INFORMATION SHARING AND OLIGOPOLY IN AGRICULTURAL MARKETS: THE ROLE OF COOPERATIVE BARGAINING ASSOCIATIONS

BRENT HUETH AND PHILIPPE MARCOUL

Paper prepared for presentation at the

American Agricultural Economics Association Meetings

Montreal, Canada, July 27-30, 2003

Date: May 19, 2003.
Contact author: Brent Hueth, 260 Heady Hall, Iowa State University, Ames, Iowa 50011. *email*: bhueth@iastate.edu.

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Abstract. We study incentives for information sharing (about uncertain future demand for final output) among agricultural intermediaries in imperfectly competitive markets for farm output. Information sharing always increases expected grower and consumer surplus, but may reduce expected intermediary profits. Even when expected intermediary profits increase with information sharing, firms face a Prisoner's Dilemma where it is privately rational for each firm to withhold information, given that other firms report truthfully. This equilibrium can be avoided if firms' information reports are verifiable, and if firms commit to an *ex ante* contract that forces *ex post* information revelation. We argue that agricultural bargaining represents one means to achieve verifiability and to implement such a contract.

Introduction

Many markets for farm output are plausibly characterized by some degree of imperfect competition. This is certainly true in most fruit and vegetable markets where growers are numerous, and where intermediation (e.g., processing or shipping/packing) is relatively concentrated. Processing or packing cooperatives, and cooperative bargaining among farmers, may in some instances be institutional responses to these market imperfections. For example, Sexton (1990) studies the role that processing cooperatives can play in promoting competitive behavior among non-cooperative processors. In the case of farm bargaining, a number of authors have argued that collective price negotiation by growers can countervail the market power of intermediaries (e.g., Helmberger and Hoos, 1965; Ladd, 1964). This perspective emphasizes the effect of cooperation on market structure, and on the transfer of economic surplus from intermediaries (and possibly consumers) to growers. An alternative view—the one we explore in this paper—is that bargaining has efficiency consequences independent of changes in market structure.

Briefly, we consider an imperfectly competitive market for farm output where information sharing among intermediaries (about uncertain future demand for final output) potentially leads to higher expected aggregate surplus. In this context, we show that a bargaining association can solve a Prisoner's Dilemma among intermediary firms where all parties (firms, consumers, and growers) are better off when information is fully shared, but where each firm's equilibrium strategy is to *not* reveal its information given that other firms report truthfully. The bargaining association serves two roles: First, the association invests costly resources in verification of firm reports (firms can choose not to reveal their information, but if they do reveal, it is impossible to lie); and second, mandatory bargaining provides a mechanism where all parties commit to reveal their information. Below, we argue that these two functions are reasonable descriptions of what bargaining associations actually do (among other things), and that they serve to solve the Prisoner's Dilemma noted above.

In what follows, we begin with a description of bargaining in agricultural markets. We then develop a model of information sharing in the spirit of work by Vives (1984), Raith (1996), and Li (1985) (see Vives (1999), Chapter 8 for an excellent summary of this literature), and demonstrate how mandatory bargaining can lead to efficiency gains. The final section concludes and discusses the empirical implications of our model.

Bargaining and Price Discovery in Agricultural Markets

Our intent in this section is not to provide an exhaustive overview of agricultural bargaining, but rather to point out ways in which descriptions of the institutional features of bargaining associations seem consistent with the notion that bargaining has efficiency consequences independent of changes in market structure, and, in particular, that bargaining facilitates price discovery via formalized "information sharing."

Bargaining occurs primarily in markets for *processing* fruits and vegetables (Hueth and Marcoul, 2003). This particular set of markets comprises only a small portion of all agricultural markets, and it is natural to ask why bargaining associations are not more widespread. If the success of bargaining as an institution hinges on delivering higher prices to growers, we should perhaps expect to observe bargaining in a larger class of commodities. In this respect, it is noteworthy that fruit and vegetable processors obtain their output primarily through forward contracts, so that traditional modes of price discovery are mostly absent. Moreover, procurement decisions are typically made in the context of uncertainty about the state of future demand (e.g., prior to planting). To the extent that price negotiations during bargaining facilitate industry-wide communication about future demand, bargaining can be viewed as a sort of indirect price discovery mechanism.

Results and discussion from two studies of farm bargaining seem consistent with this notion. First, in a national survey of processing fruit and vegetable bargaining associations, Iskow and Sexton (1992) note that "the majority of associations felt their role was not only to improve the well-being of grower-members, but also to provide services to processors." Of the services provided, "increased price stability," "improved information," and "improved price discovery process" were most frequently cited.[1] Lacking similar responses from processing firms, it is difficult to know whether, in fact, such services were provided and valued. Nevertheless, that nearly all respondents viewed price discovery and improved information as important services provided by their respective associations is certainly consistent with the hypothesis that an important consequence of farm bargaining is information transmission among market participants.

Similarly, Bunje (1980) offers a comprehensive description of bargaining in U.S. agricultural markets.[2] In summarizing the role of farm bargaining he notes that:

> "Bargaining associations can fill the needs of the market as well as the needs of the individual producer. They can serve a supply coordinating function for the market and furnish market intelligence for the producer. They can operate as a price discovery vehicle, establish market prices, and establish uniform terms of trade that serve the producer and the marketplace."

While such a quote might be viewed as self-serving coming from a representative of bargaining associations, it again conveys the idea that, at least in the minds of those who operate bargaining associations, bargaining is much more than simply "price enhancement."

Of course, there are many other possible explanations for the relative prominence of bargaining in processing fruit and vegetable markets. For example, Knoeber (1983) notes that "liquidated damage" ("most-favored customer") clauses in contracts between bargaining associations and growers (processors) can mitigate incentives for either party to renege on

[1]Of the 36 associations sampled, 31 cited increased price stability, 32 cited improved information, and 25 cited improved price discovery. When queried about services offered to growers, only "price negotiation" and "time and method of payment" were similarly cited by more than 30 associations.

[2]Ralph Bunje was a leading spokesman and proponent of farm bargaining for over 30 years during his tenure as manager of the California Canning Peach Association (forward to citation in text above).

contract terms.[3] To the extent that contract reliability is a problem peculiar to processing fruit and vegetable markets, the benefits from third party (i.e., bargaining association) contract enforcement may be relatively high. Alternatively, it may indeed be the case that the degree of imperfect competition in these markets is particularly severe. For example, Iskow and Sexton (1992) note that the four largest firms handled over 75 percent of total production in 23 of 34 markets studied.

In any case, it is not our intent in the present paper to empirically identify the primary role of bargaining in agricultural markets. Indeed, it is entirely possible that bargaining serves multiple roles. Our more modest goal is to identify and analyze a role for bargaining that seems to have gone mostly unnoticed in formal analyses of the farm bargaining problem. Importantly, our analysis suggests that bargaining, to the extent that it results in "information sharing," is efficiency enhancing. This is in contrast to the "price enhancement" hypothesis, which suggests the possibility of net welfare losses from farm bargaining.

We begin our analysis below by developing an oligopoly model of n firms who produce substitute final goods, and who obtain their raw farm input from a group of homogeneous growers represented by an aggregate supply relation. Prior to procurement, each firm is uncertain about the true state of future demand, but receives an imperfect signal of demand. We study private incentives for firms to share (or pool) their signals, and corresponding welfare implications. In this context, we interpret the intensive communication that occurs during the annual bargaining process, and ultimately the setting of a bargained price for contracted output, as a means of implementing information sharing.

Model

The Setup

There are n firms who convert farm output into a vector of final consumption goods $q = (q_1, \ldots, q_n)$, where q_i represents the quantity of final goods sold by firm i. For simplicity, we suppose that each firm transforms q_i into final output in Leontief fashion with constant

[3]For example, suppose a grower and intermediary form a contract for future delivery of produce at some agreed price (or pricing mechanism). As the delivery date approaches, unanticipated opportunities for purchase (in the case of the intermediary) or sale (in the case of the grower) of the relevant produce may arise and thus provide incentives for one or the other party to renege on the original contract.

marginal cost (normalized to zero), and, moreover, that a single unit of farm output yields a single unit of final output. Thus, for given output price $p_i(q_i, q_{-i})$, and farm price $r(q_i, q_{-i})$, firm i's profits are given by $\Pi(q_i, q_{-i}) = [p_i(q, q_{-i}) - r(q_i, q_{-i})]q_i$, where q_{-i} represents the $n-1$ vector of outputs other than i's. Growers are represented by an aggregate supply function $r = a + bQ$, where $Q = \sum_{i=1}^{n} q_i$ is the aggregate quantity of farm output purchased.[4]

Final goods are differentiated and valued by a representative consumer with utility function

$$U(q) = (\overline{\alpha} + \varepsilon) \sum_{i=1}^{n} q_i - \frac{1}{2} \left(\overline{\beta} \sum_{i=1}^{n} {q_i}^2 + 2\overline{\gamma} \sum_{i \neq j} q_i q_j \right), \tag{1}$$

where $\overline{\beta} > \overline{\gamma} > 0$, $\overline{\alpha} > 0$, and where ε is a normally distributed, aggregate source of uncertainty from the perspective of growers and intermediaries. We suppose that all uninformed agents believe that ε has mean 0 and variance σ_ε. For a given vector of prices $p = (p_1, \ldots, p_n)$, consumers choose quantities to maximize $U(q) - \sum_{i=1}^{n} p_i q_i$, yielding inverse demand schedules for each firm's output given by

$$p_i(q_i, q_{-i}) = \overline{\alpha} + \varepsilon - \overline{\beta} q_i - \overline{\gamma} \sum_{j \neq i} q_j. \tag{2}$$

The timing of actions in our model is as follows: In period 0, each intermediary firm privately receives and independent and costless signal $s_i = \varepsilon + \nu_i$, where ν_i is distributed normally and independently of ε with $E[\nu_i] = 0$, $E[\nu_i^2] = \sigma_\nu$, $E[\nu_i \nu_j] = 0$ for $i \neq j$. Thus, formally each s_i represents imperfect, though unbiased, information on the state of future demand. [5] Informally, we can think of processing firms, as part of their everyday business activities, receiving information from their respective retailers about the current state of demand.[6] Based on these signals, firms form expectations in period 1 about demand in period 2, and coordinate with growers for delivery of some quantity of farm output that arrives in period 2. Expectations depend on the information available to each firm, and we

[4]This specification of the farm sector ignores grower heterogeneity, which may be important in considering the incentives for *growers* to form a bargaining association. We would like to consider the industry-wide incentives to form a bargaining association, independent of the organizational and administrative difficulties created by grower heterogeneity.
[5]Allowing firms to have asymmetric and correlated signal technologies (e.g., $E[\nu_i^2] = \sigma_\nu^i$, and $E[\nu_i \nu_j] \neq 0$) would complicate presentation without significantly altering our qualitative conclusions. See Vives (1984) for a treatment along these lines.
[6]We do not analyze the possibility of *costly* information acquisition. However, doing so will not affect the qualitative results of our analysis so long as the cost of information acquisition is contractible.

consider two scenarios: In the first, each firm keeps its information private, and forms an expectation based on s_i (for firm i). Alternatively, firms pool their information and form expectations based on the full vector of signals $s = (s_1, \ldots, s_n)$. Finally, in period 2, firms noncooperatively choose prices to maximize their individual profit, given the quantities of output arranged for delivery in the previous period. We assume "efficient rationing" (e.g., Tirole, 1989) of quantities, so that equilibrium prices in period 2 are just those that form an equilibrium when all quantities are delivered to the market.

The structure of this market is formally equivalent to Bertrand competition with firms choosing capacities in an *ex ante* period; here "capacities" are given by the quantity of output arranged for delivery during period 1. For this equivalence to hold, it is, of course, essential that no firm have the opportunity to obtain additional output in period 2 (relative to what was arranged for delivery during period 1). This is a natural feature of the markets we study, given the time interval required to produce most kinds of farm output.[7]

Market Equilibrium Without Information Sharing

In period 1, after each firm receives its signal s_i, the firms play a Cournot game in choosing quantities of output for delivery in period 2. For given q_i, the conditional expected profit of firm i is given by

$$\overline{\Pi}(q_i, q_{-i}|s_i) = \left(\alpha + E[\varepsilon|s_i] - \beta q_i - \gamma \sum_{j \neq i} E[q_j|s_i] \right) q_i, \tag{3}$$

where $\alpha = \overline{\alpha} - a$, $\beta = \overline{\beta} + b$, and $\gamma = \overline{\gamma} + b$. Let $\rho = \sigma_\varepsilon/(\sigma_\varepsilon + \sigma_\nu)$ represent the correlation between s_i and s_j. Then firms update their priors on ε with the formula $E[\varepsilon|s_i] = \rho s_i$, which is a weighted average of the prior and s_i.

Firm i chooses q_i to maximize conditional expected profit, given expectations about ε and the production decisions of other firms. For any given strategy used by other firms (that will

[7]It is also worth noting that we take as a given each firm's desire to coordinate with growers in period 1 (rather than compete for aggregate output in period 2). This is consistent with the notion that firms "contract" with growers, rather than purchase output on some kind of spot market. Understanding why firms choose to contract is an interesting problem, but one that lies beyond the scope of this paper. Interestingly, as noted in the previous section, the absence of spot markets (and the corresponding prevalence of contracted arrangements) seems to be a necessary condition for the establishment of bargaining associations.

be conditional on other firms' signals), firm i's best response is given by

$$q_i(q_{-i}) = \frac{\alpha + \rho s_i - \gamma \sum_{j \neq i} E[q_j | s_i]}{2\beta}. \tag{4}$$

We find the equilibrium for this game by supposing that firms use strategies that are affine in their signals, and then verify that these strategies indeed form an equilibrium (Radner, 1962). Letting firm i's equilibrium strategy be given by $q_i = c_0 + c_1 s_i$, and noting that $E[s_j|s_i] = \rho s_i$, it is straightforward to verify that an equilibrium is obtained setting $c_0 = \alpha/\delta$, and $c_1 = \rho/\delta_\rho$, where $\delta = 2\beta + (n-1)\gamma$, and $\delta_\rho = 2\beta + (n-1)\gamma\rho$. The equilibrium quantity for firm i is then given by

$$q_i^p = \frac{\alpha}{\delta} + \frac{\rho s_i}{\delta_\rho}. \tag{5}$$

For future reference, we note that $E[q_i^p] = \alpha/\delta$, $E[(q_i^p)^2] = E[q_i^p]^2 + \sigma_\varepsilon \rho/\delta_\rho^2$, and $E[q_i^p q_j^p] = E[q_i^p]^2 + \sigma_\varepsilon \rho^2/\delta_\rho^2$, for $i \neq j$.

The full information equilibrium level of production when ε equals its expected value of zero is given by α/δ, so that firms increase or decrease their output relative to this benchmark, depending on whether the realization of s_i is greater or less than zero. The variance of signal noise σ_ν has an ambiguous effect on the slope term ρ/δ_ρ. On the one hand, as σ_ν decreases, firms put more weight on their signals relative to their prior, and this makes firms more responsive to their signals. This effect is reflected in the numerator of the second term in equation (5) where a decrease in σ_ν increases ρ. On the other hand, a decrease in σ_ν increases the correlation of firms' signals. This, in turn, implies that if some firm, say firm i, receives information suggesting high demand, it is likely that other firms have received similar information. Because the outputs of each firm are strategic substitutes, an equilibrium response to this is a reduction in firm i's output. This effect is reflected in the denominator, where a decrease in σ_ν increases δ_ρ. Changes in σ_ε have a similarly ambiguous, though reciprocal, effect on firm responsiveness. A reduction in σ_ε lowers the weight placed on each firm's signal, making firms less responsive, but also reduces the correlation of signals, and this tends to increase responsiveness.

Expected profit for each firm prior to observing their signal s_i, but anticipating equilibrium behavior for any realization of s, is given by

$$\overline{\Pi}_p \quad = \quad E\left[\max_{q_i} \overline{\Pi}(q_i, q_{-i}|s_i)\right], \tag{6}$$

which from (3) and (4) reduces to $\overline{\Pi}_p = \beta E[(q_i^p)^2]$. Direct calculation from (5) then yields

$$\overline{\Pi}_p = \beta\left(\frac{\alpha^2}{\delta^2} + \frac{\sigma_\varepsilon \rho}{\delta_\rho^2}\right). \tag{7}$$

The first term in this expression represents the profits each firm would receive if there were no uncertainty ($\sigma_\varepsilon = 0$). From this term, expected profits are high when aggregate demand and supply are high (high $\overline{\alpha}$ or low a), or when the total price decrease resulting from a small increase in each firm's output is small (low δ). The second term, which is strictly positive so long as σ_ν is finite, reflects the benefit from receiving a signal, relative to no information at all.

One consequence of information sharing is an increase in the precision with which firms estimate ε. Thus, before considering the market equilibrium with information sharing, it is instructive to consider how a reduction in the variance of the signal error σ_ν (which reduces the variance of each firm's estimate of ε) affects expected firm profits when there is no information sharing. From (7), a reduction in σ_ν has a similar qualitative effect on profits as on the equilibrium responsiveness of each firm's output to their signal (described above). Firms benefit from a reduction in the variance of signal noise because their output decision more accurately reflects actual demand conditions. In particular, the mean square error of each firm's estimate of ε (given by $\sigma_\varepsilon\sigma_\nu/(\sigma_\varepsilon + \sigma_\nu)$) falls when σ_ν falls. However, because the signals of each firm become more correlated, equilibrium outputs also have greater correlation, and this tends to reduce expected profits. This ambiguity suggests that whether or not firms gain from information sharing will generally depend on a direct comparison of expected profits in each regime. In the next section, we derive an expression for expected firm profits when information is shared, and make this comparison.

