative involving two L types and one H type. The simulation results demonstrate that for plausible market settings and extent of farmer risk aversion stable cooperative arrangements can be found, although in many cases they involve only partial pooling and, hence, partial insurance against quality risk.

## Two-Farmer Simulation Model

We assume that there is one L farmer (farmer 2) and one H farmer (farmer 1). There are four possible outcomes associated with product distribution:

| Scenario | Farmer H produces | Farmer L produces | Probability |
| :---: | :---: | :---: | :---: |
| 1 | H | L | $(1-p H) p L=\rho_{1}$ |
| 2 | H | H | $(1-p H)(1-p L)=\rho_{2}$ |
| 3 | L | H | $p H(1-p L)=\rho_{3}$ |
| 4 | L | L | $p H \cdot p L=1-\rho_{1}-\rho_{2}-\rho_{3}$ |

We assume farmers' utilities can be represented by the negative exponential utility function, $u(w)=-e^{-\lambda w}$, for income or wealth $w$, which is derived entirely from the farming operation. This utility function exhibits constant absolute risk aversion (CARA), $R_{A}=\lambda$, and increasing relative risk aversion (IRRA), $R_{R}=\lambda w$. The expected utility of farmer $1(\mathrm{H})$ when participating in the cooperative is:
$E\left[u_{1}^{C}\right]=\rho_{1} \cdot u\left(W_{1,1}^{C}(\delta, \phi), \tau\right)+\rho_{2} \cdot u\left(W_{1,2}^{C}(\cdot), \tau\right)+\rho_{3} \cdot u\left(W_{1,3}^{C}(\cdot), \tau\right)+\left(1-\rho_{1}-\rho_{2}-\rho_{3}\right) \cdot u\left(W_{1,4}^{C}(\cdot), \tau\right)$
where $\tau$ is the degree of absolute or relative risk aversion, $W_{1,1}^{C}=\delta+0.5(1-\delta)(1+\phi), W_{1,2}^{C}=1$, $W_{1,3}^{C}=\phi \delta+0.5(1-\delta)(1+\phi), W_{1,4}^{C}=\phi$, where the first subscript denotes farmer, the second denotes the scenario in the product distribution table, and the superscript C indicates participation in the cooperative.

The expected utility of farmer $2(\mathrm{~L})$ when participating in the cooperative is:
$E\left[u_{2}^{C}\right]=\rho_{1} \cdot u\left(W_{2,1}^{C}(\delta, \phi), \tau\right)+\rho_{2} \cdot u\left(W_{2,2}^{C}(\cdot), \tau\right)+\rho_{3} \cdot u\left(W_{2,3}^{C}(\cdot), \tau\right)+\left(1-\rho_{1}-\rho_{2}-\rho_{3}\right) \cdot u\left(W_{2,4}^{C}(\cdot), \tau\right)$
where $W_{2,1}^{C}=\phi \delta+0.5(1-\delta)(1+\phi), W_{2,2}^{C}=1, W_{2,3}^{C}=\phi$, and $W_{2,4}^{C}=\delta+0.5(1-\delta)(1+\phi)$.

Farmer i's outside option is $E\left[u_{i}^{o}\right]=p i \cdot u(\phi)+(1-p i) u(1), \quad i=L, H$. Farmer $i$ 's cooperative participation constraint is $E\left[u_{i}^{C}\right] \geq E\left[u_{i}^{O}\right]$. With only two farmers, if a participation constraint binds, it will be that of the high-type farmer.

We seek to determine if a pooling rate exists for reasonable market parameters where the high-quality farmer will participate in the cooperative with the low-quality farmer. Given the negative exponential utility function, the level of $\delta$ that equates the H farmer's expected utility in the cooperative with his expected utility from the outside option is:

$$
\delta^{I}=\frac{-[-\lambda+\lambda \phi+2 \ln [p L(1-p H) / p H(1-p L)]}{\lambda(\phi-1)}
$$

If $\delta^{I}>1$ there is no pooling arrangement that can entice the H farmer to cooperate with the L farmer.

