Some Tests of the Economic Theory of Cooperatives: Methodology and Application to Cotton Ginning

Richard J. Sexton, Brooks M. Wilson, and Joyce J. Wann

Little progress has been made in testing the often conflicting hypotheses generated from theoretical research on cooperatives. This paper addresses the deficiency by describing and applying (to California cotton ginning cooperatives) a methodology to test key hypotheses concerning (*a*) cooperatives' price-output equilibrium, (*b*) allocative efficiency, and (*c*) utilization of capital inputs. The empirical results (*a*) are consistent with predictions from the game theory model of cooperative behavior, (*b*) reject the null hypothesis of absolute allocative efficiency, and (*c*) indicate absolute overutilization of capital inputs among the sample cooperatives.

Key words: cooperatives, cotton ginning, economic efficiency, profit function.

In recent decades, considerable progress has been made in developing and refining economic theories of the behavior of cooperative enterprises. Key contributions have included identifying the restricted-membership optimum (Clark), the open-membership, welfare-maximizing solution (Ohm), and the open-membership, Ramsey second-best optimum (Helmberger and Hoos). Further refinements of the theory have been accomplished recently through use of game theory methods (Staatz 1984; Sexton 1986). Reviews of this literature are provided by LeVay (1983a), Sexton (1984), and Staatz (1987).

Scholars in the field agree that a pressing research need is to develop and implement empirical tests of the often conflicting theories (LeVay 1983a, p. 39; Staatz 1987, p. 91). We address this problem in the present paper by describing and applying a general methodology to test key hypotheses concerning cooperatives' price-output equilibrium, allocative (price) efficiency, and use of capital inputs. Our approach consists of (*a*) deriving the restricted profit function for a marketing cooperative, (*b*) augmenting the profit function with parameters to test for allocative efficiency, (*c*) statistically estimating the augmented profit function, and (*d*) conducting the tests mentioned above. The methodology is adapted from work in the public utilities' literature by Atkinson and Halvorsen (1980, 1984) and from earlier work by Lau and Yotopoulos.

We specify a cooperative's objective function as follows:

$$\max_{\{X\}} \pi^* = Pf(X, R) - WX, \tag{1}$$

where R is the volume of raw product delivered by the members and taken as given by the co-op, $X = \{X_1, \ldots, X_n\}$ is a vector of inputs used in processing, $W = \{W_1, \ldots, W_n\}$ is the vector of parametric input prices, P is the parametric price for the processed product, Y, produced according to the function $f(X, R)$.

The first-order conditions to (1),

$$PDf(X, R) = W, \tag{2}$$

where D is the vector partial derivative operator, can be used to derive a restricted profit function that is conditional upon the level of R:

$$\pi^* = \pi^*(P, W, R), \tag{3}$$

where π^* specifies the maximum net revenue obtainable from each (P, W, R) combination. For given P and W, $\pi^*(R)/R$ is the familiar

Richard J. Sexton is an assistant professor and Brooks M. Wilson and Joyce J. Wann are graduate students in the Department of Agricultural Economics, University of California, Davis.
Giannini Foundation Paper No. 888.

net-average-revenue-product ($NARP$) function introduced by Helmberger (1964):

(4) $$NARP(R) = \pi^*(R)/R.$$

Our first hypothesis test examines the debate among co-op theorists concerning the location along the $NARP$ curve of a cooperative's equilibrium output.

As the next section describes in detail, concern has been expressed that cooperatives will be run inefficiently. To rigorously examine hypotheses concerning cooperatives' efficiency, we introduce a vector of parameters, $\boldsymbol{k} = \{k_1, \ldots, k_n\}$, to allow a cooperative to systematically deviate from the usual first-order conditions for the optimization problem in (1):

(5) $$P\partial f/\partial X_i = k_i W_i,\ k_i \geq 0, \qquad i = 1, \ldots, n.$$

Statistical tests for absolute allocative efficiency concern the joint hypothesis that $k_i = k_j = 1$ for all variable inputs i, j.

For empirical purposes, π^* is specified in the translog form. Our application is to cotton ginning cooperatives in California. The results show the cooperatives overused inputs relative to the amount of cotton ginned. Moreover, the gins' location along the $NARP$ curve tends to support predictions based on the game theory approach to cooperation.

In the paper's next section we establish the basis for our tests of co-op theory and then provide details on the methodology to conduct the tests. The application to the California cotton ginning industry is then described, empirical results are presented, and the tests of theory are conducted and discussed.

Aspects of Cooperative Theory

Price and Output Equilibria

The $NARP$ function in (4) specifies the maximum break-even price the co-op can pay for a given amount of the raw product R and is fundamental to all of the traditional theories of co-op marketing behavior. In particular, all embrace the fundamental optimization condition with respect to $\boldsymbol{X}$ in (2), upon which the restricted profit function in (3) and, in turn, the $NARP$ function in (4) are based. Disagreement has concerned the location of the cooperative's equilibrium output along the $NARP$ curve.

The objective function in (1) conforms directly to the well-known Helmberger and Hoos theory. The co-op is assumed to treat member deliveries as a parameter, choosing instead to specify price via the $NARP$ function. The Helmberger-Hoos equilibrium occurs where $NARP$ intersects members' inverse supply curve, $S(R)$, $S'(R) > 0$. This solution is a single-product Ramsey second-best optimum in that it satisfies the co-op's break-even constraint by setting price for the raw product according to its average-revenue product rather than its marginal-revenue product.

An alternative solution first offered by Ohm and later championed by LeVay (1983b) requires the co-op also to optimize with respect to R by setting price for the raw product equal to its net-marginal-revenue product, $NMRP(R)$, where, from (3), $NMRP(R) = \partial\pi^*/\partial R$:

(6) $$NMRP(R) = \partial\pi^*/\partial R = r = S(R).$$

This solution is the "first-best" optimum in that it maximizes member welfare for a given $S(R)$, but the fact that $NARP \neq NMRP$, except at the former's maximum, means that the cooperative's break-even requirement (paying a price equal to $NARP$) usually cannot be met by a simple linear price. Thus, the intersection of $NMRP(R)$ and $S(R)$ is not ordinarily an equilibrium, and proponents of the solution must turn to multipart pricing schemes or supply quotas to preserve the optimum.

A third alternative solution, suggested originally by Clark, requires optimization with respect to the membership size prior to undertaking the production problem in (1). In this manner, supply is constrained to intersect the maximum $NARP$, giving members the maximum raw product price possible.[1]

The game theory approach to cooperation (Staatz 1984, Ch. 5; Sexton 1986) poses challenges to each of the traditional theories. The appealing game theory solution concept for the cooperation game is the core or an appropriate extension of the core to accommodate multi-cooperative environments (Sexton 1986). Core-mandated optimization compels pricing of R according to its $NMRP$ schedule as called for by Ohm-LeVay but in contrast to Helmberger-Hoos. However, the game theory approach rejects the traditional Ohm-LeVay solution

[1] This triumvirate of alternative solutions are easily set forth in a single diagram featuring $NARP(R)$, $NMRP(R)$, and $S(R)$. LeVay (1983a, p. 11; 1983b, p. 106) provides illustrations.

where $S(R)$ intersects $NMRP(R)$ to the right of the maximum *NARP*. These solutions are shown to be almost certainly unstable and unenforceable because a subcoalition of the members can break away from the larger co-op and raise its payoff by forming a smaller, more efficient co-op located nearer to the maximum *NARP* (Sexton 1986, p. 220).

Counterexamples to Clark's maximum *NARP* solution also emerge from the game theory models because single- and multiple-cooperative core allocations can be found where the association(s) produces at rates beyond the maximum *NARP*. These solutions, though, tend to vanish as the optimum number of cooperatives becomes large, and the core or its multico-op analogue converges to solutions wherein each co-op operates at the maximum *NARP*.

It is useful to compare the alternative results for the cooperative to the equilibrium for an equivalent competitive firm whose objective is to maximize profit with respect to choices of X and R, treating all prices as given. That is, the competitive firm faces the unrestricted profit function, $\pi^{**}(P, W, r)$. Using existing notation, the competitive firm's problem can be decomposed into the optimal choice of X given R and the optimal choice of R. These optimal choices are given respectively by (2) and (6). Thus, the competitive firm achieves the same optimization conditions as the Ohm-LeVay cooperative, although the latter faces the nonconstant supply price, $r = S(R)$.

An additional equilibrium constraint facing the competitive firm is zero profits, i.e., $\pi^*(P, W, R) - rR = 0$. Rearranging this expression and using (6) obtains:

(7)
$$NARP(R) = \pi^*(R)/R = r = \partial\pi^*/\partial R = NMRP(R).$$

The market forces of entry and exit drive the competitive market price to the maximum of $NARP(R)$, and the competitive firm attains a result identical to the technologically equivalent Clark-type Co-op and also identical to the game theory equilibrium when the optimum number of cooperatives in a market becomes large.

In sum, the game theory model predicts that cooperatives in a multico-op market will all operate very near to the maximum *NARP*. That is, we should not observe cooperatives in a multico-op market operating significantly to either the left or right of the maximum *NARP* as is most often the case in typical renderings of the Helmberger-Hoos or Ohm-LeVay solutions. Given the possibility of "flat-topped" *NARP* curves, this conclusion does not imply that the co-ops must be a similar size.

Rearranging the equality in (7), we obtain the testable game theory hypothesis that the elasticity of π^* with respect to R is unitary over the range of output observed:

(8) $$H_o: (\partial\pi^*/\partial R)(R/\pi^*) = 1.$$

Allocative Efficiency of Cooperatives

Allocative or price efficiency measures the extent to which enterprises succeed in optimizing with respect to the input and output prices they face. Concern often has been expressed that cooperatives will be run inefficiently. One basis for this hypothesis is that farmers often lack business acumen compared to the directors of nonco-op enterprises (Helmberger 1966). Another concern is the lack of an incentive structure in cooperatives to induce management to run the association efficiently (Staatz 1984, Ch. 2; Caves and Peterson). Whereas management stock options, threats of hostile takeover, and the stock price's behavior as a barometer of managerial performance all act to mitigate concerns about managerial shirking in nonco-ops, none of these mechanisms are present in cooperatives.[2]

Two studies to date have attempted to analyze aspects of the efficiency of cooperatives (Babb and Boynton; Porter and Scully). Both studies focused on the dairy processing industry but used disparate methodologies and reached opposing conclusions, indicating the need for improved methodologies and more empirical studies on this topic.

With reference to equation (5), concerns about absolute co-op allocative efficiency may be statistically tested via the hypothesis that the k_i are all unitary:

(9) $$H_1: k_1 = k_2 = \ldots = k_n = 1.$$

Rejection of H_1 implies that the cooperative has not been price efficient. Tests of overall relative price efficiency:

[2] Co-op stock is usually nontransferable and, hence, has no meaningful market price. Thus, stock option plans are not a viable management incentive, and there is no stock price barometer by which to monitor management's behavior (Fama). Finally, since stock cannot be easily acquired, takeovers of the usual corporate mode are not possible in cooperatives.

$$H_{1a}: k_1 = k_2 = \ldots = k_n,$$

or pairwise relative price efficiency:

$$H_{1b}: k_i = k_j, \quad i \neq j,$$

may be used to indicate the nature of the inefficiency.

One interpretation of the rejection of H_1 (Atkinson and Halvorsen 1984) is that decisions have not been based on $\boldsymbol{W}$ but, rather, on the "shadow" price vector, $\boldsymbol{kW} = \{k_1W_1, \ldots, k_nW_n\}$. For example, in discussions of managerial shirking, a motivation commonly attributed to managers is to surround themselves with larger staffs than would be dictated by efficiency criteria, i.e., equation (2). Implicitly or explicitly these managers behave as if labor's wage is not W_L but, rather, the shadow wage, k_LW_L, where in this case $k_L < 1$. Estimation of the k_i, thus, provides a way to uncover decision makers' shadow prices.

Cooperatives and Capital Inputs

One particularly interesting subset of the relative efficiency tests, H_{1b}, concerns the disagreement as to whether cooperatives will tend to over- or underutilize capital inputs. Reasons cited for possible underutilization are fourfold (Vitaliano; Staatz 1984, Ch. 2; Murray): (*a*) Patronage, not capital, is the residual claimant in co-ops. As such, co-ops either pay no capital dividend or pay only a limited, fixed amount, making co-op investments unattractive to outside investors; (*b*) Co-op investments are usually nonmarketable and, hence, are highly nonliquid; (*c*) Co-op investments constitute a claim on the future earnings of the co-op only in conjunction with continued patronage. No avenue exists, therefore, to internalize the revenue-producing potential of a co-op investment beyond the member's lifetime—the so-called "horizon problem"; and (*d*) Co-op members intrinsically prefer to allocate capital investments to their farms than to the cooperative.

These factors suggest that co-op members individually have no incentive to contribute equity beyond whatever contractually is required to secure patronage privileges and to free ride if possible on other members' contributions. Although cooperatives may attempt to counteract undercapitalization through increased use of long-term debt, their ability to do so is limited by creditors' unwillingness to lend to poorly capitalized ventures. Ultimately, the hypothesized deficiency of funds for long-term investments must become reflected in underutilization of capital inputs.

A counterargument to this reasoning (Caves and Peterson) is that co-op members gain utility from an impressive plant and capital equipment and may approve excessive capital investment policies when (*a*) the utility gain from impressive co-op plant and equipment is uncorrelated with a member's patronage, (*b*) the size distribution of members' patronage reflects a large number of small-volume members and a relatively few large-volume members, (*c*) investment contributions are proportional to patronage, and (*d*) investment decisions are based on one-member–one-vote democracy. These factors jointly give small-volume members the desire and ability to enforce overinvestment policies on the co-op at the expense of large-volume producers. Another argument (Murray) is that co-op managers will favor overinvestment strategies and such strategies may be implemented in the absence of strong control by the membership.

Conditional upon rejection of H_1 in (9), specific hypotheses relevant to testing concerns about capital allocation are the absolute efficiency test:

$$H_2: k_K = 1,$$

and/or the relative efficiency tests:

$$H_3: k_K = k_j,$$

where K denotes capital and j denotes any other variable input.

Methodology

Although the methodology to conduct these tests of co-op theory has general applicability, we develop it in the context of our specific application to cooperative cotton gins. The ginning process produces baled lint and cottonseed in essentially fixed proportions so that we may consider a single composite output, Y, with the parametric output price, P, being a weighted average of the prices for cottonseed and baled lint. Variable inputs into the ginning process are labor (L), energy (E), and capital (K), with parametric input prices W_L, W_E, and W_K, respectively. Capital is treated as a variable input because the gins' long periods of shut-down time, usually about nine months each year, make it easy to undertake year-to-year adjustments in buildings and equipment. Our data indicate that such adjustments were made often.

The ginning cooperatives process whatever amounts of raw cotton, R, their members deliver. Thus, the gins treat R as a parameter and face the optimization problem in (1).

Treating P as the numeraire and using it to normalize the input prices (i.e., $w_L = W_L/P$, $w_E = W_E/P$, and $w_K = W_K/P$) does not affect the solution to (1). The normalized profit function, π, is, thus, expressed in terms of the normalized input prices, $\boldsymbol{w}$, and R:

$$(3') \qquad \pi = \pi(\boldsymbol{w}, R).$$

The decision rule supplied in (5) enables the co-op to diverge behaviorally from price efficient behavior and to base decisions on the shadow prices, $\boldsymbol{kW}$. In terms of the normalized prices, $\boldsymbol{w}$, we have the following behavioral decision rule:

$$(10) \qquad \partial Y/\partial X_j = k_j w_j, \qquad j = L, E, K.$$

Therefore, the behavioral normalized profit function (Lau and Yotopoulos; Atkinson and Halvorsen) is

$$(11) \qquad \pi_b = \pi_b(\boldsymbol{kw}, R).$$

The actual input-demand and output-supply functions can be obtained from (11) via the Shepard-Uzawa-McFadden Lemma (Varian):

$$(12) \qquad X_j = -\partial\pi_b(\boldsymbol{kw}, R)/\partial(k_j w_j) = -(1/k_j)(\partial\pi_b(\boldsymbol{kw}, R)/\partial w_j), \quad j = L, E, K.$$

$$(13) \qquad Y = \pi_b - \sum_j w_j\, \partial\pi_b(\boldsymbol{kw}, R)/\partial w_j.$$

The actual normalized profit function, π_a, is obtained by substituting the actual input-demand and output-supply functions in (12) and (13) into the normalized profit equation: $\pi_a = Y - \sum_j w_j X_j$:

$$(14) \qquad \pi_a = \pi_b + \sum_j \left(\frac{1-k_j}{k_j}\right) w_j \frac{\partial\pi_b(\boldsymbol{kw}, R)}{\partial w_j}.$$

For estimation purposes, π_b is specified via the popular translog form:[3]

[3] The translog is among the class of locally flexible functional forms. These functions are capable of providing arbitrary values for elasticities at a particular data point. Among the functions satisfying this flexibility property, the translog has been found to perform well in Monte Carlo studies (Guilkey, Lovell, and Sickles). Although "globally" flexible functional forms have recently been introduced, little application, particularly in respect to estimation of production technologies, has been accomplished with these functions.

$$(15) \qquad \ln \pi_b = \alpha_o + \sum_j \alpha_j \ln(k_j w_j) + \frac{1}{2}\sum_i \sum_j \gamma_{ij}\ln(k_i w_i)\ln(k_j w_j) + \delta_R \ln R + \frac{1}{2}\beta_{RR}(\ln R)^2 + \sum_j \beta_{Rj}\ln(k_j w_j)\ln R, \quad i, j = L, E, K,$$

where symmetry of cross-price effects requires that $\gamma_{ij} = \gamma_{ji}$.

Taking antilogs of (15) and differentiating with respect to the w_j obtains

$$(16) \qquad \partial\pi_b/\partial w_j = (\pi_b/w_j)[\alpha_j + \sum_i \gamma_{ij}\ln(k_i w_i) + \beta_{Rj}\ln R], \quad j = L, E, K.$$

Using (16) to substitute into (14) for $\partial\pi_b/\partial w_j$ and using the antilog of (15) to substitute for π_b in (14) yields

$$(17) \qquad \ln \pi_a = \ln\left\{1 + \sum_j [(1-k_j)/k_j] \cdot \left[\alpha_j + \sum_i \gamma_{ij}\ln(k_i w_i) + \beta_{Rj}\ln R\right]\right\} + \alpha_o + \sum_j \alpha_j\ln(k_j w_j) + \frac{1}{2}\sum_i\sum_j \gamma_{ij}\ln(k_i w_i)\ln(k_j w_j) + \delta_R\ln R + \frac{1}{2}\beta_{RR}(\ln R)^2 + \sum_j \beta_{Rj}\ln(k_j w_j)\ln(R), \quad i, j = L, E, K.$$

If $k_i = k_j = 1$ for all i, j, (17), the actual normalized profit function, simplifies to (15), the behavioral normalized profit function.

Using the results in (12) and denoting the curly-bracketed term in (17) as Φ, the input share equations based on (17) are

$$(18) \qquad S_j = w_j X_j/\pi_a = -\partial\ln \pi_a/\partial\ln w_j = -k_j^{-1}\Phi^{-1} \cdot \left[\alpha_j + \sum_i \gamma_{ij}\ln k_i + \sum_i \gamma_{ij}\ln w_i + \beta_{Rj}\ln R\right], \quad i, j = L, E, K.$$

The basic equation system consists of (17) and the three share equations in (18). A classical disturbance term is also appended to each equation in (17) and (18) to reflect nonsystematic errors in optimization as opposed to systematic deviations from the optimization conditions in (2) which are captured by the k_i. The equations are nonlinear in parameters and are estimated using full information maximum likelihood (FIML).[4,5]

Application to the California Cotton Ginning Industry

California is the second-largest producer of cotton in the United States, accounting for about 25% of the U.S. production. The major producing region is the San Joaquin Valley (SJV). During our study period, the 1980–81 to 1984–85 ginning seasons, California had about 3,000 cotton producing farms. Most of the farms were sole proprietorships or closed corporations with an average size of 270 acres compared to a national average of 110.

The ginning process separates the cottonseed from the lint. A typical ginning facility includes a storage yard, a business office, and the gin structure, consisting of a concrete slab, gin equipment, and a building. The equipment transports the raw cotton by air flow through the gin, dries it using natural gas or propane, removes stems, leaves, dirt, and other trash, separates the lint from the cottonseed, further cleans the lint, and compresses it into 500-pound bales. Gin plant capacities currently range from 10 to 40 bales per hour.

The SJV cotton is ginned through any one of about 35 cooperatives, two privately held corporations which operate multiple facilities, or several grower-owned, nonco-op facilities. The co-op normally is given title to the cottonseed as payment for the ginning service. Seed revenues always exceeded ginning costs in our sample, with the surplus receipts returned to growers in accord with standard co-op practice. The grower retains title to the lint. None of our tests are dependent upon the specifics of the cooperatives' methods of payment to growers. Rather, tests are based on the cooperatives' level of raw product input (H_0) and the use of capital, labor, and energy inputs relative to their market prices and the market prices for the baled cotton and cottonseed (H_1, H_{1a}, H_{1b}, H_2, and H_3).

Variable Measurement and Data Sources

Twenty-two SJV ginning cooperatives contributed financial and operations data for the 1980–81 to 1984–85 ginning seasons. Labor expenditures for each gin were measured as the sum of its annual direct and indirect expenditures (e.g., payroll taxes and fringe benefits) for full- and part-time employes. The wage rate, W_L, for each gin was computed by dividing its labor expenditures by the annual hours worked (including overtime) by the gin's full- and part-time employes.

Energy expenditures for each gin were the sum of its annual expenditures for electricity, natural gas, and/or propane. BTU prices were computed from the gin's utility rate schedules and aggregated into a single BTU price, W_E, for each gin using BTU quantity weights for each energy source.[6]

Ginning equipment (G) and buildings (B) comprised the capital stock. Each was measured using the perpetual inventory method:

$$K_{it} = I_{it} + (1 - \theta_i)K_{i,t-1}, \qquad i = G, B,$$

where K_{it} is the real end-of-year stock, I_{it} is the quantity of real investment during the year, and θ_i is the rate of replacement. The K_{it} and I_{it} were obtained from each gin's financial statements, and based on industry opinion, we used $\theta_i = 1/T_i$, where T_i is the asset's service life set at 15 (25) years' life for equipment (buildings). None of the paper's results are sensitive to the choice of depreciation rate used in either the perpetual inventory or capital rental price formulas.[7]

[4] Nonzero covariances between cross-equation disturbances for each observation are to be expected. An iterative Zellner-efficient (seemingly unrelated regression) estimation methodology is, thus, appropriate. In this case, maximum likelihood estimation is equivalent to Zellner-efficient estimation (Oberhofer and Kmenta).

[5] Our estimation methodology assumes that the k_i are constant parameters across observations. Given our short time series and homogeneous cross section of gins, this standard assumption seems reasonable. If necessary, the k_i could be allowed to differ across observations using dummy variables or a random coefficients approach.

[6] Natural gas and electricity were supplied to the gins by either of two utilities. Moreover, some gins served by the same utility were on different rate schedules. These facts, the additional fact that some gins use natural gas while others use propane, and the gin-specific weights attached to the individual energy source prices all introduce cross-sectional as well as intertemporal variation in W_E.

[7] To test for possible sensitivity of results to the choice of $\theta_i = 1/T_i$, all estimation was reconducted using double-declining balance depreciation, $\theta_i = 2/T_i$. These results were very similar to those reported here and yielded identical conclusions concerning the hypothesis tests.

Dollar value of investment data obtained from each gin was converted to the quantity measure, I_{it}, by dividing by real purchase prices per bale of ginning capacity per hour. Current purchase prices, q_t, for various capacity gins were obtained directly from a leading gin manufacturer and projected to earlier years using the relevant producer price indexes. Capital stock for the base year, 1980, was obtained via the procedure described by Stevenson (p. 168).

The capital rental price, W_K, was obtained using the Christensen-Jorgenson (p. 304) formula:

$$W_{it} = [1 - U_t Z_{it} - V_t + b_t V_t U_t Z_{it}] \\ [q_{i,t-1} r_t + q_{it}\theta_i - (q_{it} - q_{i,t-1})] \\ - d_t q_{it}, \qquad i = G, B,$$

where U_t is the average marginal income tax rate for the co-op members,[8] Z_t is the present value for tax purposes of one dollar of depreciable investment,[9] V_t is the 10% investment tax credit (ITC), and $b_t = .5$ for 1984, 1985; $b_t = 0$ for 1981–83 so that $b_t V_t U_t Z_t$ reflects reduction in the depreciable base by half the ITC in 1984, 1985. The q_{it} are the real purchase prices for gin capacity discussed previously; r_t is the cooperatives' opportunity cost of capital set equal to the Sacramento Bank for Cooperatives average term lending rate for each year; θ_i are the real depreciation rates discussed earlier; $(q_{it} - q_{i,t-1})$ measures capital gain or loss on the asset; and d_t is the property tax rate, effectively 1% in California.

Expenditures for each capital asset, G and B, were measured as the product of the stock and the rental rate and then summed to obtain total capital expenditures. The overall capital rental price, W_K, for each gin was obtained using an expenditure weighted average of the gin's rental prices for buildings and equipment.

The output price per bale for cotton was computed as

$$P_t = P_{Ct} + \phi_t P_{St},$$

where P_C is the price per 500-pound bale of lint, P_S is the price per ton of cottonseed, and ϕ is the ratio of tons of seed per 500-pound bale of lint. Specifically, P_C was the annual price paid to SJV growers for the Valley's predominant SLM ("Strict Low Middling") grade of lint by Calcot, Ltd., the marketing cooperative which handles 48% of the California–Arizona lint cotton sales; P_S was computed for each gin as its annual net payment per ton of clean seed from Ranchers Cotton Oil, the federated seed marketing cooperative in which nearly all SJV co-op gins are members. Cross-sectional and time-series variation is present in P_S and ϕ due to quality differences in the raw cotton, while P_C varies only intertemporally.

Gross annual revenues are the product of P_t and the annual bale production. Gross operating profit is the gross revenues less the expenditures on labor, energy, and capital. Sample means for these financial variables were labor expenditure, \$412,000; capital expenditure, \$364,000; energy expenditure, \$254,000; lint revenue, \$2,808,000; and seed revenue, \$2,180,000.

Estimation

In estimating the system, {0,1} dummy variables $D81$–$D84$ were added to (17) to account for possible year-to-year shifts in the profit function due to exogenous factors such as growing conditions. The augmented intercept to (17) is, thus, $a_0 + d_1 D81 + d_2 D82 + d_4 D84$, where d_1, d_3, and d_4 are parameters.[10] Because the dummy variables are assumed to affect only the intercept of the profit function, they do not enter into the share equations.

FIML parameter estimates for the unrestricted profit function and input share system are reported in table 1. Most of the estimated parameters are statistically significant and the model's overall explanatory power is very high (pseudo $R^2 = .9999$).[11]

A well-behaved normalized profit function must be decreasing and convex in the normalized input prices. The first property is sat-

[8] Income acquired by cooperatives is taxable to the members. Since nearly all California cotton farms are sole proprietorships, partnerships, or closed corporations, we used the annual mean marginal U.S. income tax rate for individual returns to represent U. Failure of the IRS to provide farm tax return data apparently precludes doing any better.

[9] Nearly all of the ginning co-ops used straight-line depreciation for tax purposes with tax lives (T_i) of 12 (25) years for equipment (buildings). Hence, $Z_{it} = (1/r_t T_i)[1 - (1/(1 + r_t)^{T_i}]$ (Christensen and Jorgenson).

[10] The 1983 ginning season was deleted from the sample because PIK-program-inspired reductions in cotton acreage plus abnormally low yields on the planted acreage dramatically reduced throughput (more than 50% in many cases) for the SJV gins.

[11] The pseudo R^2 (Berndt and Khaled) is calculated as $1 - \exp[2(L_R - L_U)/T]$ where L_R is the maximum value of the log likelihood function when the coefficients on all right-hand side variables are constrained to be zero, L_U is the value of the log likelihood function for the unrestricted model, and T is the number of observations.

Table 1. Maximum Likelihood Estimation Results

Parameter	Estimated Coefficient	Absolute Asymptotic *t*-Statistic
α_L	−0.0357	5.752
α_K	−0.0034	3.085
α_E	−0.0120	0.984
γ_{LL}	−0.0048	4.958
γ_{KK}	−0.0009	6.648
γ_{EE}	−0.0239	12.558
γ_{LK}	0.0006	6.208
γ_{LE}	−0.0051	3.973
γ_{KE}	−0.0009	3.361
δ_R	0.9943	56.834
β_{RR}	−0.0011	0.603
β_{RL}	0.0041	4.693
β_{RK}	0.0005	3.829
β_{RE}	0.0071	6.592
D_{81}	0.0016	1.645
D_{82}	0.0018	1.701
D_{84}	0.0025	2.103
k_L	0.1182	4.837
k_K	0.0165	6.208
k_E	0.5205	27.775
Constant	0.0148	0.173
Pseudo R^2	.9999	

isfied if the fitted expenditure shares are positive, while convexity is met if the Hessian matrix of partial derivatives, $\partial^2\pi_a/\partial w_i\partial w_j$, $i, j = L, E, K$, is positive definite. The monotonicity property was satisfied for each observation in the sample, while convexity was satisfied at the data means and also for the majority of individual observations.

Turning to tests of the hypotheses set forth earlier, the individual k_i were significantly less than one in each case. To formally test the joint hypothesis, H_1: $k_L = k_E = k_K = 1$, the equation system was reestimated excluding the k_i. The resulting model is the ordinary normalized translog profit function system.

The test statistic for H_1 is the likelihood ratio test, $-2(L_R - L_U)$, where $L_R(L_U)$ is the maximum value of the log likelihood function for the restricted (unrestricted) model. The test statistic is asymptotically distributed as χ^2 with degrees of freedom equal to the number of restrictions. H_1 imposes three restrictions and, as the calculations in table 2 indicate, was strongly rejected at the .01 level. However, the relative efficiency hypothesis,

$$H_{1a}\colon k_L = k_K = k_E,$$

which imposes two restrictions, was not rejected by the data (table 2). Also tested and rejected was the hypothesis that the behavioral profit function, equation (15), was Cobb-Douglas, i.e., that coefficients for the nine cross-product terms in (15) were all zero.

Table 2. Tests of Hypothesis

	Cobb-Douglas Form	Absolute Price Efficiency	Relative Price Efficiency
Number of Restrictions	9	3	2
Test Statistic	168.0	212.84	0.14
χ^2 Critical Value .01 Level	21.67	11.34	9.21

Thus, given rejection of H_1, we conclude that the ginning cooperatives in our sample did not exhibit absolute price efficiency, tending on average to overutilize variable inputs, including capital (H_2), relative to their optimal levels. Failure to reject H_{1a} indicates, however, that we cannot conclude that the sample cooperatives either under- or overutilized capital relative to the other variable inputs, labor and energy. In particular, because the tests of relative efficiency between specific pairs of k_i are conditional upon rejection of H_{1a}, the hypotheses H_{1b} and H_3 cannot be rejected either.

To interpret these results, note that the unknown cotton ginning technology approximated by the translog must exhibit nearly quasi-fixed proportions in that little substitution is possible between R and the other inputs, although L, E, and K may be somewhat substitutable among themselves.

Since R is treated as given by the co-op gins, its level, along with the prices for the other variable inputs, enters the marginal-revenue-product function for any variable input, say L:

$$MRP_L = MRP_L(L, w_E, w_K, R).$$

If the technology were exactly quasi-fixed proportions, i.e., if

$$Y = \min\{R/\psi, h(L, E, K)\},$$

where ψ is the fixed conversion factor between raw cotton and the composite cotton/seed output, Y, then MRP_L must fall discontinuously to zero at the employment level where $Y = R/\psi$.

Although minor substitution between R and the variable inputs may be possible, the marginal revenue products for L, E, and K must decline rapidly near the point where $Y = R/\psi$

so that even small absolute errors in factor employment may become manifest in very small values for the k_i as were observed in our analysis.

As to capital usage, our results contradict the common presumption that cooperatives will underutilize captial, tending instead to support the Caves and Peterson hypothesis that capital may be absolutely overutilized. In this regard, our sample gins generally met the four necessary conditions to induce the Caves and Peterson hypothesis.

A referee has suggested that perishability of cotton makes timely ginning important to preserve quality. What would appear to be excessive use of capital and other inputs may, therefore, be a rational response to perishability. This point is undoubtedly valid for many agricultural products, but perishability concerns are limited in our application because over half of SJV cotton is harvested in nonperishable modules.

Analyzing cooperatives' behavior along the *NARP* and specifically, H_o in (8), entails computation and examination of the elasticity, $\epsilon_{\pi,R}$, of profit with respect to the cotton input. Two measures of $\epsilon_{\pi,R}$ are relevant. The actual elasticity, $\epsilon_{\pi_a,R}$ is computed from the actual profit function, π_a, in (17):

$$\begin{aligned}\epsilon_{\pi_a,R} &= \frac{\partial \ln \pi_a}{\partial \ln R} \\ &= \frac{1}{\Phi}\left[\sum_j \frac{(1-k_j)}{k_j}\beta_{Rj}\right] \\ &\quad + \delta_R + \beta_{RR}\ln R \\ &\quad + \sum_j \beta_{Rj}\ln(k_j w_j), \\ j &= L, E, K,\end{aligned}$$

where Φ is the term in curly brackets in (17).

However, producer behavior is based not on π_a but on π_b, the behavioral function in (15) and the shadow prices, $\boldsymbol{kw}$, where our earlier results for the k_j reject the hypothesis that π_a and π_b are the same function. Computing the behavioral elasticity from (15) obtains

$$\begin{aligned}\epsilon_{\pi_b,R} &= \partial \ln \pi_b / \partial \ln R \\ &= \delta_R + \beta_{RR}\ln R + \sum_j \beta_{Rj}\ln(k_j w_j), \\ j &= L, E, K.\end{aligned}$$

$\epsilon_{\pi_a,R}$ and $\epsilon_{\pi_b,R}$ were computed for each sample observation. The first three rows of table 3 report the minimum, mean, and maximum of these elasticities. The fourth row reports the elasticities evaluated at the means of the data.