Market Equilibrium With Full Information Sharing

Here, we suppose that some mechanism is available for firms to share their information. Later in the paper, we will argue that bargaining can be one such mechanism. To focus on the potential benefits from information sharing, we continue to assume that firms act as oligopsonists in the market for farm output.[8]

When information sharing occurs, each firm receives the full vector of signals s, and thus all firms form a common estimate of ε. With n independent signals, the best estimate of ε is given by $E[\varepsilon|s] = \rho_n \overline{s}$, where $\rho_n = \sigma_\varepsilon/(\sigma_\varepsilon + \sigma_\nu/n)$, and $\overline{s}$ is the mean value of the vector s (DeGroot, 1970). Proceeding as in the previous section, firm $i's$ reaction function is then given by

$$q_i(q_{-i}) = \frac{\alpha + \rho_n \overline{s} - \gamma \sum_{j \neq i} E[q_j|s]}{2\beta}, \tag{8}$$

yielding the equilibrium quantity

$$q_i^s = \frac{\alpha + \rho_n \overline{s}}{\delta}, \tag{9}$$

with $E[q_i^s] = E[q_i^p] = \alpha/\delta$, and $E[(q_i^s)^2] = E[q_i^s q_j^s] = E[q_i^s]^2 + \sigma_\varepsilon \rho_n/\delta^2$.

Thus, equilibrium expected output is the same, regardless of whether or not firms share information on their common demand uncertainty. Firms are more responsive to their aggregate signal $\overline{s}$ than to their private signal s_i when

$$\frac{\rho_n}{\rho} \geq \frac{\delta}{\delta_\rho}, \tag{10}$$

and it is straightforward to verify that this condition is always satisfied (for $\beta > \gamma$). Information sharing increases the precision of each firm's estimate of ε, and this makes firms more responsive to their signals; but information sharing also leads to perfect correlation in firms' strategies, and this makes firms less responsive to their signals. The satisfication of the inequality (10) indicates that the net effect of these countervailing forces is always an increase in firm responsiveness.

[8] Bargaining that leads to competitive pricing for farm output would, of course, generate efficiency gains, but we would like to evaluate the benefits from information sharing independent of changes in market structure.

As in the previous section, expected firm profits are given by (β times) the expected value of equilibrium quantity squared. Thus, expected firm profits with information sharing are given by

$$\overline{\Pi}_s = \beta\left(\frac{\alpha^2}{\delta^2} + \frac{\sigma_\varepsilon \rho_n}{\delta^2}\right), \tag{11}$$

and comparison of profits under each regime reduces to a comparison between the relative magnitudes of ρ_n/δ^2 and ρ/δ_ρ^2.

Welfare Comparison

In this section we evaluate the effect of information sharing on total expected welfare, and on the expected welfare of firms, consumers, and growers individually. We evaluate *ex ante* welfare (prior to the firms receiving their signals), but suppose, as in the previous section, that firms anticipate the equilibrium outcome in either scenario for a given realization of s. We begin with the difference in expected firm profits with and without information sharing.

It is straightforward (though somewhat tedious) to show that $\overline{\Pi}_s \geq \overline{\Pi}_p$ whenever

$$4\beta(\beta-\gamma) - (n-1)\gamma^2(1+n\rho) \geq 0. \tag{12}$$

The following proposition summarizes the conditions under which information sharing leads to higher expected firm profits:

Proposition 1. (Firm Profits) *Information sharing increases expected firm profits when*

(i) *outputs are highly differentiated ($\overline{\gamma}$ small);*

(ii) *own demand is relatively inelastic ($\overline{\beta}$ large);*

(iii) *there are few firms;*

(iv) *the correlation among firms' signals is small (σ_ε small and σ_ν large)*

Intuitively, a high degree of product differentiation is analogous to each firm acting as a monopolist in the downstream market for farm output. Improved information on future demand increases each firm's ability to price discriminate, and this in turn increases expected profitability. Firms similarly gain from information sharing when own demand is sufficiently inelastic. When there are a small number of firms, and when the correlation among firms' signals is relatively weak, correlation among firms' strategies is relatively unimportant and this tends to make information sharing more attractive to firms.

Surplus for growers is given by $\frac{1}{2}(r(Q) - a)Q = \frac{b}{2}Q^2$, so that expected grower surplus is given by

$$\frac{nb}{2}\left(E[q_i^2] + (n-1)E[q_iq_j]\right). \tag{13}$$

Using the expressions for $E[q_i^2]$ and $E[q_iq_j]$ obtained in the previous sections, it is straightforward to verify that growers always benefit from information sharing. Intuitively, both growers and firms gain from increased precision in estimating aggregate demand. However, the increase in correlation among firms' outputs lowers expected firm profits, and increases expected grower surplus. Thus, the two effects associated with information sharing—increased precision in estimating aggregate demand and increased correlation among firms' outputs—are countervailing with respect to firm profits, but complementary with respect to grower surplus.

Consumer surplus is given by $U(q) - \sum_{i=1}^{n} p_iq_i$. Taking expectations (and assuming equilibrium behavior by firms) yields

$$\frac{n}{2}\left(\overline{\beta}E[q_i^2] + (n-1)\overline{\gamma}E[q_iq_j]\right). \tag{14}$$

Thus, consumers also benefit from the correlation among firms' outputs, but only when there is some degree of product substitutability. As with grower surplus, the effects of information sharing on consumer surplus tend to complement, though to a lesser degree since $E[q_iq_j]$ is weighted by $\overline{\gamma} < \overline{\beta}$. Using the expressions for $E[q_i^2]$ and $E[q_iq_j]$ from the previous section, consumers gain from information sharing whenever

$$\frac{\rho_n}{\rho} \geq \frac{\delta^2(\overline{\beta} + (n-1)\overline{\gamma}\rho)}{\delta_\rho^2(\overline{\beta} + (n-1)\overline{\gamma})}. \tag{15}$$

Because $\rho < 1$, if information sharing leads to higher expected profits for intermediaries, then expected consumer surplus also increases. Also, note that when $b = 0$ this inequality will always be satisfied since then $\delta = \overline{\beta} + (n-1)\overline{\gamma}$ and $\delta_\rho = \overline{\beta} + (n-1)\overline{\gamma}\rho$. For $b > 0$, condition (15) will generally hold, but can be violated. Thus, consumers generally gain from information sharing, though we cannot rule out the possibility that expected consumer surplus falls.

