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**The Empirical Analysis of Oligopsony in
Agricultural Markets: Residual Supply
Estimation in California's Processing Tomato
Market**

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Food Marketing Policy Center
Research Report No. 15

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Acknowledgements

This paper was presented at the Competitive Strategy Analysis in the food System Conference, June 3-5, 1991 Alexandria, Virginia. The author would like to thank both the Food Marketing Policy Center for its support and Richard Sexton who served as the author's dissertation committee chair and provided helpful comments on this paper. Any errors in fact or analysis in the paper are the responsibility of the author. This research was supported by Special Research Grant No. 88-34178-3739 with the Cooperative State Research Service, USDA, and by the Storrs Agricultural Experiment Station. This report is Scientific Contribution No. 1432, Storrs Agricultural Experiment Station, Storrs, CT 06269.

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Table of Contents

List of Tables	iv
List of Figures	v
1. Introduction	1
2. Prior Research	1
3. Comparison of Conjectural Variations and Residual Demand Approaches	3
4. Residual Supply	7
5. Farm Supply	9
6. Processor Demand	10
7. Derivation of Residual Supply for a Single Firm with Market Power	14
8. Residual Supply for a Group of Firms	18
9. Processing Tomato Industry	19
10. Data and Econometric Model	20
11. Results	25
12. Conclusion	34
References	36

List of Tables

Table 1	COMPARISON OF CONJECTURAL VARIATIONS AND RESIDUAL DEMAND APPROACHES	4
Table 2	RESIDUAL SUPPLY PRICE FLEXIBILITIES, PRICE ELASTICITIES, AND CONFIDENCE INTERVALS . .	27
Table 3	RESIDUAL SUPPLY EQUATIONS	30

List of Figures

Figure 1	ILLUSTRATIONS OF RESIDUAL SUPPLY	8
Figure 2	PROCESSING PLANT AND PRODUCTION LOCATIONS	22

1. Introduction

The food processing sector accounts for a large portion of retail food costs and, therefore, the industry's competitiveness and efficiency are important to both the producers of the raw product and the consumer of the retail good. The processing sector generally has a small number of firms in contrast to large numbers of producers and consumers. Studies on the structure of agricultural markets have primarily focused on the market power of the firm as a seller rather than buyer. However, many fruits and vegetables for processing have three characteristics which suggest the possibility of a spatially-determined monopsony power. These characteristics include many dispersed producer-sellers, a small number of processor-buyers, and a perishable and bulky raw product form which is costly to transport.

In this paper a model is developed to analyze the market power which may occur in a market with these characteristics. New empirical methods developed to analyze imperfect competition have tested market power primarily with either conjectural elasticities estimated from a structural model of firm behavior, or on estimates of the elasticity of residual demand. The residual demand methodology estimates a summary statistic which incorporates the conjectural and total demand elasticities into a single parameter. Residual demand is thus the demand facing a producer, or group of producers, after rivals' supply is accounted for. In this paper the residual demand methodology is extended to the examination of input markets, and then applied to California's processing tomato market.

The characteristics which suggest a spatially-determined oligopsony power are exemplified by the processing tomato market in California. There were 22 firms processing tomatoes in California in 1989, with plants from the Arizona border to 200 miles south of the Oregon border. Owing to the dispersal of plants and raw product production, growers in some instances have only one or two processing plants within a fifty mile radius. Transportation costs are approximately a quarter of raw product costs.

2. Prior Research

The 1980s were a period of great activity in the analysis of market power. Structure-conduct-performance studies (SCP)

of the type initiated by Bain (1951) have been altered to account for the critiques made by Demsetz (1973) and others. A number of new approaches have also been developed. These approaches, which have been termed the New Empirical Industrial Organization (NEIO), differ from SCP approaches primarily by explicitly modeling firm behavior. Discussions of the SCP literature are found in Schmalensee (1989), and Scherer and Ross (1990). Geroski (1988) and Bresnahan (1989) provide surveys of the NEIO.

One of the most commonly applied models of the NEIO has its origin in Appelbaum's work (1979, 1982) in which firm behavior is modeled in a dual approach. The firm's problem is to

$$\text{Max } \prod_j = p(Y,z)y_j - c(y_j,w) \quad \text{w.r.t. } y_j$$

where $p(Y,z)$ is total industry demand for the product Y , and z represents exogenous demand shifters, and y_j is firm j 's production, $c(y_j,w)$ is the cost function and w is a vector of input prices. The derivative of the profit function w.r.t. firm output y_j is set equal to zero and rearranged as the behavioral equation $p = -(\partial p/\partial Y)(\partial Y/\partial y_j)y_j + \partial c(y_j,w)/\partial y_j$. Via Shephard's Lemma the k factor demands with respect to input prices are derived as $x_k = \partial c(y_j,w)/\partial w_k$. These equations are estimated in conjunction with the market demand equation $p = p(Y,z)$. The markup term of price over marginal cost, $(\partial p/\partial Y)(\partial Y/\partial y_j)y_j$, incorporates both the total price flexibility and the conjectural elasticity; and parameterization of the latter is enabled by the shared parameters in (1) the market level demand equation and the markup term in the behavioral equation; i.e., $(\partial p/\partial Y)$ and (2) between the factor demands and marginal cost of the behavioral equation. A number of studies have extended this approach to agricultural input markets to examine monopsony power. Included in this group are Schroeter (1988), Azzam and Pagoulatos (1989)--who use a primal approach first suggested by Gollop and Roberts (1979), Lopez and Dorsainvil (1990), and Wann (1990). A more recently adapted approach of the NEIO is to examine the residual demand faced by a firm. Baker and Bresnahan (1985) and Scheffman and Spiller (1987) used this framework to examine oligopoly in differentiated product markets and in spatial markets, respectively. Residual demand models are intended to estimate whether the demand facing a firm, having incorporated rivals' behavior, is sufficiently inelastic to enable the firm to exercise market power. Thus, the elasticity estimated from a residual demand equation can be used as a