## Parameter Selection for the Simulation Model

There are 4 exogenous parameters needed to conduct the simulation: $\mathrm{pL}, \mathrm{pH}, \phi$, and $\tau$. Quality differences for agricultural products may be due to a wide variety of factors, such as a product's size, brix level, coloration, and extent of pest damage. Mazor and Erez (2004) found infestation
rates in apples and nectarines as large as 0.625 , and the incidence of overripe fruit resulting from pest attacks in persimmons to be in excess of 0.2 , demonstrating that the gap between pH and pL may be quite large. For this simulation we set $\mathrm{pH}=0.1$ and allowed pL to vary in increments of 0.05 in the range [0.15-0.5].

We inferred a range of reasonable values for $\phi$ from relative prices in the market place for products of different grades or quality levels. A prominent example is fruits, where high-quality products are designed for fresh-market sales and earn a premium relative to lower-quality fruits that are consigned for processing uses (Babcock, Lichtenberg, and Zilberman 1992). This comparison is especially relevant when the same basic product form is grown for both markets, as is often the case. From U.S. Department of Agriculture data we inferred prices for L product relative to the H product price ranging from $\phi=0.18$ (Texas grapefruit) to 0.75 (Florida Valencia oranges). Examples within this range include 0.25 (tart cherries), 0.34 (prunes), 0.4 (pears), and 0.61 (potatoes-U.S. average). Given this range of plausible values, we simulated values of $\phi$ in the range $\phi \in[0.25,0.75]$.

Absolute risk-aversion parameter estimates in the literature vary widely. Most estimates are in the range of $\lambda \in[3,5]$, e.g., Saha, Shumway, and Talpaz (1994), although Chavas and Holt estimated $\lambda=12.17$ for U.S. corn and soybean producers. We simulated values of $\lambda \in[2,8]$ in increments of 1.0.

## Simulation Results

Results for the two-farmer simulation case are presented in tables $2(\phi=0.75), 3(\phi=0.5)$, and $4(\phi=0.25)$ for the parameter ranges discussed for pL and $\lambda$, with pH set equal to 0.1 throughout the simulations. Column 3 in each table asks whether the participation constraint of
the H-type farmer is satisfied in a cooperative with the L farmer and full pooling, i.e., $\delta=0$, the outcome preferred by the L farmer (Lemma 2). Column 5 in each table indicates the H farmer's preferred $\delta$. If this $\delta>1$, then there is no implementable $\delta$, and the H type will not join in a cooperative with the L type. The column labeled "implementable delta" indicates the value of $\delta^{I}$ if $0<\delta^{I} \leq 1$, i.e., the value of $\delta$ that just satisfies the participation constraint of the H type. ${ }^{3}$

The results in tables $2-4$ demonstrate that, despite the adverse selection problem built into the simulation model, it is possible for the H and L type farmers to agree to form a cooperative to take advantage of the risk-sharing opportunity it affords. However, in many market settings, whereas a cooperative with partial pooling is implementable, a cooperative with full revenue pooling is not implementable because it would be rejected by the H type. When a cooperative with L and H is implementable there is always disagreement between them as to the preferred pooling rate. The L type always prefers full pooling (Lemma 2), and the H type always prefers partial pooling (Lemma 3). The $\delta$ values in column $4 \epsilon(0,1)$ represent the range of values over which the L and H type farmer could bargain in setting the cooperative's pooling value, except when $\delta=0$ is implementable, in which case the range of values for bargaining is given by the $\delta$ value in column 5 .

In general cooperation between the L and H types is more likely the less heterogeneous they are, i.e., the lower is pL relative to $\mathrm{pH}=0.1$ and the more risk averse they are. Interestingly and perhaps surprisingly, more implementable cooperatives exist for lower values of $\phi$. Lower values of $\phi$ increase the risk associated with production of a low-quality crop and, thus, the benefit of risk pooling, but they also increase the magnitude of the adverse selection problem. Tables 2-4 suggest that, for the parameter ranges considered therein, the risk impact dominates, leading to more implementable combinations of pL and $\lambda$, and to lower values of $\delta^{I}$.

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## Three-Farmer Simulation Model

In this section, we explore the conditions under which a three-farmer cooperative is stable. We assume that there are two farmers of the $L$ type and one farmer of the $H$ type. That is, we investigate the stability of the cooperative-partition $\mathrm{S}=(\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}, \delta)$ for $\delta \in[0,1)$. To ensure the stability of S it must be that a L-type farmer has no incentive to leave the cooperative by himself, to create a new cooperative with the other L type, or to create a new cooperative with the H type. In addition, stability of the three-farmer cooperative agreement requires that the H-type farmer has no incentive to leave by himself or to participate in a two-farmer cooperative with one of the L types. Therefore, the cooperative $\mathrm{S}=(\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}, \delta)$ is stable if and only if

1. $u^{L}(\{L, L, H\}, \delta) \geq u^{L}(\{L\}, 1)$,
2. $u^{L}(\{L, L, H\}, \delta) \geq u^{L}(\{L, L\}, 0)$,
3. $u^{H}(\{L, L, H\}, \delta) \geq u^{H}(\{H\}, 1)$,
4. $u^{L}\left(\{L, H\}, \delta^{\prime}\right) \geq u^{L}(\{L, L, H\}, \delta) \Rightarrow u^{H}\left(\{L, H\}, \delta^{\prime}\right)<u^{H}(\{L, L, H\}, \delta)$.

Lemmas 1 and 2 imply that condition 1 is satisfied for all values of $\delta$. Condition 2 indicates that the L type farmers must favor the pooling arrangement $\delta$ relative to joining together in an L type cooperative where $\delta=0$ is then the preferred pooling arrangement. Depending upon risk aversion and market parameters, such farmers may prefer full insurance in their own cooperative to partial pooling with the H producer. Condition 3 pertains to the H farmer's participation constraint. We designate as $\delta_{\min }$ the value of $\delta$ that solves this participation constraint at equality: $u^{H}(\{L, L, H\}, \delta)=u^{H}(\{H\}, 1)$, and designate as $\delta_{\max }$ the value of $\delta$ such that $u^{L}(\{L, L, H\}, \delta)=u^{L}(\{L, L\}, 0)$. The value $\delta_{\max }$ is in the open segment $(0,1)$ because $u^{L}(\{L, L, H\}, 0)>u^{L}(\{L, L\}, 0)$ and $u^{L}(\{L, L, H\}, 1)<u^{L}(\{L, L\}, 0)$. Finally, we designate as $\delta_{H}^{*}$ the value of $\delta$ that maximizes the ex ante utility of the H type in the cooperative ( $\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}, \delta)$.

The 3 -farmer cooperative agreement $(\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}, \delta)$ is stable if and only if $\delta$ lies in the interval:

$$
\Delta=\left[\max \left(\delta_{\min }, \delta_{e}\right), \min \left(\delta_{\max }, \delta_{H}^{*}\right)\right]
$$

where $\delta_{e}$ is defined by the condition

$$
\begin{aligned}
& u^{L}\left(\{L, L, H\}, \delta_{e}\right)=u^{L}\left(\{H, L\}, \delta_{L}\right), \\
& u^{H}\left(\{L, L, H\}, \delta_{e}\right)=u^{H}\left(\{H, L\}, \delta_{H}\right), \\
& \delta_{H}=\delta_{L}
\end{aligned}
$$

The value $\delta_{\text {min }}$ defines the minimum amount of production that the H farmer must be allowed to sell outside of the pooling arrangement to meet his participation constraint, whereas $\delta_{\text {max }}$ represents the maximum amount of "outside selling" that the L farmers can accept before they are better off in their own cooperative and with full insurance. If $\delta_{\min }>\delta_{\max }$ the interval $\Delta$ will be empty. The value $\delta_{e}$ indicates where the expected utility curves for the H and L types may "cross" as a function of $\delta$ for the $\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}$ three-person cooperative and the $\{\mathrm{L}, \mathrm{H}\}$ twoperson cooperative, and these crossing points may affect the range of values for $\delta$ that yield stable cooperative agreements.

The interval will also be empty if $\partial u^{H}(\{L, L, H\}, 1) / \partial \delta>0$. In this case the H farmer's utility is increasing in the share of product marketed independently throughout the relevant range, and the H farmer will prefer to be on his own. This corresponds to the case $\delta_{\text {min }}=1$ and is illustrated in figure $1 .{ }^{4}$ In figure $1, \mathrm{E}\left[u^{H}\right]$ is increasing in $\delta$ throughout the range $[0,1]$ in both the two-person cooperative $\{\mathrm{L}, \mathrm{H}\}$ (red line) and three-person cooperative $\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}$ (green line). Instances when the H-type will never participate in a cooperative with the L types under any pooling arrangement occur, not surprisingly, when the H type is less risk averse and, hence,

[^3]benefits less from the insurance attained through pooling and when $p L$ is large relative to $p H$, meaning that the adverse-selection problem is severe. For example for CARA coefficients $\lambda \epsilon[1.5,3.0]$, in all instances except when $p L-p H$ is small, so that producer heterogeneity is minimal, the H farmer will not participate in the $\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}$ cooperative under any pooling arrangement.

A second important subcase involves settings when the H farmer will participate in the three-person cooperative under full pooling even though he might prefer a partial pooling arrangement. Figure 2 illustrates this case. ${ }^{5}$ Here the $H$ farmer's expected utility in the cooperatives $\{\mathrm{L}, \mathrm{H}\}$ (red line) and $\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}$ (green line) is everywhere greater than his utility on his own (pink line). The pooling rate that maximizes the H farmer's expected utility in this simulation is $\delta_{H}^{*}=0.46$, meaning that the members would bargain to determine a pooling rate in the interval $\Delta \epsilon[0,0.46]$. Many parameter combinations supported this outcome in the simulations. All were characterized by relatively high rates of farmer risk aversion and smaller values for $p L-p H$. For example, for $\lambda=8$, this subcase holds for all values of $p L \in(0.2,0.4]$, given that $p H$ was set at 0.2 .

Figure 3 illustrates the important subcase where the cooperative $\{\mathrm{L}, \mathrm{L}, \mathrm{H}\}$ is stable but only for certain values of $\delta$ that involve partial pooling of revenues. ${ }^{6}$ In figure $3 \delta_{\text {min }}=0.31, \delta_{H}^{*}=$ 0.65 , and $\delta_{\max }=0.70$. Notice that an L farmer's best option in this simulation is to join in a two-person cooperative $\{\mathrm{L}, \mathrm{H}\}$ with the H farmer and have a high rate of pooling, i.e., the crossing point for the curve $\mathrm{E}\left[u^{L}(\{L, L, H\}, \delta)\right]$ (blue line) and the curve $\mathrm{E}\left[u^{L}(\{L, H\}, \delta)\right]$ (black line) is $\delta=0.37$. However, the H farmer's utility in the two-person cooperative for those pooling rates (red line) is less than the H farmer can obtain in the three-person cooperative for

[^4]pooling rates $\delta \in\left[\delta_{\min }, \delta_{H}^{*}\right]$. Given $\delta_{H}^{*}<\delta_{\max }$, all of the pooling rates in this range are implementable and subject to a bargaining agreement between the H type and L types, with the latter, of course, preferring $\delta$ values close to $\delta_{\text {min }}$. Values for the simulation parameters in their midranges tended to support the existence of stable cooperatives involving partial pooling arrangements-i.e., moderate farmer risk aversion and moderate differences between the H and L types in their likelihood of producing a low-quality product.

## Conclusion

Some form of revenue pooling is endemic to the pricing and financing practices of almost any type of cooperative. This study is the first analytical evaluation of cooperatives' pooling practices in the presence of ex ante differences among farmers in their ability to produce highquality product, i.e., in the presence of adverse selection. The insurance aspect of pooling in the presence of stochastic production of high-quality product, as studied by Saitone and Sexton (2009), can be an important benefit of cooperative membership in markets where product quality is heterogeneous, but heretofore it was unknown whether such pooling arrangements could withstand defection by producers with a greater likelihood of producing high-quality products due to the adverse selection problem. This study has shown that stable cooperative pooling arrangements can exist if producers are sufficiently risk averse and the heterogeneity among producers is not too great.

Importantly, many of the stable cooperative settings identified in the simulation involved only partial pooling because full pooling would be rejected by the high-quality farmers in favor of marketing their product independently. Even when full pooling meets a high-quality farmer's participation constraint, he will prefer a lower rate of pooling than that preferred by low-quality farmers, which is always full pooling. Thus, even when stable pooling arrangements exist, they may be contentious and subject to disagreement among the membership.