Adding up the expected surplus measures for each party, total expected surplus is given by

$$\frac{n}{2}\left(3\beta E[q_i^2] + (n-1)\gamma E[q_i q_j]\right), \tag{16}$$

and is greater when information is shared if

$$\frac{\rho_n}{\rho} \geq \frac{\delta^2(3\beta + (n-1)\gamma\rho)}{\delta_\rho^2(3\beta + (n-1)\gamma)}. \tag{17}$$

As with expected consumer surplus, total expected surplus increases with information sharing whenever expected firm profits increase, but again we cannot rule out the possibility that expected total surplus falls. In general, however, it seems difficult to violate the inequality in (17).

The following proposition summarize the effects of information sharing on grower, consumer, and total surplus:

Proposition 2. (Welfare) *Information sharing always benefits growers. Expected consumer and total surplus increase whenever expected firm profits increase, and may increase even as expected firm profits fall.*

Because the expressions for changes in expected profit and consumer surplus resulting from information sharing yield ambiguous results, we evaluate these measures (and expected grower surplus) for a particular specification of our model. We set $n = 5$, $\overline{\alpha} = 1$, $\overline{\beta} = 0.3$, $a = 0$, $b = 0.1$, $\sigma_\varepsilon = 0.3$, and $\sigma_\nu = .1$. With this specification, we then let $\overline{\gamma}$ range from 0 to $\overline{\beta}$ and evaluate differences in expected surplus with and without information sharing. The results are displayed in Figure 1. When outputs are sufficiently substitutable, expected firm profits fall when information is shared, though by a relatively small amount. Growers gain most from information sharing when outputs are highly differentiated. Interestingly, the change in expected consumer surplus with information sharing is initially increasing with the degree of product substitutability, then decreasing.

Figure 2 displays the results of a similar comparative static, but where we hold $\overline{\gamma}$ constant at 0.05, and let n range between 2 and 10 firms. Again, information sharing leads to a

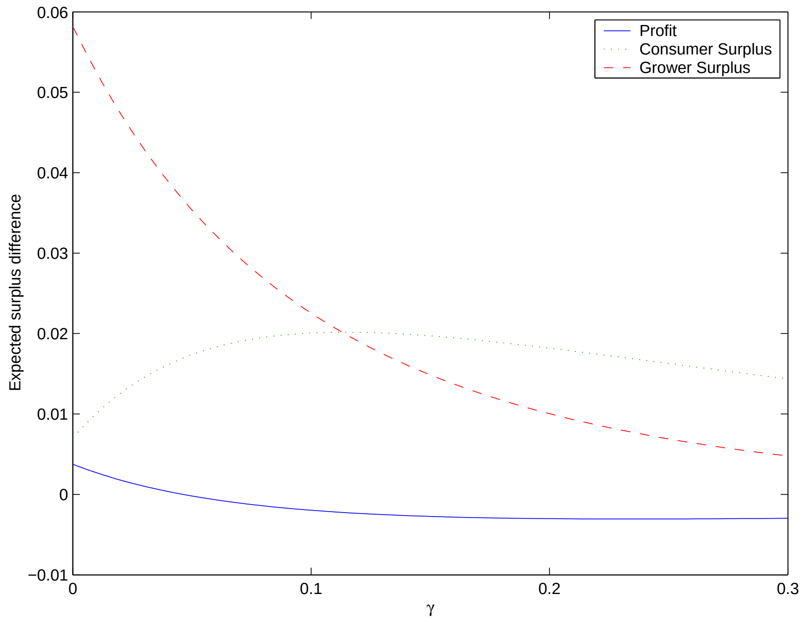

Figure 1. Difference in expected surplus with and without information sharing as firm outputs become increasingly substitutable in consumer preferences.

decrease in expected firm profits, but now for n sufficiently large. Information sharing benefits growers (and to a lesser degree, consumers) by a larger amount, as the number of firms increase.

Though not reported, a decrease in b (making supply more elastic for any given quantity of aggregate output) increases expected consumer surplus with information sharing, and reduces expected surplus for growers. In all cases analyzed, expected total surplus increases from information sharing, and the benefit to firms is relatively small (and sometimes negative).

It is also noteworthy that growers seem to gain substantially from information sharing, relative to firms, thus adding further potential benefit from bargaining beyond what might be achieved through changes in markets structure (i.e., more competitive pricing of farm output). We commented briefly on this point earlier, where we stated our assumption that bargaining leaves market structure unaltered. For example, in the context of our model, rather than allow firms to compete *a la* Cournot, we could allow the bargaining association to fix some price $\widetilde{r}$ as the price of farm output and let firms compete at this (fixed) price. Growers gain further (relative to the information sharing equilibrium) for an appropriately chosen price, but this would only repeat arguments made in previous analyses regarding the role of bargaining in countervailing market power.

Finally, one further point: In the context of agricultural markets, supply is an important source of uncertainty, in addition to demand. Adding supply uncertainty to our model changes very little, and even enhances the potential role for a bargaining association, if the association can collect information about aggregate supply that is unavailable to each firm individually. To see this, suppose that $r = a + \eta + bQ$, where now η is an aggregate source of supply uncertainty over which the association and firms share a common (normal) prior with $E[\eta] = 0$ and $E[\eta^2] = \sigma_\eta$. If the association receives a signal $s_0 = \eta + \omega$ with $E[\omega] = 0$, $E[\omega^2] = \sigma_\omega$, and $E[s_0 s_i] = 0$ for all i, then it is simple to verify that adding s_0 to s in the information sharing regime unambiguously increases expected welfare for all parties, relative to information sharing without s_0. It seems plausible that a bargaining association, through its communication with *all* member growers (rather than the growers of a single processor) can add important information concerning current-period supply conditions, further enhancing "price discovery."

Private Incentives To Reveal Information and Implementation

We have seen that information exchange among firms can lead to a market equilibrium that Pareto dominates the equilibrium with no information exchange; however, it turns out that when we examine each firm's *private* incentive to share information, a firm increases its

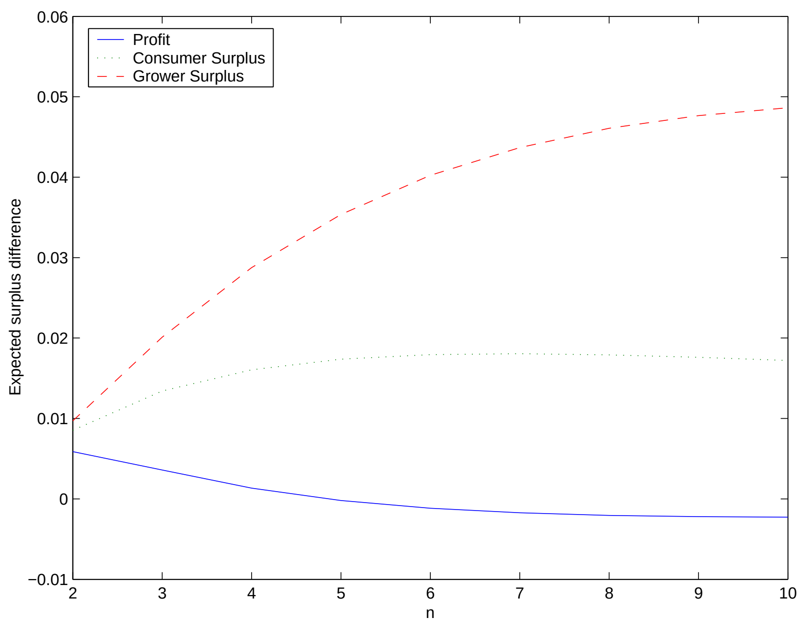

FIGURE 2. Difference in expected surplus with and without information sharing as the number of firms increase.

expected profits by not reporting, given that all other firms have reported truthfully, and that reports become public information.[9] More formally, suppose that firms play a two-stage game where each firm can truthfully report its signal or report nothing in the first stage, and

[9]If reporting firms can prohibit nonreporting firms from receiving information submitted by reporting firms, then information sharing may be an equilibrium outcome. For a paper that considers exclusionary information sharing of this sort, see Kirby (1988). However, exclusionary information sharing presumes that firms

then firms choose quantities and prices noncooperatively in the second stage, conditional on equilibrium reports in the first stage. The following proposition (adapted from Raith (1996)) summarizes the first-stage equilibrium of this game:

Proposition 3. (Information Revelation) *In the two-stage game where firms first decide whether or not to report their signal to other firms, and then choose quantities and prices non-cooperatively (conditional on the vector of equilibrium first-stage reports), each firm's dominant equilibrium first-stage strategy is to not report its signal.*

Proof: see Appendix.

In other words, given that all firms $j \neq i$ report their signals truthfully, firm i gains by deviating and reporting nothing. Intuitively, given that all other firms report their signals, firm i obtains the full benefits from increased precision in estimating aggregate demand, and, by withholding its signal, reduces the correlation among equilibrium outputs. This unambiguously raises expected profits for firm i, relative to the equilibrium in which it also reports its signal.

Thus, firms potentially face a Prisoner's Dilemma in which all parties gain from information sharing, but equilibrium behavior is to not share. Moreover, as we've seen in the previous section, this equilibrium generally leads to lower expected welfare for consumers and growers. It is, thus, useful to consider the kinds of institutions that might lead to an efficient outcome. Vives (1990) and Kirby (1988) suggest that "Trade Associations" are such an institution in markets where firms' outputs are strategic complements. With strategic complementarity, information sharing unambiguously increases expected firm profits, and it is a dominant strategy for firms to report their information. Thus, by collecting industry-wide information, and reporting back aggregate statistics, it is argued that these associations effectively implement an information sharing outcome.

However, even in this example where there is no Prisoner's Dilemma, implementing the sharing equilibrium requires a highly detailed information gathering effort by the association. In particular, we noted earlier that firms' reports of their signals must be *verifiable* in the sense that firms are unable to misreport their signals (though they can choose to not report

are playing something other than a simultaneous move game at the information reporting stage. In any case, firms will reveal *some* information when choosing quantities, so that full exclusion will never be possible.

entirely). Ziv (1993) studies information sharing when firms can strategically distort their signals, and finds that firms will always choose to report nontruthfully. Thus, in practice, verifiability is likely to be a substantial informational barrier, and it is not clear from existing theoretical work whether trade associations actually overcome this barrier, or whether their primary service is in other dimensions (e.g., lobbying and promotional activities).

When firm outputs are strategic substitutes (as in the markets we study), implementation becomes even more difficult. However, assuming verifiability of information reports, there is a simple solution to the Prisoner's Dilemma noted in Proposition 3. In particular, if reports can be verified in the sense described above, then firms can *contractually* implement the information sharing equilibrium. That is, each firm can formally commit to report its information, and with an appropriately chosen penalty for nonreporting, all firms will report in equilibrium.

A bargaining association can be viewed as an institution that facilitates information among industry participants. Indeed, the annual price negotiation that occurs with bargaining is an opportunity for explicit consideration of future supply and demand conditions (perhaps even the primary activity), and this facilitates verification of information reports by individual firms. Moreover, the structure of bargaining legislation effectively forces information revelation, since firms are *required* to engage in price negotiation under "good faith" bargaining provisions. Further, we can view the setting of a bargained price as a specific mechanism for implementing the information sharing equilibrium represented by equation (9). To see this, note that the supply price r, given equilibrium strategies for each firm, is given by

$$r^* = a + b\frac{bn}{\delta}(\alpha + \rho_n \overline{s}). \tag{18}$$

Thus, there is a strictly monotonic relationship between the supply price and the relevant aggregate statistic of firm reports. As a result, announcing r^* and letting firms compete at this *fixed* price is equivalent to announcing $\overline{s}$ and letting firms compete *a la* Cournot. We summarize this result in the following Proposition:

Proposition 4. (Implementation) *There exists a unique supply price r^* that implements the information sharing equilibrium q_i^s for $i = 1, \ldots, n$.*

Each firm's information about downstream demand can thus be transmitted to competing firms through input price negotiation with the bargaining association. This result provides a clear link between information sharing and the traditional role of bargaining associations in setting an "industry" price, and contrasts with information sharing in the context of a trade association where there is no clear mechanism for implementation.