statistical test of market power. In application the price flexibility is generally estimated rather than the elasticity because the statistical test, examining whether the flexibility is significantly greater than zero, is more straightforward.

3. Comparison of Conjectural Variations and Residual Demand Approaches

The following discussion, which is summarized in Table 1, only presents two of the models developed for the analysis of market power. The conjectural variations or structural model approach is chosen for comparison to the residual demand approach because of its more common application and its parallels to the residual demand approach.

The choice of a residual demand rather than a conjectural variations¹ approach may be predicated by the data available for estimation. The residual demand model, which is estimated in a quasi-reduced form, requires the firm's total output and output price; the structural model used in estimating a conjectural variation parameter also requires the firm's costs and input quantities or prices. These data requirements mean that in many instances use of the structural model will be precluded by data availability. A structural model, of course, also requires a functional form to be chosen. The possibility of specification bias must be considered in this regard, though careful examination of the industry being studied should allow for a reasonable determination, and the impact of possible biases can be considered in analyzing the results acquired in estimating the model. These problems do not occur or are less critical in estimating residual demand functions; however, in analysis of firm behavior the conjectural variations models are superior. In a residual demand model a summary statistic is estimated which incorporates in one parameter the market demand elasticity and the conjectural elasticity which structural models are able to separate. Because the residual demand elasticity does not distinguish between the two, it is less useful in terms of analyzing behavior. The parameters estimated from a residual function

¹The use of the term conjectural variation for $\partial y/\partial y^j$ (change in total output for change in own output) to refer to the parameter estimated in these models has been questioned because estimates are made from observed market behavior rather than expected or conjectured reaction.

Table 1 COMPARISON OF CONJECTURAL VARIATIONS AND RESIDUAL DEMAND APPROACHES

Approach	Conjectural Variations	Residual Demand
Estimation	<p>Behavioral Model: $\text{Max } \Pi_j = p(Y, z)Y_j - c(Y_j, w_j)$ w.r.t. Y_j where p is price, Y is total industry output, z is a vector of exogenous demand shifters, Y_j is the output of firm j, c is a cost function and w is a vector of cost shifters.</p> <p>Structural model—system of equations includes market demand</p> <p>(MD) $P = p(Y, z)$,</p> <p>where $Y = \sum_{i=1}^N Y_i$</p> <p>the behavioral equation—</p> <p>(BE) $P = -(\partial p / \partial Y)(\partial Y / \partial Y_j) Y_j + \partial c(Y_j, w) / \partial Y_j$</p> <p>Via Shephard's Lemma the k factor demands with respect to input prices are derived as:</p> <p>(FD) $x_k = \partial c(Y_j, w) / \partial w_k$</p> <p>$\partial p / \partial Y$ is found in both (MD) and (BE) as are cost parameters in (BE) and the (FD)s allowing the conjectural parameter to be distinguished.</p>	<p>Output generally is either spatially distinct or non-homogeneous. Price is a function of all competing products.</p> <p>(i) $P_j = P_j(Y_{1..n}, Y_N, z_j)$</p> <p>where each $Y_{i..j}$ is solved for in terms of only Y_j and its exogenous variables or</p> <p>(ii) $Y_{i..j} = Y_{i..j}(Y_j, z_i, w_i, z_i)$</p> <p>and thus is replaced in the Residual Demand equation.</p> <p>(RD) $P_j = P_j(Y_j, z_i, w_i, z_i)$</p> <p>where z_i and w_i are vectors containing all elements $i \neq j$.</p> <p>Estimation is in a quasi-reduced form where the only endogenous variables are price and output of firm j. Own quantity is estimated as a function of all the exogenous variables (z_i, w_i, z_i, and w_i) and the estimated values are used as instruments in the actual estimation.</p>
Market parameters estimated.*	A conjectural parameter $\partial Y / \partial Y_j$ as well as total demand parameter, $\partial p / \partial Y$. Also Lerner index.	Summary parameter, $\partial Y / \partial Y_j$, which incorporates both the conjectural and total demand relationship.
Advantages	Can allow testing of behavioral hypothesis, if firm level data is available.	Excellent methodology for analysis of mergers and market independence, possible to analyze potential market power.
Disadvantages	Data requirements, determining correct functional form.	Limited usefulness in behavioral analysis.
Estimation problems	Accounting style data usually gives total costs categorized by function, e.g. labor and energy, but input levels must be derived.	It is critical that some element of w_i is not contained in w_i in order for the residual demand equation to be identified. