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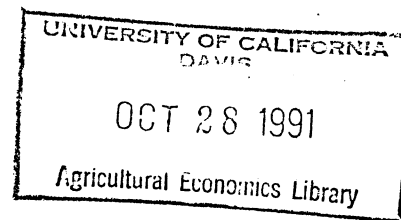
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Imperfect competition in multiproduct  
food industries with application to  
pear processing

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## IMPERFECT COMPETITION IN MULTIPRODUCT FOOD INDUSTRIES WITH APPLICATION TO PEAR PROCESSING

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## IMPERFECT COMPETITION IN MULTIPRODUCT FOOD INDUSTRIES WITH APPLICATION TO PEAR PROCESSING

Evidence on food industry market structure suggests that many food product markets are not perfectly competitive (Connor et al., Just and Chern, Schroeter). Many food processing industries comprise relatively few processors who purchase a raw farm product from many local producers and transform it usually into multiple product forms and then sell to a number of consumers. Such an industry structure may result in imperfect competition on both the buying and selling sides of the market. Attendant impacts include distorting the farm-retail margins for food, thus affecting the welfare of both farmers and consumers.<sup>1</sup>

This study attempts to improve understanding of market behavior in food processing by developing and estimating a generalized market model of farm-retail price spread determination that reflects the key structural characteristics of agricultural markets. The model assumes the existence of an identifiable raw product input market and allows for multiple processed product output markets and for imperfect competition in both the output markets and raw product input market.

A key feature of the model is its ability to distinguish input market power from output market power based on the assumption that there exists a perfectly competitive "benchmark" processed product form. The marketing margin for the benchmark product can be used to estimate input market (oligopsony) power. Oligopoly power in the other processed product

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<sup>1</sup>Although most studies of market power in the food industries have analyzed developed economies such as the U.S., Canada (Lopez), and the United Kingdom (Borooah and Van Der Ploeg), the exercise of oligopsony power in raw product input markets is likely to be even more pervasive in developing countries. See, for example, Lopez and Dorsainvil.

markets can be estimated by comparing the margin for these products with the margin for the benchmark product.

The California pear processing industry was chosen for application of the conceptual model. Estimation results indicate that this industry has exercised market power in both its farm input market and the markets for canned pears and fruit cocktail.

### PRIOR WORK

Prior to 1980 analyses of market power in the food industries were generally based upon the structure-conduct-performance paradigm pioneered by Bain. These studies usually involved interindustry analyses of profitability or price-cost margins as functions of concentration ratios and other structural measures. This work is aptly summarized in Connor et al. Modern variations on this theme specify models to explain price (not profits) as a function of market structure variables and usually focus on the behavior of single industries. Recent studies by Cotterill (Vermont grocery retailing) and MacDonald (rail shipping) illustrate this approach.

The present study is in the evolving tradition of what has become known as NEIO, the new empirical industrial organization (Bresnahan). NEIO studies usually focus on a single industry and involve econometric estimation of firm or industry marginal cost and conduct parameters. A cornerstone methodology of the NEIO analyzes firm or industry conduct through the estimation of conjectural elasticities. In a model with quantity-setting firms, these elasticities are computed as  $\theta^i = (\partial Q / \partial q^i)(q^i / Q)$ , where  $Q$  denotes industry output and  $q^i$  is output by the  $i^{\text{th}}$  firm in the industry. When given a literal interpretation  $\theta^i$  is said to measure the firm's

expectation of the percentage industry output change in response to its own output change.<sup>2</sup>

The initial applications of the conjectural variations framework were concerned exclusively with oligopoly power and included studies by Gollop and Roberts, Appelbaum (1979, 1982), and Roberts. The fundamental approach to these studies involved estimating  $\theta^i$  (or an industry-wide counterpart) as part of a system model consisting of consumer demand and firm or industry supply and factor demand behavior derived from profit maximization conditions.

As noted, the structural characteristics of many raw agricultural product markets also suggest the possible exercise of oligopsony power by handlers. For example, due to the bulkiness and perishability of many raw products, transportation cost considerations dictate that raw product markets are geographically local or regional in scope and, hence, more highly concentrated than comparable markets for the finished products. The conjectural variations framework was first extended to consider the joint exercise of oligopoly and oligopsony power in Schroeter's study of the U.S. beef industry. An important limitation of Schroeter's analysis was the assumption that conduct as measured by the conjectural elasticity was identical in the raw product (input) and processed product (output) markets. This same restriction applies to the extension of Schroeter's work to the multiproduct case (beef and pork) by Schroeter and Azzam.

The technical reasons for Schroeter's and Schroeter and Azzam's identical conjecture assumption are worth noting. Within the dual cost function framework introduced into this field by Appelbaum, behavior in individual input markets cannot be distinguished unless the cost function is made separable in some of the inputs through invoking a fixed proportions

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<sup>2</sup>As Karp and Perloff have noted, use of the conjectural variations framework does not compel the interpretation of  $\theta^i$  as an actual "conjecture." Rather,  $\theta^i$  may be interpreted simply as an index of market structure.

assumption on the production technology. This assumption, however, makes it impossible in the Schroeter and Schroeter and Azzam formulations to distinguish behavior in the input market from the output market, i.e., the conjectural elasticities are necessarily the same.

Because the geographical scope of raw and processed agricultural products differ significantly in most instances, the identical conjectures feature is a significant restriction and led Azzam and Pagoulatos to suggest resolution of the problem through adopting a primal production function framework. Here individual inputs are distinguished in the first order profit maximization conditions and no fixed proportions assumption is needed. Other problems, however, arise with this formulation; first, it may not be possible to analyze multiple products with a production function formulation.<sup>3</sup> Second, econometric considerations usually favor the dual over the primal formulation of production behavior.<sup>4</sup>

The goal of the present paper is to extend the methodologies described here to permit the analysis of market power in both multiple processed product and raw product markets. The model developed in the next section accomplishes this objective by returning to a cost function specification of technology and invoking two key assumptions that are reflective of many agricultural product industries: (1) fixed proportions exist between raw and processed product(s), and (2) at least one product market can serve as a competitive benchmark.

