Evaluating the Competitive Yardstick Effect of Cooperatives on Imperfect Markets: A Simulation Analysis

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Presented at Western Agricultural Economics Association 1997 Annual Meeting
July 13-16, 1997
Reno/Sparks, Nevada

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Abstract

This paper analyzes the effect of farmer cooperatives on the performance of imperfect markets through simulation analysis. Results suggest that, in addition to restricting output or overproducing, cooperatives can contribute to the diminution of economic welfare because of the increased costs of producing raw product due to disproportionate market shares.

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Farmer cooperatives have benefited from favorable public policies because they generally are perceived as procompetitive forces that improve the performance of imperfect markets and increase general economic welfare (Sexon and Iskow). Central to this notion is the "competitive yardstick" concept, which maintains that the existence of a cooperative in a market will force profit-maximizing firms to behave more competitively. The logic behind the yardstick is that the cooperative will offer farmers more favorable prices because of its practice of providing members service at cost. Competing firms must match the cooperative's performance to avoid losing patrons to it. Consequently, the market will move toward competitive equilibrium.

Helmberger argued that an important factor in determining the existence of the yardstick effect was the cooperative's membership policy. If faced with a downward-sloping demand function or increasing average processing costs, only an open-membership cooperative could be expected to exert a yardstick effect on competition. In fact, Helmberger concluded that a closed-membership cooperative could produce "socially undesirable" market performance by restricting output to a level less than that associated with a profit-maximizing monopsony. In a spatial oligopsony analysis, Sexton found that a closed-membership cooperative could result in poorer performance than an industry consisting entirely of profit-maximizing processors.

LeVay challenged Helmberger's conclusions about the socially undesirable effects of a closed-membership cooperative. LeVay maintained that an open-membership cooperative *over*produced by accepting whatever quantity of raw product members chose to supply. By offering members the highest price possible, an open-membership cooperative processed at a level beyond the social optimum because the value of the raw product input exceeded its derived demand. LeVay conceded that total economic welfare still could be enhanced by the stimulating effect the cooperative would have on competing firms but maintained that this role might also be filled by a cooperative that restricted output in order to maximize its members' welfare.

This paper analyzes the effect of cooperatives on the performance of imperfect markets through the use of several oligopoly/oligopsony models in which cooperative processors are alternately assumed to process whatever quantity of raw product members choose to supply and to restrict output in order to maximize member welfare. Simulation analysis is used to determine the market structures and behavioral assumptions under which cooperatives can be expected to exert a salutary effect on competitors. Our results suggest that, in addition to restricting output or overproducing, cooperatives can contribute to the diminution of economic welfare because of the increased costs of producing raw product attributable to increased production intensity and disproportionate market shares.

A Cournot Model of Oligopsony and Oligopoly

Several oligopoly models commonly employed in industrial organization studies and documented in Scherer and Ross (pp. 227–33) and Carlton and Perloff (pp. 270–73) were adapted to fit the structure of the oligopsonistic raw product markets and oligopolistic processed product markets in which agricultural processors may operate. These models include the Cournot model, two conjectural variations models in which processors alternately hold Bertrand and symmetric conjectures, and the von Stackelberg leader-follower model. In this section, we present the Cournot model because it is the simplest to describe in a limited amount of space. In the Cournot model, each firm sets its output under the assumption that the output of competing firms is invariant with respect to its actions. We briefly describe the conjectural variations and von Stackelberg models in a later section.

In all of the models, farmers (designated level *A*) produce a raw product they sell to processors (level *B*). The processors use the raw product to manufacture a processed product they sell to consumers. We assume that farmers face increasing linear marginal costs and that processors face a downward-sloping linear demand function. In addition, we assume that processors are subject to a fixed-proportions production technology, i.e., they employ one unit of the raw product in fixed proportion with other intermediate inputs in producing a unit of the processed product, and that the marginal cost of processing the raw product is constant. There is strong empirical evidence that short-run marginal costs in manufacturing industries are constant over broad ranges of output (Johnston, p. 13, and Dean, pp. 3–35). In addition, there is considerable empirical support for constant long-run costs over substantial output ranges (Scherer and Ross, p. 22).