Examination of the elasticities proves to be quite illuminating. Previous studies of the ginning technology using economic engineering methods (Shaw, Cleveland, and Ghetti) have indicated the presence of pervasive size economies or, in the terminology of this paper, an upward-sloping *NARP* curve. Our results confirm this finding in that the mean value of the actual elasticity $\epsilon_{\pi_a,R}$ is nearly 1.10 and is quite stable across the range of the data.

However, the behavioral elasticities $\epsilon_{\pi_b,R}$ were very nearly unitary for each observation, ranging from 1.0052 to 1.0139. Because the behavioral elasticities reflect actual decision making, they are the appropriate elasticities to examine the unitary elasticity hypothesis, H_0. However, the $\epsilon_{\pi_b,R}$ formula is a nonlinear function of the estimated parameters and exogenous variables, and its statistical properties are unknown.

An approximate variance for $\epsilon_{\pi_b,R}$ is obtained by linearly approximating the elasticity formula using a first-order Taylor's series expansion and then using the standard variance formula for linear functions. The resulting standard error, $SE[\epsilon_{\pi_b,R}] = .0042$, is appropriate to test H_0 at the point of means only if $\epsilon_{\pi_b,R}$ is distributed normally. Unfortunately, there is no basis to justify this assumption in the small sample case. Moreover, simulation methods proposed to address the problem (Krinsky and Robb) do not work in our application.[12] Thus, although we are unable to conduct a formal test of H_0, the qualitative closeness of the behavioral elasticities to unitary (e.g., a doubling of gin size is predicted to raise profits by less than 101% at the means) leads us to conclude that the results are consistent with the game theory hypothesis that multico-op environments must be characterized by each association operating very near the maximum behavioral *NARP*.

In this sense our results both confirm the existence of actual size economies in the industry and explain producers' observed reluctance to consolidate gins; economies of size are not important when evaluated at decision makers' $\boldsymbol{kW}$ shadow prices.[13]

[12] The Krinsky and Robb method involves conducting random draws of new parameters from a multivariate normal distribution. Because our model involves the logarithms of estimated parameters, the procedure aborts if the algorithm chooses negative values for those parameters.

[13] The spatial costs of transporting cotton from the farm to the gin also likely play a role in this regard.

Concluding Remarks

This study's objective has been to set forth and apply an econometric methodology to test key hypotheses that have emerged from the extensive theoretical literature on the economics of cooperatives.

Our empirical results have indicated that San Joaquin Valley cotton ginning cooperatives tended to overemploy variable inputs including capital relative to the levels obtained from equating marginal revenue products with input prices. These results, thus, lend some support to the hypothesis that the co-op organizational form may encourage allocative inefficiency, but they reject the argument that cooperatives will tend to underutilize capital.

Although actual economies of size apparently exist in the ginning industry, our estimates of the behavioral elasticities of profit with respect to cotton input were nearly unitary across observations. These results imply that the gins were all located very near the maximum of a flat-topped behavioral *NARP* curve, a finding consistent with the game theory model of cooperation and with the behavioral implications of Clark's much earlier work.

Leamer has noted that the strength of inferences such as these hinges upon their invariance to changes in model specification. Pratt and Schlaifer have focused in particular on the inconsistency of estimates caused by omission of concommitant variables (covariates).

We believe our results stand up quite well to these critiques. The profit function formulation has strong theoretical underpinnings, and the translog specification is designed to minimize the judgmental assumptions that concern Leamer. Theory also offers strong guidance in variable selection for the profit function, namely input and output prices and quantities of fixed inputs. Have important variables been excluded? Land requirements for gins are inconsequential. Other possible inputs such as bags and ties for the processed cotton must be nearly perfectly collinear with the level of raw cotton. Where specific judgmental assumptions were necessary, e.g., choice of depreciation formulas, we have attempted to conduct the sensitivity analysis requested by Leamer, and our results have been unaffected.

A single test of the hypotheses examined here cannot be considered conclusive evidence, however, and we hope the methodology will stimulate further inquiry into the behavioral implications of cooperative theory. An important asset of the methodology is that it enables relevant firm-level analysis of cooperatives to proceed without necessitating accompanying data for comparable noncooperative enterprises. Although such comparisons are certainly useful, finding market environments containing large numbers of both types of organizations and obtaining the requisite disclosure of proprietary data severely limit opportunities to conduct such analyses. Finally, because our approach is designed to isolate allocative inefficiencies and examine economies of size, it has prospective value as a normative tool to promote improved economic performance of marketing cooperatives.

Table 3. Elasticities of Normalized Profit with Respect to Raw Cotton Input Supply

	Profit Function	
	Behavioral	Actual
Minimum	1.0052	1.0806
Mean	1.0095	1.0968
Maximum	1.0139	1.1172
Data Means	1.00945	1.0964

[*Received March 1988; final revision received October 1988.*]

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