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<sup>3</sup>For example, in the Azzam and Pagoulatos study meat products are lumped into a single, aggregate product category.

<sup>4</sup>Binswanger lists six advantages to estimating cost versus production function parameters. Among these are that input prices (for processing inputs in our analysis) are properly treated as exogenous, whereas input quantities are usually endogenous, and that multicollinearity is likely to be less troublesome for input prices than input quantities.

## THE MODEL

Assume that a hypothetical food manufacturing industry processes a homogeneous farm product  $R$ . The farm input may be processed into multiple forms  $q = \{q_1, \dots, q_k\}$ , which may be sold in imperfectly competitive markets. Each of the product forms requires the material input in a fixed proportion, i.e.,  $q_j = \gamma_j R_j$ ,  $j = 1, \dots, k$ , where  $\gamma_j$  is the coefficient converting  $R_j$  amount of material input into  $q_j$  level of the  $j^{\text{th}}$  output.

The model is developed for the general case of  $k$  processed forms with the market for product 1 designated as the competitive benchmark. A representative firm's profit function is

$$(1) \quad \begin{aligned} \Pi^i = & P_1 \gamma_1 R_1 + \sum_{j=2}^k P_j(Q_1, Q_2, \dots, Q_k) \gamma_j R_j^i - C^i(q_1^i, \dots, q_k^i, w_m, F) \\ & - w^i(R^i, L(R^i)) R^i, \quad R^i = \sum_j R_j^i, \end{aligned}$$

where  $P_1$  is the parametric output price for product 1,  $Q_j$ ,  $j = 2, \dots, k$ , represents the industry output of product form  $j$ ,  $P_j(\cdot)$ ,  $j = 2, \dots, k$ , is the industry inverse demand function for product form  $j$ , and  $R^i$  is the total amount of the farm input used by the  $i^{\text{th}}$  firm in processing.

Given that processing inputs are assumed to be nonsubstitutable for the raw product, processing costs, represented by  $C(q_1^i, \dots, q_k^i, w_m, F)$  where  $w_m$  is a vector of variable input prices and  $F$  is a vector of fixed input quantities, are separable from raw product costs. These latter costs are modelled in a spatial market framework (Greenhut, Norman, and Hung, Sexton), where the raw product input "mill" price paid by the  $i^{\text{th}}$  firm,  $w^i$ , depends upon its level of purchases,  $R^i$ , and its market radius,  $L^i$ , which, in turn, depends upon  $R^i$  and rivals' reactions to the  $i^{\text{th}}$  firm's behavior.

The decision problem for the  $i^{\text{th}}$  processor is to determine the optimal allocation for the alternative uses of the raw farm product, i.e., to choose  $R_j^i$ ,  $j = 1, \dots, k$  in order to maximize (1). The first order condition for the benchmark product,  $q_1 = \gamma_1 R_1$ , can be rearranged to yield the following relative price-spread formulation:

$$(2) \quad \frac{\gamma_1(P_1 - C_1) - w^i}{w^i} = \left( \frac{R^i}{w^i} \right) \left( \frac{dw^i}{dR^i} \right) = \eta_{w^i, R^i},$$

where  $C_j$ ,  $j = 1, \dots, k$  denotes marginal costs for processing the  $j^{\text{th}}$  product form. Equation (2) states that the relative markup after adjusting for processing costs for the competitive benchmark product equals the firm's perceived total flexibility of raw product price with respect to its volume of raw product purchases. Through total differentiation, the flexibility,  $\eta_{w^i, R^i}$ , is shown in Sexton to be expressible as

$$(3) \quad \eta_{w^i, R^i} = \epsilon_{w^i, R^i} + \eta_{w^i, L^i} \cdot \eta_{L^i, R^i},$$

where  $\epsilon_{w^i, R^i} = (\partial w^i / \partial R^i)(R^i / w^i)$  is growers' price flexibility of supply for the raw product,  $\epsilon_{w^i, L^i} = (\partial w^i / \partial L^i)(L^i / w^i)$  measures the response of the firm's mill price,  $w^i$ , to its market radius, and  $\eta_{L^i, R^i} = (dL^i / dR^i)(R^i / L^i)$  measures the firm's conjecture of the response of its market area to its change in output.<sup>5</sup> Sexton shows that  $\epsilon_{w^i, L^i} < 0$  in all cases<sup>6</sup> and that  $\eta_{L^i, R^i}$  is the key

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<sup>5</sup>Specification of input market power in a spatial markets context reflects the perception that spatial factors are often the genesis of input market power. However, the model does not depend upon this formulation. Raw product supply could be specified merely as a general function  $w(R)$ , where  $R$  is aggregate raw product volume purchased in the market. Then first order conditions for the benchmark product could be stated simply as

$$\partial \pi / \partial R_1^i = \gamma_1 P_1 - c_1 - w^i - R^i (\partial w / \partial R) (\partial R / \partial R^i) = 0,$$

where  $(\partial R / \partial R^i)(R^i / R)$  would denote the conjectural elasticity in the raw product market.

<sup>6</sup>The intuition for this result is that larger market areas decrease competition among processors and, hence, reduce the equilibrium price paid for the farm product.



determinant of competitiveness in the raw product market. For example, if  $\eta_{Li,Ri} = 0$ ,  $\eta_{wi,Ri} = \epsilon_{wi,Ri}$ , the growers' supply flexibility, and processing firms can act as monopsonists within their market areas (Greenhut, Norman, and Hung).  $\eta_{wi,Ri} = 0$  corresponds to the competitive case. That is, the firm perceives no effect from its purchase quantity,  $R^i$  on the raw product price,  $w^i$ , it pays. Thus, in general,  $\eta_{wi,Ri} \in [0, \epsilon_{wi,Ri}]$ .<sup>7</sup>

The first-order conditions to (1) for the  $k-1$  nonbenchmark product forms can be arranged in elasticity form to yield the following relative price-spread formulations:

$$(4) \quad \frac{\gamma_j(P_j - C_j) - w^i}{w^i} = \eta_{w^i,R^i} - \frac{P_j \gamma_j}{w^i} \theta_j^i \left( \eta_{P_j, Q_j} + \sum_{\substack{m=2 \\ m \neq j}}^k \frac{S_m^i}{S_j^i} \eta_{P_m, Q_j} \right) + \frac{P_j \gamma_j}{w^i} \left( \sum_{m=2}^k \frac{S_m^i}{S_j^i} \sum_{\substack{s=2 \\ s \neq j}}^k \eta_{P_m, Q_s} \theta_{sj}^i \right), \quad j=2, \dots, k.$$

In (4)  $\eta_{P_j, Q_j}$  is the inverse market demand elasticity (price flexibility) for product form  $j$ ,  $j = 2, \dots, k$ ,  $\theta_j^i = (dQ_j/dq_j^i)(q_j^i/Q_j)$  is the  $i^{\text{th}}$  firm's quantity conjectural elasticity for product  $j$ ,  $j = 2, \dots, k$ . If an output market is competitive, a change in the firm's output level will not induce any net change in market quantity; hence,  $\theta_j^i = 0$ , which is the case for the benchmark product. In contrast to perfect competition,  $\theta_j^i$  is unity for a pure monopoly ( $q_j^i = Q_j$ ). Therefore,  $\theta_j^i \in [0, 1]$ , and its value can be estimated empirically for testing market structure. Notice in the multiproduct case that the effect of  $\theta_j^i$  on the price spread depends not only on the own price flexibility,  $\eta_{P_j, Q_j}$ , but also on the share-weighted cross price flexibilities,  $\eta_{P_m, Q_j}$ ,  $m \neq j$ .

<sup>7</sup>The values of  $\eta_{Li,Ri}$  and  $\eta_{wi,Ri}$  for "intermediate" modes of competition including Cournot and Bertrand (Hotelling-Smithies) competition are developed in Sexton.

The final set of terms in (4) measure cross price effects, i.e., the manner in which production changes for product  $j$  influence production of other product forms  $s \neq j$ . In particular,  $S_j^i$  is the firm's revenue share for product  $j$  and  $\eta_{P_m, Q_s}$  is a cross price flexibility measuring the price response of product form  $m$  to a change in production of product form  $s$ . Finally, the  $\theta_{s,j}^i = (\partial Q_s / \partial q_j^i)(q_j^i / Q_s)$  are cross-product conjectural elasticities which, interpreted literally, measure the  $i^{\text{th}}$  firm's expectation of the percentage response of output in product form  $s$  due to a percentage change in its output of product form  $j$ .

To evaluate behavior for the nonbenchmark products relative to the benchmark merely requires substituting (2) into (4) to obtain:<sup>8</sup>

$$(5) \quad \frac{\gamma_j P_j - \gamma_1 P_1}{\gamma_j P_j} = \frac{\gamma_j C_j - \gamma_1 C_1}{\gamma_j P_j} - \theta_j^i \left( \eta_{P_j, Q_j} + \sum_{\substack{m=2 \\ m \neq j}}^k \frac{S_m^i}{S_j^i} \eta_{P_m, Q_j} \right) + \sum_{m=2}^k \frac{S_m^i}{S_j^i} \sum_{\substack{s=2 \\ s \neq j}}^k \eta_{P_m, Q_s} \theta_{s,j}^i, \quad j = 2, \dots, k.$$

Equation (5) indicates that after adjusting for processing cost differentials, markups of

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<sup>8</sup>Because the sums and double sums in (4) and (5) have the potential to be confusing, we present (5) for product form 2 for the case of  $k=4$  with product 1 as the competitive benchmark:

$$\begin{aligned} \frac{\gamma_2 P_2 - \gamma_1 P_1}{\gamma_2 P_2} = & \frac{\gamma_2 C_2 - \gamma_1 C_1}{\gamma_2 C_2} - \theta_2^i \left( \eta_{P_2, Q_2} + \frac{S_3^i}{S_2^i} \eta_{P_3, Q_2} + \frac{S_4^i}{S_2^i} \eta_{P_4, Q_2} \right) \\ & + \frac{S_2^i}{S_2^i} (\eta_{P_2, Q_3} \theta_{3,2}^i + \eta_{P_2, Q_4} \theta_{4,2}^i) + \frac{S_3^i}{S_2^i} (\eta_{P_3, Q_3} \theta_{3,2}^i + \eta_{P_3, Q_4} \theta_{4,2}^i) \\ & + \frac{S_4^i}{S_2^i} (\eta_{P_4, Q_3} \theta_{3,2}^i + \eta_{P_4, Q_4} \theta_{4,2}^i). \end{aligned}$$

nonbenchmark products over the benchmark are due to oligopoly power in the nonbenchmark markets as measured by the last two sets of terms on the right-hand side of (5).

Notice that in the presence of imperfect competition, consideration of impacts among multiple processed products is likely to raise the price spread. In particular, most processed products from a given raw product are likely to be substitutes, so  $\eta_{pm,Qj} < 0$  in (5). Moreover, if higher output and, hence, lower prices for a given product  $j$  results in greater output of competing product forms,  $\theta^i_{s,j} > 0$ , causing the second term in curly brackets in (5) to be negative and also contribute to a greater margin.