The processors may be profit-maximizing firms or cooperatives. The effects of cooperatives on industry output and economic welfare can be analyzed by successively introducing cooperative processors into a market initially predominated by profit-maximizing firms. Each cooperative's membership is assumed to be fixed in the short run through marketing agreements by which members are contractually bound to sell their raw product exclusively to it. The remaining producers are assumed to sell to the profit-maximizing processors through an open raw product market. Long-run dynamics can be modeled by shifting producers from the raw product market to cooperative membership in response to higher raw product prices or progressively replacing profit-maximizing processors with cooperatives to represent the discipline of the competitive yardstick or the exit of profit-maximizing firms and the organization of new cooperatives by farmers.

The conduct of cooperative processors is defined by two alternate behavioral assumptions. Under the first, a cooperative (which we label an *active* cooperative) maximizes the total welfare or profits of its members (including its own earnings, which are returned to members as patronage refunds) by setting the quantity of raw product it processes. Under the second, a cooperative is *passive* in that it does not or cannot set the quantity of raw product it processes. Instead, it accepts whatever quantity of raw product its members choose to supply. This assumption conforms to the classic Helmberger and Hoos model of a marketing cooperative, in which equilibrium occurs where the raw product supply price equals the cooperative's average net returns from processing.

Consider r producers and n processors, k of which are cooperatives. Each cooperative has m members, leaving r-km producers who sell to the remaining n-k processors through the raw product market.

Producers

In order to derive linear raw product supply functions, we assume that each of the r producers has the following quadratic cost function:

$$F_i = e\,x_i + \frac{f}{2}x_i^2 + g \qquad e \geq 0,\ f \geq 0,\ g \geq 0 \qquad i = 1, 2, \ldots, r \qquad \textbf{1}$$

where x_i represents the quantity of raw product produced by the ith producer and g represents fixed cost. We assume that each producer who is not a member of a cooperative sets marginal cost equal to p_A, the price set by the raw product market:

$$\frac{dF_i}{dx_i} = e + f\, x_i = p_A \qquad i = 1, 2, \ldots, r \tag{2}$$

Aggregating over the r-km producers that sell to the raw product market, the inverse raw product supply function facing the n-k profit-maximizing processors is

$$p_A = e + \frac{1}{(r - km)} f \sum_{i=km+1}^{r} x_i \tag{3}$$

Similarly, the inverse raw product supply function facing each of the k cooperative processors is

$$p_A^* = e + \frac{1}{m} f \sum_{i=1}^{m} x_i \qquad i = 1, 2, \ldots, k \qquad 4$$

where p_A^* represents the raw product price set by the cooperatives.

Profit-Maximizing Processors

The objective function of each of the profit-maximizing processors can be written

$$\pi_i^B = (p_B - p_A - c)y_i \qquad i = k+1, k+2, \ldots, n \qquad 5$$

where c is the marginal cost of processing the raw product and y_i is the quantity of processed product produced by the ith processor. The price of the processed product p_B is determined by the processed product demand function, which takes the following linear form:

$$p_B = a - b\left(\sum_{i=1}^{k} u_i + \sum_{i=k+1}^{n} y_i\right) \qquad a > 0,\ b > 0 \qquad 6$$

where u_i represents the quantity of processed product produced by the ith cooperative processor. Thus the first-order condition for each of the profit-maximizing processors is

$$\frac{d\pi_i^B}{dy_i} = a - e - b\sum_{j=1}^{k} u_j - \left[b + \frac{f}{(r-km)}\right]\sum_{j=k+1}^{n} y_j - \left[b + \frac{f}{(r-km)}\right]y_i - c = 0 \qquad i = k+1, k+$$