Conclusion

We provide a rationale for the existence of bargaining associations in agricultural markets that is entirely independent of the role they may play in countervailing market power. In markets with a large proportion of contracted production, and a corresponding absence of spot markets, traditional modes of price discovery are mostly absent. One possible substitute for price discovery via markets is direct communication among competing firms concerning expected future supply and demand conditions. In the spirit of work by Vives (1984), Li (1985) and Raith (1996), we model this communication as a Bayesian game among oligopolists in which each of n firms receives a signal of future demand, and evaluate the welfare implications of each firm sharing its signal with other firms.

Information sharing tends to benefit consumers and growers, but has ambiguous consequences for expected firm profits. Information sharing allows firms to increase the precision of estimated future demand, but because the signals are positively correlated (a natural assumption, given the nature of the markets we study), information sharing also tends to increase the correlation among firms' equilibrium strategies. In markets where final outputs are substitutes, firm strategies are strategic substitutes, so that a positive correlation of strategies reduces expected profit. Thus, the effects of information sharing tend to countervail with respect to expected profits, and complement with respect to consumer and grower surplus. Even when expected profits for firms increase as a result of information sharing, firms face a Prisoner's Dilemma in which the equilibrium behavior of each firm is to not report its information (not reporting when other firms report reduces the correlation of strategies, with no effect on the precision of estimated future demand). This equilibrium can be overcome if firms form an *ex ante* contract requiring full information disclosure once signals have been received. We demonstrate how cooperative bargaining, and in particular the setting of an industry price for farm output, represents one means of implementing such a contract.

Whether bargaining is primarily a mechanism for information exchange and price discovery, or a means for growers to countervail, or possibly even to exercise, market power has important consequences for the welfare effects of farm bargaining. Though it is not immediately clear how to go about testing the relative merits of these hypotheses, it is worth noting that our model encompasses both possibilities. Thus, with appropriate data one could test if predictions associated with information sharing add explanatory power, relative to a model based purely on the exercise of market power. Given the nested nature of these hypotheses in our model, such a test could, in principle, be carried out.

Appendix

Proof of Proposition 3:

To prove this result, we consider an equilibrium where $n-k$ firms report their private signal whereas the k remaining firms do not. In the first step, we compute the equilibrium strategies of a firm who belongs to the set of non revealing firms, and we derive the equilibrium expected profit for this firm. In the second step, we compute the equilibrium strategies and expected profit of the same firm when it reports its signal. Comparing expected profits in the two cases, we then show that chosing to reveal results in a lower expected profit for any $k \in \{1, 2, ..., n\}$.

Step 1: We first define and compute a firm's strategy when it belongs to the set of non revealing firms. We use the subscript i (resp. j) when referencing nonrevealing (resp. revealing) firms. Given the information available when production decisions are made, the expected profit for a nonrevealing firm is given

$$\Pi_i\left(q_i, q_j \mid \sum_{j=1}^{n-k} s_j, s_i\right) = q_i\left[\alpha + E\left(\varepsilon \mid \sum_{j=1}^{n-k} s_j, s_i\right) - \beta q_i - \gamma(k-1)E\left(q_i' \mid \sum_{j=1}^{n-k} s_j, s_i\right) - \gamma(n-k)q_j\right],$$

where a prime is used to indicate nonrevealing firms other than i. Similarly, the expected profit (conditional on information reports) of a revealing firm is given by

$$\Pi_j\left(q_j, q_i \mid \sum_{j=1}^{n-k} s_j\right) = q_j\left[\alpha + E\left(\varepsilon \mid \sum_{j=1}^{n-k} s_j, s_i\right) - \beta q_j - \gamma k E\left(q_i \mid \sum_{j=1}^{n-k} s_j\right) - \gamma(n-k-1)q_j'\right].$$

We suppose that firms use strategies that are affine in the relevant signals, with the following form:

$$q_i = C_{0i} + C_{1i}\sum_{j=1}^{n-k} s_j + C_{2i}s_i \tag{19}$$

$$q_j = C_{0j} + C_{1j}\sum_{j=1}^{n-k} s_j \tag{20}$$

Noting that

$$
\begin{aligned}
E\left(\varepsilon \mid \sum_{j=1}^{n-k} s_j, s_i\right) &= \frac{\sigma_\varepsilon}{(n-k+1)\,\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k} s_j + \frac{\sigma_\varepsilon}{(n-k+1)\,\sigma_\varepsilon+\sigma_\nu} s_i, \\
E\left(\varepsilon \mid \sum_{j=1}^{n-k} s_j\right) &= \frac{\sigma_\varepsilon}{(n-k)\,\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k} s_j, \\
E\left(s_{i'} \mid \sum_{j=1}^{n-k} s_j, s_i\right) &= \frac{\sigma_\varepsilon}{(n-k+1)\,\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k+1} s_j \text{ with } i^{'} \neq i \text{ , and} \\
E\left(s_i \mid \sum_{j=1}^{n-k} s_j\right) &= \frac{\sigma_\varepsilon}{(n-k)\,\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k} s_j,
\end{aligned}
$$

and using the strategies defined in (19) and (20), we can then derive the first order conditions for each type of firm. Doing so yields,

$$
\begin{aligned}
&2\beta C_{0i} + 2\beta C_{1i}\sum_{j=1}^{n-k} s_j + 2\beta C_{2i} s_i = \alpha + \tfrac{\sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k} s_j + \tfrac{\sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu} s_i - \gamma\,(k-1)\,C_{0i} \\
&-\gamma\,(k-1)\sum_{j=1}^{n-k} s_j C_{1i} - \tfrac{\gamma(k-1)\sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu}\left(\sum_{j=1}^{n-k} s_j + s_i\right) C_{2i} - \gamma\,(n-k)\left(C_{0j} + C_{1j}\sum_{j=1}^{n-k} s_j\right)
\end{aligned}
$$

for firm i, and

$$
\begin{aligned}
&2\beta C_{0j} + 2\beta C_{1j}\sum_{j=1}^{n-k} s_j = \alpha + \tfrac{\sigma_\varepsilon}{(n-k)\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k} s_j - \gamma k C_{0i} - \gamma k \sum_{j=1}^{n-k} s_j C_{1i} \\
&-\tfrac{\gamma k \sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu}\left(\sum_{j=1}^{n-k} s_j C_{2i} + s_i\right) C_{2i} - \gamma\,(n-k-1)\left(C_{0j} + C_{1j}\sum_{j=1}^{n-k} s_j\right)
\end{aligned}
$$

for firm j.