Equations (2) and (5) together provide a complete base for testing the presence of competitive behavior/market power of processing firms in both the input and output markets. The processor possesses market power in the raw product market if the hypothesis

$$H_0: \eta_{wi,Ri} = 0$$

is rejected. The presence of imperfect competition in the nonbenchmark output markets can be examined by testing the hypotheses

$$H_j: \theta_j = 0, j = 2, \dots, k.$$

### *Aggregation Issues.*

Some applications of the conjectural elasticity methodology have utilized cross-sectional, firm-level data (Gollop and Roberts, Roberts). This type of data will most often be unavailable, however, and analyses must proceed with time series data aggregated to the industry level (Appelbaum 1982, Schroeter, Schroeter and Azzam, Azzam and Pagoulatos). The application to pear processing in this study is facilitated by the availability of time series cost data calculated as a weighted average across firms in the industry for each year. (The data are discussed in

detail later in the paper.) Therefore, empirical results in this paper may be interpreted to apply directly to the behavior of an average firm in the industry--the interpretation preferred by Bresnahan (p. 1030).

Most applications will, however, have to proceed with aggregate data, and it is useful, therefore, to consider the problems presented by aggregation in the multiproduct case. It is well known that for cost and factor demand functions to be well-defined at the industry level, it is necessary that the firm-level cost functions be of the Gorman polar form (Appelbaum) with constant and identical marginal costs but fixed costs which may vary among firms. A further assumption necessary in the multiple products case is nonjointness in production (Hall, Schroeter and Azzam), which implies that the marginal costs for a given product  $j$  are unaffected by the production level of other products  $i \neq j$ .

The remaining aggregation problem in the multiple products model concerns interpretation of the conjectural elasticities. Schroeter and Azzam suggest a procedure whereby the aggregate industry conjectural elasticity is derived as a quantity-share weighted average of individual firm conjectures. The Schroeter and Azzam procedure calls for multiplying (5) through by  $q_j^i$ , summing over  $N$  firms in the industry, and dividing the result by industry output,  $Q_j$ . To illustrate a problem with this approach, let  $j=2$  and  $k=3$ , with product 1 again acting as the benchmark. Schroeter and Azzam's aggregation procedure then implies

$$(6) \quad \theta_2 = \sum_{i=1}^N \frac{q_2^i \theta_2^i}{Q_2} = \sum_{i=1}^N \frac{q_3^i \theta_2^i}{Q_2},$$

$$(7) \quad \theta_{3,2} = \sum_{i=1}^N \frac{q_2^i \theta_{3,2}^i}{Q_2} = \sum_{i=1}^N \frac{q_3^i \theta_{3,2}^i}{Q_2}.$$

Inspection of (6) and (7) reveals that consistent aggregation is assured to hold only if each firm's share is identical across product forms or if all firms entertain the same conjectures.<sup>9</sup> The first condition is unlikely to hold exactly but may be an acceptable approximation in some cases. The second condition was argued to hold *ex post* by Appelbaum, who was criticized for this position by Bresnahan, who argued that firms would normally not exhibit the same conduct. Bresnahan is correct on this point, and it has been adopted by the most recent work in this field (Schroeter and Azzam, Azzam and Pagoulatos).

Nonetheless Appelbaum is correct logically for the case when firms produce homogeneous products and, hence, face identical prices and have identical marginal costs. That is, when these conditions hold, optimizing behavior compels that *ex post* firms' conjectures are identical. Because aggregation of costs to the industry level entails assuming constant and identical marginal costs across firms, as in Schroeter and Azzam and Azzam and Pagoulatos, the assumption of identical conjectures in equilibrium is achieved at no additional cost in generality.

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<sup>9</sup>Equations (6) and (7) also indicate a methodological issue to be clarified regarding the construction of aggregate models for the multiproducts case. Because the aggregate conjecture is defined as the share-weighted average, the aggregate quantity ratio  $Q_3/Q_2$  should not appear in the estimating equations as in Schroeter and Azzam equations (21) and (22).

## THE CALIFORNIA PEAR PROCESSING INDUSTRY

The California pear processing industry reflects prototypical structural characteristics of modern food processing; a large number of pear growers (over 1,100 in 1987) sell their products to relatively few pear processors, who transform raw pears into various processed forms including grade pack pears (25-40% of total production), fruit cocktail (40-60% percent of total production), mixed fruits, fruit salad, baby food, and juiced pear products. California produced about 60% of the U.S. pear supply in the 1980s, followed by Washington and Oregon with average contributions of 26 and 13 percent, respectively. For previous work on the U.S. pear industry see O'Rourke and Masud and the references contained therein.

In California, pear processing is handled either by cooperatives or independent firms. Most of the processors are multiple product canners, often packing both pear halves and fruit cocktail. The number of pear processors in California has decreased from 26 firms in the early 1950s to 11 in the late 1980s. Presently, about two-thirds of California's canning pear tonnage is processed by two cooperatives. Most of the remaining one-third is purchased by three private firms (one of which is dominant) with the other six firms constituting a fringe, which processes substantially smaller amounts for either baby food, frozen pears or nectar.

The domestic market has been the primary outlet for U.S. canned pear products. Foreign sales now account for less than 1.0% of total grade pack pear movement. Annual exports of canned fruit cocktail have accounted for 10-20% of the total movements since World War II. Limited quantities of fresh pears have been imported into the U.S. annually, mainly to supplement domestic supplies during March-June, the off season for domestic pears.

For purposes of empirical analysis the California pear industry was assumed to produce three product forms, fresh pears, canned pears, and canned fruit cocktail, since other product forms are of minor importance. The market for fresh pears was considered to be the competitive benchmark market. California fresh Bartletts have been marketed by a relatively large number of handlers (over 20 packing houses in 1989), and none has had a dominant position in shipping fresh Bartletts.

### EMPIRICAL SPECIFICATION

The empirical model of the industry includes specifications for growers' raw product supply, market demand for processed products, and the relative margins separating raw pear prices from prices for the end uses. Time series data were collected for the years 1950-1986.

#### *Growers' Supply*

Variables used to explain intertemporal variations in Bartlett pear acreage (BA) were similar to those specified in the work on acreage response for the asparagus industry by French and Willet:

$$(8) \quad \ln BA_t = \alpha_0 + \epsilon_{R,w} \ln w_t + \alpha_1 \ln BA_{t-1} + \alpha_2 \ln RU_{t-7} + \alpha_3 \ln (RU_{t-7})^2 + \alpha_4 DR_{t-1} + \alpha_5 T,$$

where  $w_t$  is the average mill price received by California Bartlett pear growers,  $RU$  is the cash return to pear bearing acreage,  $DR$  is a dummy variable indicating years with serious pear decline (a disease), and  $T$  is a time trend. Pear trees usually begin bearing six years from planting, so current bearing acreage is assumed to depend on the return of the seventh previous year. The reciprocal of  $\epsilon_{R,w}$  is substituted into (3) for the growers' supply price flexibility,  $\epsilon_{w,R}$ .

### *Output Demand.*

As the analysis was conducted at the processor level, the relevant industry demand functions are the wholesale demands for canned pear products at the shipping point. Because export demand and government purchases have been very low relative to domestic consumption, they were treated as exogenous. The double-log inverse demand functions in (9) and (10) express the wholesale prices of canned pears ( $P_P$ ) and fruit cocktail ( $P_C$ ) as functions of quantities demanded for own product ( $Q_P$  or  $Q_C$ ) and substitutes ( $Q_C$  or  $Q_P$ ), U.S. per capita income ( $Y$ ), beginning stocks (PINV or CINV) and a time trend (T70) beginning in 1970 to capture the change in canned fruit consumption since the early 1970s (French and King):

$$(9) \quad \ln P_{Pt} = d_{10} + \eta_{PP,QP} \ln Q_{Pt} + \eta_{PP,QC} \ln Q_{Ct} + d_{11} \ln \text{PINV}_t + d_{12} \ln Y_t + d_{13} T70_t,$$

$$(10) \quad \ln P_{Ct} = d_{20} + \eta_{PC,QC} \ln Q_{Ct} + \eta_{PC,QP} \ln Q_{Pt} + d_{21} \ln \text{CINV}_t + d_{22} \ln Y_t + d_{23} T70_t.$$

### *Marketing Margins*

In addition to raw pears, labor ( $L$ ), sugar ( $S$ ), and canning material ( $M$ ) were assumed to be the variable inputs used in pear processing, and capital stock ( $K$ ) was assumed to be a fixed factor in the short run. Given that substitution elasticities in pear processing are believed to be low *a priori*, the generalized Leontief multiproduct cost function, known to perform well when substitution elasticities are low (Guilkey, Lovell, and Sickles), was chosen for the processing cost function:<sup>10</sup>

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<sup>10</sup>As noted, the empirical model applies to the weighted average firm in the industry. Superscripts to denote firms are omitted in this section to simplify notation.



$$\begin{aligned}
C_1(q_P, q_C, w_L, w_M, w_S, K) = & \sum_i^2 \sum_j^2 \sum_m^3 \sum_s^3 \beta_{ijms} (q_i q_j w_m w_s)^{1/2} \\
(11) \quad & + \sum_i^2 \sum_j^2 \sum_m^3 \beta_{ijmK} (q_i q_j w_m K)^{1/2} + \sum_i^2 \sum_j^2 \beta_{ijK} (q_i q_j)^{1/2} K \\
& + \sum_m^3 \beta_m w_m + \beta_K K + TREND \sum_i^2 \sum_m^3 \beta_{iim} q_i w_m + TREND \sum_i^2 \beta_{iTK} q_i K,
\end{aligned}$$

where subscripts  $i$  and  $j$  denote outputs  $P$  (canned pears) and  $C$  (fruit cocktail), and subscripts  $m$  and  $s$  stand for variable processing inputs  $L, M$ , and  $S$ . A time trend was added to  $C_1$  to serve as an indicator of technical change and to allow for variations in marginal cost over time. The symmetry restrictions,  $\beta_{ijms} = \beta_{jim s}$  for all  $i, j$ , and  $\beta_{ijms} = \beta_{ij sm}$  for all  $m, s$  are imposed a priori. In addition, restrictions associated with output nonjointness,  $\beta_{PCms} = 0$  for all  $m, s$ ,  $\beta_{PCmK} = 0$  for all  $m$ , and  $\beta_{PCK} = 0$  are also imposed. Marginal cost functions for grade pack pears and canned fruit cocktail are obtained by differentiating  $C_1$  with respect to  $q_P$  and  $q_C$ , respectively. Input demand functions for the variable inputs can also be obtained from (11) via Shephard's lemma. For example, the labor input demand function is as follows:

$$\begin{aligned}
X_{L_t} = & q_{P_t} \beta_{PPLL} + 2q_{P_t} [\beta_{PPLM} (w_{M_t}/w_{L_t})^{1/2} + \beta_{PPLS} (w_{S_t}/w_{L_t})^{1/2} + \beta_{PPLK} (K_t/w_{L_t})] \\
(12) \quad & + q_{C_t} \beta_{CCLL} + 2q_{C_t} [\beta_{CCLM} (w_{M_t}/w_{L_t})^{1/2} + \beta_{CCLS} (w_{S_t}/w_{L_t})^{1/2} + \beta_{CCLK} (K_t/w_{L_t})] \\
& + \beta_L + q_{P_t} \beta_{PTL} TREND_t + q_{C_t} \beta_{CTL} TREND_t.
\end{aligned}$$