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Aggregating over the n-k profit-maximizing processors, we obtain

$$a - e - b\sum_{i=1}^{k} u_i - \frac{(n-k+1)}{(n-k)}\left[b + \frac{f}{(r-km)}\right]\sum_{i=k+1}^{n} y_i - c = 0 \qquad 8$$

Active Cooperative Processors

Each active cooperative is assumed to maximize the welfare of its members, which is defined as the total on-farm profits of the members plus the profit of the cooperative, the latter of which is assumed to be returned to members as patronage refunds:

$$\pi_i^* = \pi_i^B + \sum_{j=1}^{m} \pi_j^A = (p_B - c)u_i - \sum_{j=1}^{m} F_j \qquad i = 1, 2, \ldots, k \tag{9}$$

The first-order condition for each cooperative is

$$\frac{d\pi_i^*}{du_i} = a - e - b\left(\sum_{j=1}^{k} u_j + \sum_{j=k+1}^{n} y_j\right) - \left(b + \frac{f}{m}\right)u_i - c = 0 \tag{10}$$

Aggregating over the *k* cooperative processors, we obtain

$$a - e - \left[\frac{(k+1)}{k}b + \frac{1}{k}\frac{f}{m}\right]\sum_{i=1}^{k} u_i - b\sum_{i=k+1}^{n} y_i - c = 0 \tag{11}$$

Reaction Functions

From equations (8) and (11), we can derive the aggregate reaction functions of the profit-maximizing and cooperative processors:

$$\sum_{i=k+1}^{n} y_i = \frac{(n-k)}{(n-k+1)}\left[b + \frac{f}{(r - km)}\right]^{-1}\left(a - e - b\sum_{i=1}^{k} u_i - c\right) \tag{12}$$

and

$$\sum_{i=1}^{k} u_i = \left[\frac{(k+1)}{k}b + \frac{1}{k}\frac{f}{m}\right]^{-1}\left(a - e - b\sum_{i=k+1}^{n} y_i - c\right) \tag{13}$$

Solving equations (12) and (13) simultaneously, we can determine the equilibrium levels of output for the profit-maximizing and noncooperative processors.

Passive Cooperative Processors

Here we assume that the cooperatives are passive in terms of accepting whatever quantity of raw product its members choose to supply. Each member recognizes the existence of patronage refunds and produces the quantity for which marginal cost equals the net price it receives from the cooperative, which consists of the cash price p_A^* plus the per-unit patronage refund s:

$$e + f\ x_i = p_A^* + s \qquad i = 1, 2, \ldots, m \qquad \textbf{14}$$

The per-unit patronage refund consists of the cooperative's profit divided by the quantity of raw product it processes:

$$\begin{aligned} s &= \frac{(p_B - c)u_i - \sum_{j=1}^{m} p_A^* x_j}{\sum_{j=1}^{m} x_j} \qquad i = 1, 2, \ldots, k \\ &= p_B - c - p_A^* \end{aligned} \qquad \textbf{15}$$

Substituting equation (15) into (14) for s, we obtain

$$\begin{aligned} e + f\ x_i &= p_A^* + \left(p_B - c - p_A^*\right) \\ &= p_B - c \end{aligned} \qquad i = 1, 2, \ldots, m \qquad \textbf{16}$$

Aggregating over m members provides

$$e + \frac{1}{m} f \sum_{i=1}^{m} x_i = p_B - c \qquad \textbf{17}$$

and replacing the quantity of raw product supplied by members with the processed product manufactured by the cooperative yields

$$e + \frac{1}{m} f\, u_i = p_B - c \qquad i = 1, 2, \ldots, k \qquad \textbf{18}$$

Aggregating over *k* cooperatives and solving for the final product price, we obtain

$$p_B = e + \frac{1}{k} \frac{f}{m} \sum_{i=1}^{k} u_i + c \qquad \textbf{19}$$

which represents the inverse aggregate supply function of the cooperatives. Setting it equal to the final product price in (6), we can derive the aggregate equilibrium condition for the cooperatives:

$$\sum_{i=1}^{k} u_i = \left(b + \frac{1}{k} \frac{f}{m}\right)^{-1} \left(a - e - b \sum_{i=k+1}^{n} y_i - c\right) \qquad \textbf{20}$$

which replaces the aggregate reaction function for the active cooperatives in (13).

Other Models

In conjectural variations models, each firm sets its output by considering the effects it expects a change in its output will have on its rivals' levels of output (see Carlton and Perloff, p. 276). Under the Bertrand conjecture, each firm thinks that the other firms will decrease their output to offset any increase in its output. Consequently, it believes it cannot affect industry output or the market price and behaves as a price-taker, setting its price equal to marginal cost. As a result, if all firms share the Bertrand conjecture, the industry will tend toward a competitive equilibrium. Under the symmetric conjecture, each firm believes that other firms will change their output to match any change in its output. Consequently, the firm believes it can affect total industry output but not its market share. Accordingly, it behaves as if it were a member of a joint-profit-maximizing cartel. In our conjectural variations models, we assume that profit-maximizing processors alternately hold Bertrand and symmetric conjectures with respect to the output of other profit-maximizing processors and Cournot conjectures with respect to the output of cooperative processors. We also assume that cooperative processors hold Cournot conjectures with respect to the output of all other processors.

In the von Stackelberg models, we alternately assume that an active cooperative and a profit-maximizing processor act as the leader and *n*-1 profit-maximizing processors act as followers. Taking the output of all other firms as given, each follower seeks to maximize its profit. However, recognizing its rivals' behavior, the leader determines the optimal level of its output by incorporating the aggregate reaction function of the followers into its objective function. The leader in a von Stackelberg model usually is distinguished from the followers by some special characteristic, such as a lower cost structure or greater market share. In our models, the firms are assumed to have identical costs. The cooperative leader in the first model is unique because of its objective function. On the other hand, the leader in the second model is identical to the followers. That model is presented to serve as a benchmark for comparing the cooperative model instead of a model of behavior.

Results

Some of our simulation results are reported in table 1 for the parameter values presented at the foot of the table. Although these particular parameters were arbitrarily selected, the qualitative results are robust over a broad range of values given the linearity of the relationships (see Wu). The simulations were conducted under the assumption that there initially were 10 profit-maximizing processors. The effects of cooperatives on industry output and economic welfare were studied by progressively replacing profit-maximizing processors with either active or passive cooperative processors. As table 1 shows, adding cooperative processors did not always have a substantial or positive effect on output and welfare.

Cooperatives had the greatest impact in the symmetric conjectures model, especially when the cooperatives were passive. Passive cooperative processors substantially increased both output and economic welfare in that model. Indeed, as the number of passive cooperative processors increases, the output and economic welfare of the symmetric model approaches the quasi-competitive solution of the

Bertrand model.

Both output and economic welfare are lower in the von Stackelberg model with a cooperative leader than in the model with a profit-maximizing leader. In addition, in both the Cournot and Bertrand models, there are ranges over which total economic welfare decreases with the addition of a cooperative processor. This effect is most pronounced in the Cournot model with passive cooperative processors. When the first cooperative is added to that model, industry output increases but total economic welfare drops abruptly. With additional cooperative processors, economic welfare increases, and it eventually surpasses its initial level.

This phenomenon can be related to the increasing cost functions of producers, as shown in table 2. When the first cooperative processor is added to the model, it acquires a disproportionately large share of the market (37%). Because of increased production intensity, its members produce raw product at a very high average cost (6.07) relative to the initial average cost of production (1.59). Due to less intense production by nonmember producers, their average cost drops to 1.15. However, the weighted average cost of producing raw product rises to 2.97. Although consumer surplus increases with the greater output, the increase does not offset the loss in profits attributable to the increased production costs. Consequently, total economic welfare declines.

As additional cooperatives are added to the model, the market shares of individual cooperatives decline until each cooperative eventually has a proportionate market share. As market shares decrease, production of the raw product is more evenly distributed among producers and the average cost of production declines. Profits decrease, but with raw product production occurring at a lower average cost, the increase in consumer surplus more than offsets the decline in profits so that total economic welfare increases.

The diminution of welfare that occurs in this model is obviously unrelated to output restriction. It also is not associated with overproduction because the sum of the marginal costs of producing and processing the raw product do not exceed the processed product price. Instead, the decline in economic welfare can be attributed to increased production costs due to the increased intensity of production by cooperative members relative to producers that supply profit-maximizing processors.

Conclusions

The simulation analyses conducted in this study suggest that the existence of a competitive yardstick effect is not universal with respect to various scenarios regarding market structure and behavior. In particular, cooperative processors did not always have a substantial or positive effect on industry output or economic welfare. Cooperatives appear to be most effective in improving the performance of markets in which processors hold symmetric conjectures and tend toward collusive equilibria. On the other hand, the existence of cooperatives in the von Stackelberg, Cournot, and Bertrand models produced the potential for diminished market performance. This potential seems to be greatest in the Cournot model in which cooperative processors accept whatever quantity of raw product their members choose to supply. In that situation, the introduction of a cooperative into a market predominated by profit-maximizing processors abruptly decreased economic welfare. This result is attributable to increased costs of producing raw product due to a disproportionate market share held by the cooperative and the increased production intensity of its members.

Table 1. Industry Output and Total Economic Welfare for Selected Numbers of Cooperative Processors, *n*=10

Model[a]		Active Cooperatives (*k*)				Passive Cooperatives (*k*)			
	0	1	3	5	10	1	3	5	10
Cournot	265	265	265	265	265	274	282	286	291
	21,501	*21,501*	*21,501*	*21,501*	*21,509*	*21,241*	*21,307*	*21,444*	*21,681*
Bertrand	291	290	289	286	265	291	291	291	291
	21,681	*21,645*	*21,560*	*21,451*	*21,509*	*21,681*	*21,681*	*21,681*	*21,681*
Symmetric	146	190	230	248	265	249	277	285	291
	16,261	*18,751*	*20,447*	*21,057*	*21,509*	*19,120*	*20,760*	*21,262*	*21,681*

Note: Industry output in roman, total economic welfare in italic.
Parameter values: a=150, b=0.50, c=1, e=0, f=1.2, g=0, m=100/n, r=100.
[a] von Stackelberg model with cooperative leader: Industry output=271, welfare=21,417. von Stackelberg model with profit-maximizing leader: Industry output=277, welfare=21,626.

Table 2. Effects of Increasing Cooperative Processors on Industry Output, Raw Product Production Costs, and Economic Welfare, Cournot Model, *n*=10

k	Industry Output	Market Share per Cooperative (%)	Average Cost of Producing Raw Product		Producer and Processor Profits	Consumer Surplus	Total Economic Welfare
			Member	Nonmember			
0	264.6	0	[a]	1.59	4,004	17,498	21,501
1	273.7	37	6.07	1.15	2,511	18,730	21,241
2	278.9	28	4.77	0.90	1,793	19,451	21,245
3	282.3	23	3.92	0.74	1,382	19,925	21,307
4	284.7	20	3.33	0.62	1,118	20,259	21,377
5	286.4	17	2.90	0.54	936	20,508	21,444
6	287.8	15	2.56	0.47	803	20,700	21,503
7	288.8	13	2.30	0.42	703	20,853	21,556
8	289.7	12	2.08	0.37	624	20,978	21,602
9	290.4	11	1.90	0.31	560	21,642	21,642
10	291.0	10	1.75	[a]	508	21,173	21,681

[a] Not applicable.

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