Table 1. Two-Farmer Simulations: $\phi=0.75$

| pL | CARA | Participation Constraint of $\mathbf{H}$ Satisfied? | Implementable $\delta$ ? | $\delta$ that max E[u] Hin Coop |
| :---: | :---: | :---: | :---: | :---: |
| 0.50 | 8 | NO | NO | 1.10 |
| 0.45 | 8 | NO | 1.00 | 1.00 |
| 0.40 | 8 | NO | 0.79 | 0.90 |
| 0.35 | 8 | NO | 0.58 | 0.79 |
| 0.30 | 8 | NO | 0.35 | 0.67 |
| 0.25 | 8 | NO | 0.10 | 0.55 |
| 0.20 | 8 | YES | N/A | 0.41 |
| 0.15 | 8 | YES | N/A | 0.23 |
| 0.50 | 7 | NO | NO | 1.26 |
| 0.45 | 7 | NO | NO | 1.14 |
| 0.40 | 7 | NO | NO | 1.02 |
| 0.35 | 7 | NO | 0.80 | 0.90 |
| 0.30 | 7 | NO | 0.54 | 0.77 |
| 0.25 | 7 | NO | 0.26 | 0.63 |
| 0.20 | 7 | YES | N/A | 0.46 |
| 0.15 | 7 | YES | N/A | 0.26 |
| 0.50 | 6 | NO | NO | 1.46 |
| 0.45 | 6 | NO | NO | 1.33 |
| 0.40 | 6 | NO | NO | 1.19 |
| 0.35 | 6 | NO | NO | 1.05 |
| 0.30 | 6 | NO | 0.80 | 0.90 |
| 0.25 | 6 | NO | 0.46 | 0.73 |
| 0.20 | 6 | NO | 0.08 | 0.54 |
| 0.15 | 6 | YES | N/A | 0.31 |
| 0.50 | 5 | NO | NO | 1.76 |
| 0.45 | 5 | NO | NO | 1.60 |
| 0.40 | 5 | NO | NO | 1.43 |
| 0.35 | 5 | NO | NO | 1.26 |
| 0.30 | 5 | NO | NO | 1.08 |
| 0.25 | 5 | NO | 0.76 | 0.88 |
| 0.20 | 5 | NO | 0.30 | 0.65 |
| 0.15 | 5 | YES | N/A | 0.37 |
| 0.50 | 4 | NO | NO | 2.20 |
| 0.45 | 4 | NO | NO | 2.00 |
| 0.40 | 4 | NO | NO | 1.79 |
| 0.35 | 4 | NO | NO | 1.58 |
| 0.30 | 4 | NO | NO | 1.35 |
| 0.25 | 4 | NO | NO | 1.10 |
| 0.20 | 4 | NO | 0.62 | 0.81 |
| 0.15 | 4 | YES | N/A | 0.46 |
| 0.50 | 3 | NO | NO | 2.93 |
| 0.45 | 3 | NO | NO | 2.66 |
| 0.40 | 3 | NO | NO | 2.39 |
| 0.35 | 3 | NO | NO | 2.10 |
| 0.30 | 3 | NO | NO | 1.80 |
| 0.25 | 3 | NO | NO | 1.46 |
| 0.20 | 3 | NO | NO | 1.08 |
| 0.15 | 3 | NO | 0.23 | 0.62 |
| 0.50 | 2 | NO | NO | 4.39 |
| 0.45 | 2 | NO | NO | 3.99 |
| 0.40 | 2 | NO | NO | 3.58 |
| 0.35 | 2 | NO | NO | 3.16 |
| 0.30 | 2 | NO | NO | 2.70 |
| 0.25 | 2 | NO | NO | 2.20 |
| 0.20 | 2 | NO | NO | 1.62 |
| 0.15 | 2 | NO | 0.85 | 0.93 |