Costs for fresh pear packing were estimated separately since the production process for fresh pear packing differs fundamentally from that for canning pears. Labor and packing materials are the two principal inputs used for packing fresh pears. The cost function for fresh packing was also defined as a generalized Leontief because packing labor and material are not likely to be good substitutes:

$$(13) \quad C_2(q_F, wF_L, wF_M) = q_F[\beta_{FLL}wF_L + \beta_{FMM}wF_M + 2\beta_{FLM}(wF_LwF_M)^{1/2}] + \beta_{FL}wF_L + \beta_{FM}wF_M,$$

where  $wF_L$  and  $wF_M$  are the wage rate for packing house workers and the price for pear packing material, respectively. Capital stock is not included as an input because fresh packing requires very little capital equipment. From (13) the marketing margin for the benchmark fresh pears at time  $t$  can be stated explicitly in price-dependent form as follows:

$$(14) \quad PF_t = [\beta_{FLL}wF_{Lt} + \beta_{FMM}wF_{Mt} + 2\beta_{FLM}(wF_{Lt}wF_{Mt})^{1/2}] + w_t[1 + \epsilon_{w,R} + \epsilon_{w,L}\eta_{L,R}]/\gamma_F,$$

where  $PF$  is the f.o.b. wholesale price for fresh Bartletts. Equation (14) is the empirical analog of (2) for the benchmark product. The price flexibility of supply,  $\epsilon_{w,R}$ , in (14) is restricted to be the inverse of  $\epsilon_{R,w}$  in (8), the grower supply function, while  $\epsilon_{w,L}$  was treated as a parameter to be generated within the system estimation. Among the hypotheses to be tested are that cooperative processors and a cooperative bargaining association have had a procompetitive effect on the raw pear input market. To formulate these tests, the spatial market conjectural elasticity,  $\eta_{L,R}$ , was specified as a linear function of variables to reflect the cooperatives' and bargaining association's involvement over time in the market:

$$(15) \quad \eta_{L,Rt} = g_0 + g_1BGA_t + g_2MO_t + g_3CO59_t + g_4CO72_t + g_5CO78_t + g_6CO81_t,$$

where  $BGA_t$  is the percentage of pears marketed annually through the pear bargaining association,  $MO_t$  is a dummy variable reflecting the presence of a federal marketing order for processed Bartletts since 1967, and the four "CO" variables are indicators to reflect those years that cooperatives have gained significant market share in the pear market.

From (11) the price-dependent margin equation for grade pack pears is:

$$\begin{aligned}
 P_{P_i} = & \beta_{PFL} w_{L_i} + \beta_{PFMM} w_{M_i} + \beta_{PFSS} w_{S_i} + \beta_{PPK} K_i + \beta_{PTL} TREND_i w_{L_i} + \beta_{PTM} TREND_i w_{M_i} \\
 & + \beta_{PTS} TREND_i w_{S_i} + \beta_{PTK} TREND_i K_i + 2\beta_{PPLM} (w_{L_i} w_{M_i})^{1/2} + 2\beta_{PFPS} (w_{L_i} w_{S_i})^{1/2} \\
 (16) \quad & + 2\beta_{PPLK} (w_{L_i} K_i)^{1/2} + 2\beta_{PFMS} (w_{M_i} w_{S_i})^{1/2} + 2\beta_{PFMK} (w_{M_i} K_i)^{1/2} + 2\beta_{PFSS} (w_{S_i} K_i)^{1/2} \\
 & + \frac{(\gamma_F/\gamma_P)[PF_i - \beta_{FLL} wF_{L_i} + \beta_{FMM} wF_{M_i} + 2\beta_{FLM} (wF_{L_i} wF_{M_i})^{1/2}]}{1 + \theta_P[\eta_{PP,QP} + (S_C/S_P)\eta_{PC,QP}]},
 \end{aligned}$$

where  $S_C$  and  $S_P$  denote the cocktail and pear share, respectively. Apart from the inclusion of an additional term to represent the per unit cost of other fruits (peaches, grapes, cherries, and pineapples) used in fruit cocktail, the fruit cocktail margin equation is similar to (16) and is omitted for brevity. Equation (16) is the empirical analog of (5).

Own and cross price flexibilities,  $\eta_{P_i,Q_i}$  and  $\eta_{P_j,Q_i}$ , are obtained from the inverse output demands in (9) and (10), and  $\theta_P$  represents the pear output market conjectural elasticity. To simplify the estimating equations, the cross conjectural elasticities,  $\theta_{i,j}$ , for processed pear products were assumed to be zero.<sup>11</sup>

## DATA AND ESTIMATION

Data used in estimating the model for the period 1950-1986 were obtained from a number of sources and are discussed in detail in Wann. Farm production data on bearing acreage, average yield, and quantity of raw pears utilized for processing, fresh sales, and residual uses were obtained from the California Agricultural Statistics Service (CASS). The mill price ( $w$ ) was the average annual price paid to growers and was also available from the CASS.

<sup>11</sup>Schroeter and Azzam found the cross product conjectures for beef and pork to be very small and statistically insignificant.

Domestic f.o.b. prices for grade pack pears and fruit cocktail were available from Kuznets and from the private label f.o.b. prices published by the American Institute of Food Distribution. Data on the total pack produced, movement and inventory (PINV, CINV) were obtained from the California League of Food Processors.

The primary data source for the processing cost function was the annual cost study of the pear processing industry conducted by the accounting firm Touche Ross & Co. Total costs per standard case of grade pack pears and fruit cocktail were decomposed by type of processing inputs and services, including production and warehouse labor, raw product, cans, labels, cases, sugar, energy, and water as variable inputs. Because the cost of energy and water was negligible, variable inputs for pear processing were considered to be labor, canning material, and sugar. The input prices used were the July, August, and September average wage rate for fruit processing for  $w_L$ , the wholesale price of sugar for  $w_s$ , and the combined costs of cases, cans, and labels per case for  $w_M$ .

The quantity of fixed capital stock was calculated based on the perpetual inventory method by using average annual investment expenditures on depreciation, repairs, rent, and factory supplies reported in the Touche Ross annual studies.<sup>12</sup> The wholesale prices of fresh bartletts at San Francisco published by the Federal-State Market News Service were used as the

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<sup>12</sup>The perpetual inventory formula for capital stock is

$$K_t = I_t + (1 - \Delta)K_{t-1},$$

where  $K$  denotes the real capital stock,  $I$  is real investment, and  $\Delta$  represents the asset depreciation rate. Assuming straight-line depreciation,  $\Delta = 1/16$  based on industry opinion of the weighted average useful life of processing equipment and buildings. Investment,  $I$ , was computed by deflating the net dollar investment by the producer price index of food products machinery and equipment. Base year (1950) capital stock was obtained by following the procedure described in Stevenson.

f.o.b. price, PF, for fresh pears. Packing cost data for fresh pears were collected from the California Tree Fruit Agreement.