These first-order conditions yield a system of 5 equations in 5 unknowns. Solving this system yields

$$
\begin{aligned}
C_{0i} &= \frac{\alpha}{\delta} \\
C_{1i} &= \frac{\sigma_1\left(\sigma_1\,(n-k)\,(2\beta-\gamma) + 2\beta\sigma_2\right)}{\delta\left[2\beta\sigma_1\,(n-k+1) + 2\beta\sigma_2 + \gamma\sigma_1\,(k-1)\right]\left(\sigma_1\,(n-k)+\sigma_2\right)} \\
C_{2i} &= \frac{\sigma_1}{2\beta\left[\sigma_1\,(n-k+1)+\sigma_2\right] + \gamma\sigma_1\,(k-1)},
\end{aligned}
$$

with *ex ante* expected profit

$$\begin{aligned}
\overline{\Pi}_i &= \beta E\left[\left(q_i^{ns}\right)^2\right] = \beta\left\{\tfrac{\alpha^2}{\delta^2} + \mathrm{Var}\left(C_{0i} + C_{1i}\sum_{j=1}^{n-k} s_j + C_{2i}s_i\right)\right\} \\
&= \beta\left\{\tfrac{\alpha^2}{\delta^2} + C_{1i}^2\mathrm{Var}\left(\sum_{j=1}^{n-k} s_j\right) + C_{2i}^2\mathrm{Var}(s_i) + 2C_{1i}C_{2i}\mathrm{Cov}\left(\sum_{j=1}^{n-k} s_j, s_i\right)\right\} \\
&= \beta\left\{\begin{array}{c} \frac{\alpha^2}{\delta^2} + \frac{(\sigma_1(n-k)(2\beta-\gamma)+2\beta\sigma_2)[\sigma_1(2\beta(n-k)+\gamma(n+k))+2\beta\sigma_2+2\sigma_1(2\beta-\gamma)](n-k)\sigma_1^2}{\delta^2(2\beta\sigma_1(n-k)+2\beta\sigma_2+2\beta\sigma_1+\gamma\sigma_1(k-1))^2(\sigma_1(n-k)+\sigma_2)} \\ +\frac{(\sigma_1+\sigma_2)\sigma_1^2}{(2\beta\sigma_1(n-k)+2\beta\sigma_2+2\beta\sigma_1+\gamma\sigma_1(k-1))^2} \end{array}\right\}.
\end{aligned}$$

Step 2: Next, we compute the expected profit of a firm when it chooses to not report its signal. There are now $n-k+1$ reporting firms and $k-1$ nonreporting firms. Using the same reasonning as in Step 1, the first-order conditions can be stated as

$$2\beta C_{0i} + 2\beta C_{1i}\sum_{j=1}^{n-k+1} s_j + 2\beta C_{2i}s_i = \alpha + \tfrac{\sigma_\varepsilon}{(n-k+2)\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k+1} s_j + \tfrac{\sigma_\varepsilon}{(n-k+2)\sigma_\varepsilon+\sigma_\nu}s_i - \gamma\left(k-2\right)C_{0i} -$$

$$\gamma\left(k-2\right)\sum_{j=1}^{n-k+1} s_jC_{1i} - \tfrac{\gamma(k-2)\sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu}\left(\sum_{j=1}^{n-k+1} s_j + s_i\right)C_{2i} - \gamma\left(n-k+1\right)\left(C_{0j} + C_{1j}\sum_{j=1}^{n-k} s_j\right)$$

for firm i, and

$$2\beta C_{0j} + 2\beta C_{1j}\sum_{j=1}^{n-k+1} s_j = \alpha + \tfrac{\sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu}\sum_{j=1}^{n-k+1} s_j - \gamma\left(k-1\right)C_{0i} - \gamma k\sum_{j=1}^{n-k} s_jC_{1i}$$

$$-\tfrac{\gamma k\sigma_\varepsilon}{(n-k+1)\sigma_\varepsilon+\sigma_\nu}\left(\sum_{j=1}^{n-k} s_j + s_i\right)C_{2i} - \gamma\left(n-k-1\right)\left(C_{0j} + C_{1j}\sum_{j=1}^{n-k} s_j\right)$$

for firm j.

Again, solving this system for the five unknown parameters in equations (19) and (20) yields a new set of equilibrium coefficients. In this case, we are only concerned with the coefficients associated with a reporting firm, which are given by

$$\begin{aligned}
C_{0j} &= \frac{\alpha}{\delta} \\
C_{1j} &= \frac{\sigma_1}{\delta\left(\sigma_1 n - \sigma_1 k + \sigma_2 + \sigma_1\right)}.
\end{aligned}$$

Then *ex ante* expected profit for a reporting firm is

$$\overline{\Pi}_j = \beta \left\{ \frac{\alpha^2}{\delta^2} + \frac{\sigma_1^2 (n-k+1)}{\delta^2 (\sigma_1 (n-k+1) + \sigma_2)} \right\}.$$

Finally, it is tedious but fortunately not difficult to show that $\overline{\Pi}_j$ is strictly smaller than $\overline{\Pi}_i$. In particular, we obtain

$$\Delta\overline{\Pi} = \overline{\Pi}_i - \overline{\Pi}_j = \frac{(\sigma_2(n-1)+\sigma_1 n(n-k))[(2\beta+\delta)\sigma_2+\sigma_1(n-k)(4\beta+\gamma n)+2\gamma\sigma_1(k-1)+4\beta\sigma_1]\sigma_1^2\sigma_2\gamma}{\delta^2[2\beta\sigma_1(n-k+1)+2\beta\sigma_2+\gamma\sigma_1(k-1)]^2(\sigma_1(n-k)+\sigma_2)(\sigma_1(n-k+1)+\sigma_2)} > 0. \tag{21}$$

It is immediate to verify that the inequality (21) holds for any $k \in \{1, 2, ..., n\}$, and therefore that nonrevelation is a dominant strategy for all firms. *QED*.

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