Table 2. Two-Farmer Simulations: $\phi=0.50$

| pL | CARA | Participation Constraint of $\mathbf{H}$ Satisfied? | Implementable $\delta$ ? | $\delta$ that max E[u] Hin Coop |
| :---: | :---: | :---: | :---: | :---: |
| 0.50 | 8 | NO | 0.10 | 0.55 |
| 0.45 | 8 | YES | N/A | 0.50 |
| 0.40 | 8 | YES | N/A | 0.45 |
| 0.35 | 8 | YES | N/A | 0.39 |
| 0.30 | 8 | YES | N/A | 0.34 |
| 0.25 | 8 | YES | N/A | 0.27 |
| 0.20 | 8 | YES | N/A | 0.20 |
| 0.15 | 8 | YES | N/A | 0.12 |
| 0.50 | 7 | NO | 0.26 | 0.63 |
| 0.45 | 7 | NO | 0.14 | 0.57 |
| 0.40 | 7 | NO | 0.02 | 0.51 |
| 0.35 | 7 | YES | N/A | 0.45 |
| 0.30 | 7 | YES | N/A | 0.39 |
| 0.25 | 7 | YES | N/A | 0.31 |
| 0.20 | 7 | YES | N/A | 0.23 |
| 0.15 | 7 | YES | N/A | 0.13 |
| 0.50 | 6 | NO | 0.46 | 0.73 |
| 0.45 | 6 | NO | 0.33 | 0.67 |
| 0.40 | 6 | NO | 0.19 | 0.60 |
| 0.35 | 6 | NO | 0.05 | 0.53 |
| 0.30 | 6 | YES | N/A | 0.45 |
| 0.25 | 6 | YES | N/A | 0.37 |
| 0.20 | 6 | YES | N/A | 0.27 |
| 0.15 | 6 | YES | N/A | 0.15 |
| 0.50 | 5 | NO | 0.76 | 0.88 |
| 0.45 | 5 | NO | 0.60 | 0.80 |
| 0.40 | 5 | NO | 0.43 | 0.72 |
| 0.35 | 5 | NO | 0.26 | 0.63 |
| 0.30 | 5 | NO | 0.08 | 0.54 |
| 0.25 | 5 | YES | N/A | 0.44 |
| 0.20 | 5 | YES | N/A | 0.32 |
| 0.15 | 5 | YES | N/A | 0.19 |
| 0.50 | 4 | NO | NO | 1.10 |
| 0.45 | 4 | NO | 1.00 | 1.00 |
| 0.40 | 4 | NO | 0.79 | 0.90 |
| 0.35 | 4 | NO | 0.58 | 0.79 |
| 0.30 | 4 | NO | 0.35 | 0.67 |
| 0.25 | 4 | NO | 0.10 | 0.55 |
| 0.20 | 4 | YES | N/A | 0.41 |
| 0.15 | 4 | YES | N/A | 0.23 |
| 0.50 | 3 | NO | NO | 1.46 |
| 0.45 | 3 | NO | NO | 1.33 |
| 0.40 | 3 | NO | NO | 1.19 |
| 0.35 | 3 | NO | NO | 1.05 |
| 0.30 | 3 | NO | 0.80 | 0.90 |
| 0.25 | 3 | NO | 0.46 | 0.73 |
| 0.20 | 3 | NO | 0.08 | 0.54 |
| 0.15 | 3 | YES | N/A | 0.31 |
| 0.50 | 2 | NO | NO | 2.20 |
| 0.45 | 2 | NO | NO | 2.00 |
| 0.40 | 2 | NO | NO | 1.79 |
| 0.35 | 2 | NO | NO | 1.58 |
| 0.30 | 2 | NO | NO | 1.35 |
| 0.25 | 2 | NO | NO | 1.10 |
| 0.20 | 2 | NO | 0.62 | 0.81 |
| 0.15 | 2 | YES | N/A | 0.46 |