The empirical model for the California pear industry consists of equations (8)-(10), (12)-(14), (16), plus the fruit cocktail margin equation and one additional processing input demand function. Each equation was assumed to be associated with an additive error to capture unexplained factors. The stochastic nature of the margin equations was assumed due to errors in optimization.

To accommodate the large number of parameters to be estimated and attendant multicollinearity problems, the acreage supply function, (8), and the wholesale demand functions, (9) and (10), were estimated separately from the rest of the equation system (Gollop and Roberts, Schroeter and Azzam, Azzam and Pagoulatos). Estimates for (8) were obtained using OLS, while (9) and (10) were estimated jointly using maximum likelihood estimation. The margin equations, cost functions, and input demand functions were estimated as a system using FIML. The errors in this equation system were assumed to be jointly normally distributed with mean zero and nonsingular variance-covariance matrix. A first-order autoregressive parameter was added to the system to adjust for serial correlation.

Equation (17) provides OLS estimation results for the acreage

$$(17) \quad \ln BA_t = \frac{-0.680}{(0.428)} + \frac{0.029 \ln w_t}{(0.031)} + \frac{0.966 \ln BA_{t-1}}{(0.071)} - \frac{0.015 \ln RU_{t-7}}{(0.008)} \\ + \frac{0.307 \ln(RU_{t-7})^2}{(0.158)} - \frac{0.030 \ln DR_{t-1}}{(0.015)} - \frac{0.0004 T}{(0.0005)}, \quad R^2 = 0.93.$$

response function. Standard errors are indicated in parenthesis.

The short-run elasticity of supply,  $\epsilon_{R,w} = 0.029$  is small as expected since a high price in the

current period is likely to have only a small effect on orchard removal decisions. This inelastic supply implies a price flexibility of supply of  $\epsilon_{w,R} = 1/\epsilon_{R,w} = 34.0$ . Other estimated coefficients in the acreage response equation all had the anticipated effects.

Estimated parameters and asymptotic standard errors for the wholesale demand functions are presented in eqs. (18) and (19):

$$(18) \quad \ln P_P = \frac{1.791}{(0.264)} - \frac{0.500 \ln Q_P}{(0.100)} - \frac{0.214 \ln Q_C}{(1.133)} - \frac{0.005 \ln PINV_t}{(0.010)} \\ + \frac{0.571 \ln Y_t}{(0.109)} + \frac{0.002 T70}{(0.006)}$$

$$(19) \quad \ln P_C = \frac{1.234}{(0.216)} - \frac{0.342 \ln Q_C}{(0.115)} - \frac{0.127 \ln Q_P}{(0.086)} - \frac{0.004 \ln CIN V_t}{(0.008)} \\ + \frac{0.430 \ln Y_t}{(0.090)} + \frac{0.011 T70}{(0.005)}$$

Based on the estimates of the own price flexibilities,  $\epsilon_{PP,QP} = -0.500$  and  $\epsilon_{PC,QC} = -0.342$ , canned pears and fruit cocktail both have elastic demands. The negative cross price flexibilities in the two inverse demand equations indicate that grade pack pears and fruit cocktail are substitutes as anticipated. Converting the income flexibilities in (18) and (19) to elasticities yields estimated income elasticities of  $\epsilon_{QP,Y} = 1.14$  for canned pears and  $\epsilon_{QC,Y} = 1.26$  for fruit cocktail.

The maximum likelihood 1parameter estimates and their respective standard errors for the conjectural elasticities and the cost, input demand, and margin functions are reported in Table 1. The majority of the 44 estimated parameters in Table 1 are significantly different from zero at the 5% level. Many of insignificant parameters are cross product coefficients in the canning cost function and might be attributable to the limited substitution possibilities

between the variable canning inputs. The monotonicity and concavity properties of the cost function are satisfied at the sample means and for most of the observation points in both the estimated fresh packing and processing cost functions.

The estimates for  $\epsilon_{w,L}$ ,  $\theta_P$ , and  $\theta_C$  were plausible and consistent with theory. A negative and significant elasticity of the mill price to market radius,  $\epsilon_{w,L} = -10.42$  was obtained. The output conjectural elasticities  $\theta_P$  and  $\theta_C$ , which measure the degree of competition, both fell significantly into the  $(0, 1)$  range.<sup>13</sup> Thus, the hypotheses that the wholesale markets for grade pack pears and fruit cocktail have been perfectly competitive over the study period are rejected. Correspondingly, a hypothesis that the industry had been characterized by collusive, monopoly behavior would also be rejected. The estimated conjectural elasticity for grade pack pears,  $\theta_P = 0.076$ , was considerably smaller than that for fruit cocktail,  $\theta_C = 0.482$ , implying that the market for fruit cocktail has been less competitive than the grade pack pear market. This finding is consistent with the fact that fruit cocktail has been packed exclusively in California, while grade pack pears have also been produced in Oregon and Washington, making the selling side of the grade pack pear market less concentrated relative to that for fruit cocktail.

Given the estimates of the price flexibilities of demand and the output conjectural elasticities for grade pack pears and fruit cocktail, the markup after adjusting for processing cost differentials for the nonbenchmark products relative to the benchmark can be estimated

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<sup>13</sup>Assuming that the  $\theta_j$  are distributed normally, their 95% confidence intervals are as follows:  $\theta_P \in [0.050, 0.102]$ ,  $\theta_C \in [0.441, 0.523]$ .

for each year of the sample period using (5). Given the simplifying assumption that  $\theta_{i,j} = 0$   $\neq j$ , the markup for canned pears becomes:

$$\frac{\gamma_P P_P - \gamma_F P_F}{\gamma_P P_P} - \frac{\gamma_P C_P - \gamma_F C_F}{\gamma_P C_P} = -\theta_P \left( \eta_{P_P Q_P} + \frac{S_C}{S_P} \eta_{P_C Q_P} \right).$$

The average markups over the sample period as a percentage of the processed product prices were 7.1% and 19.7% for canned pears and fruit cocktail, respectively.

The hypothesis that cooperatives have had a procompetitive effect on the farm product market can be analyzed by testing each of the coefficients,  $g_3, \dots, g_6$ , associated with the major historical changes in processing cooperatives' activity in the raw pear market. All of the estimated cooperative coefficients were negative and all statistically significant except  $g_5$ , which corresponds to the establishment of Glorietta Foods in 1978. Because the indicator variables associated with  $g_3 - g_6$  all correspond to growth in cooperatives' market position, these results imply that growth of cooperatives in the California pear processing industry did not enhance competition among processors in purchasing raw pears and may actually have reduced farm input market competition. This result is consistent with predictions from Sexton's theoretical model for the case when cooperatives have closed membership policies as has been the usual practice for cooperatives in the California pear processing industry. The industry bargaining cooperative, however, does appear to have enhanced competition since  $g_1 = 3.89$  ( $t = 5.32$ ).

Estimates of the spatial conjectural elasticities,  $\eta_{L,R}$ , range from 2.7 to 5.2 over the sample period. The mean value is 3.9 (standard error = 0.73), leading to rejection of the hypothesis that the raw pear market has been characterized by monopsony (Loschian)



behavior. However, the mean value of  $\eta_{w,R}$  (eq. (3)) was 1.46 (standard error = 0.72), causing rejection also of the hypothesis that the raw product market was on average competitive over the sample period.

## CONCLUSIONS

Many agricultural markets exhibit structural characteristics suggestive of oligopoly power on the selling side and oligopsony power on the buying side of the market. This paper has developed and estimated a model of farm-retail price spread determination for these types of markets. A key feature of the model is its ability to distinguish market power in the raw product input market from market power in multiple processed product markets. The key to accomplishing this decomposition of market power is the assumption that there exists a competitive "benchmark" processed product form that can be used to estimate oligopsony power based upon the margin between the benchmark product price and the raw product price. Oligopoly power for each of the other processed forms is estimated by comparing the margin between its price and the benchmark price.

Application of the model to the California pear industry revealed some modest price enhancement above the competitive norm in both the canned pear and fruit cocktail markets. The hypothesis of competition in the raw pear input market was also rejected. Increases in the share of product handled by marketing cooperatives did not appear to increase the competitiveness of the raw product market.

TABLE 1. Nonlinear Full Information Maximum Likelihood Estimation Results

Parameter	Estimated Coefficient	Asymptotic Standard Error
Fresh Packing Cost Function:		
$\beta_{FLL}$	-0.26871E-02*	0.13920E-02
$\beta_{FMM}$	-0.59912E-02*	0.28492E-02
$\beta_{FLM}$	0.47312E-02**	0.20076E-02
$\beta_{FL}$	0.42391	1.0223
$\beta_{FM}$	-1.4596	2.4357
Canning Cost Function:		
$\beta_{PL}$	-0.43727E-03	0.73773E-03
$\beta_{PLM}$	0.10535E-04	0.70539E-05
$\beta_{PLS}$	-0.26677E-04	0.19109E-04
$\beta_{PLK}$	0.65326E-05	0.76296E-05
$\beta_{PTL}$	0.13922E-04	0.22018E-04
$\beta_{CL}$	-0.31547*	0.15063
$\beta_{CLM}$	-0.81817E-03	0.20545E-02
$\beta_{CLS}$	0.70683E-02	0.47978E-02
$\beta_{CLK}$	0.68783E-02**	0.15837E-02
$\beta_{CTL}$	0.68948E-02*	0.38831E-02
$\beta_{PM}$	-0.36753E-04	0.58626E-04
$\beta_{PMS}$	-0.13960E-05	0.87773E-05
$\beta_{PMK}$	0.82949E-06	0.61740E-06
$\beta_{PTM}$	0.27384E-05	0.19058E-05
$\beta_{CM}$	0.15617**	0.19676E-01
$\beta_{CMS}$	0.52299E-03	0.22984E-02
$\beta_{CMK}$	-0.41109E-03*	0.18868E-01
$\beta_{CTM}$	-0.12802E-02*	0.63946E-02
$\beta_{PS}$	-0.29320E-03	0.38807E-03
$\beta_{PSK}$	0.11137E-05	0.79077E-06
$\beta_{PTS}$	0.17193E-04	0.12464E-04
$\beta_{CS}$	0.76756E-01	0.11910
$\beta_{CSK}$	-0.88988E-04	0.21534E-03
$\beta_{CTS}$	-0.39354E-02	0.38703E-02
$\beta_{PK}$	0.12557E-01**	0.77649E-03
$\beta_{PTK}$	0.77703E-04**	0.26089E-04
$\beta_{CK}$	0.31166E-01**	0.13676E-02
$\beta_{CTK}$	0.33852E-02**	0.46697E-03
Spatial Conjectural Elasticity function:		
$\varepsilon_{w,L}$	-10.415**	0.99684
$\eta_0$	3.4548**	0.55041
$\eta_1$	3.8858**	0.72909
$\eta_2$	0.77917**	0.33295
$\eta_3$	-1.5107**	0.41120
$\eta_4$	-0.78089**	0.22489
$\eta_5$	-0.10515	0.13155
$\eta_6$	-0.23415**	0.08404
Output Conjectural Elasticities:		
$\theta_P$	0.07603**	0.01333
$\theta_C$	0.48221**	0.02094
$\rho^a$	0.95109**	0.01555

\*\* Significantly different from zero at 0.01 level.

\* Significantly different from zero at 0.05 level

<sup>a</sup>  $\rho$  is the first-order autocorrelation coefficient

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