Table 3. Two-Farmer Simulations: $\phi=0.25$

| pL | CARA | Participation Constraint of H Satisfied? | Implementable $\delta$ ? | $\delta$ that max $\mathrm{E}[\mathbf{u}]$ Hin Coop |
| :---: | :---: | :---: | :---: | :---: |
| 0.50 | 8 | YES | N/A | 0.37 |
| 0.45 | 8 | YES | N/A | 0.33 |
| 0.40 | 8 | YES | N/A | 0.30 |
| 0.35 | 8 | YES | N/A | 0.26 |
| 0.30 | 8 | YES | N/A | 0.22 |
| 0.25 | 8 | YES | N/A | 0.18 |
| 0.20 | 8 | YES | N/A | 0.14 |
| 0.15 | 8 | YES | N/A | 0.08 |
| 0.50 | 7 | YES | N/A | 0.42 |
| 0.45 | 7 | YES | N/A | 0.38 |
| 0.40 | 7 | YES | N/A | 0.34 |
| 0.35 | 7 | YES | N/A | 0.30 |
| 0.30 | 7 | YES | N/A | 0.26 |
| 0.25 | 7 | YES | N/A | 0.21 |
| 0.20 | 7 | YES | N/A | 0.15 |
| 0.15 | 7 | YES | N/A | 0.09 |
| 0.50 | 6 | YES | N/A | 0.49 |
| 0.45 | 6 | YES | N/A | 0.44 |
| 0.40 | 6 | YES | N/A | 0.40 |
| 0.35 | 6 | YES | N/A | 0.35 |
| 0.30 | 6 | YES | N/A | 0.30 |
| 0.25 | 6 | YES | N/A | 0.24 |
| 0.20 | 6 | YES | N/A | 0.18 |
| 0.15 | 6 | YES | N/A | 0.10 |
| 0.50 | 5 | NO | 0.17 | 0.59 |
| 0.45 | 5 | NO | 0.06 | 0.53 |
| 0.40 | 5 | YES | N/A | 0.48 |
| 0.35 | 5 | YES | N/A | 0.42 |
| 0.30 | 5 | YES | N/A | 0.36 |
| 0.25 | 5 | YES | N/A | 0.29 |
| 0.20 | 5 | YES | N/A | 0.22 |
| 0.15 | 5 | YES | N/A | 0.12 |
| 0.50 | 4 | NO | 0.46 | 0.73 |
| 0.45 | 4 | NO | 0.33 | 0.67 |
| 0.40 | 4 | NO | 0.19 | 0.60 |
| 0.35 | 4 | NO | 0.05 | 0.53 |
| 0.30 | 4 | YES | N/A | 0.45 |
| 0.25 | 4 | YES | N/A | 0.37 |
| 0.20 | 4 | YES | N/A | 0.27 |
| 0.15 | 4 | YES | N/A | 0.15 |
| 0.50 | 3 | NO | 0.95 | 0.98 |
| 0.45 | 3 | NO | 0.77 | 0.89 |
| 0.40 | 3 | NO | 0.59 | 0.80 |
| 0.35 | 3 | NO | 0.40 | 0.70 |
| 0.30 | 3 | NO | 0.20 | 0.60 |
| 0.25 | 3 | YES | N/A | 0.49 |
| 0.20 | 3 | YES | N/A | 0.36 |
| 0.15 | 3 | YES | N/A | 0.21 |
| 0.50 | 2 | NO | NO | 1.46 |
| 0.45 | 2 | NO | NO | 1.33 |
| 0.40 | 2 | NO | NO | 1.19 |
| 0.35 | 2 | NO | NO | 1.05 |
| 0.30 | 2 | NO | 0.80 | 0.90 |
| 0.25 | 2 | NO | 0.46 | 0.73 |
| 0.20 | 2 | NO | 0.08 | 0.54 |
| 0.15 | 2 | YES | N/A | 0.31 |

Figure 1. H Farmer Will Not Participate in the Cooperative $\{\mathbf{L}, \mathrm{L}, \mathrm{H}\}$


Figure 2. H Farmer will Participate in the Cooperative $\{\mathbf{L}, \mathrm{L}, \mathrm{H}\}$ with Full Pooling


Figure 3. Stable Cooperative Agreements Exist with Partial Pooling


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[^1]:    ${ }^{1}$ This price-taking assumption is in contrast to Saitone and Sexton, who assumed downward sloping demands for both the H and L products based upon the vertical product differentiation paradigm. The downward-sloping demands are central to their result that pooling can mitigate competitive producers' tendency to produce excessive H product relative to the collective profit maximum. This issue, accordingly, does not arise in this paper.
    ${ }^{2}$ Equivalently, if the pooled product is truly commingled, the cooperative is able to sell the pooled product at a price $\epsilon(\phi, 1)$ that reflects the weighted average quality of the commingled product.

[^2]:    ${ }^{3} \mathrm{~N} / \mathrm{A}$ in this column indicates that the participation constraint of the H farmer is satisfied at $\delta=0$.

[^3]:    ${ }^{4}$ Figure 1 is constructed with parameter values $p H=0.2, p L=0.7, \lambda=2.0$, and $\phi=0.75$.

[^4]:    ${ }^{5}$ Parameter values for figure 2 are $p H=0.2, p L=0.4, \lambda=8.5$, and $\phi=0.75$.
    ${ }^{6}$ Parameter values for figure 3 are $p H=0.2, p L=0.5, \lambda=9.0$, and $\phi=0.75$.

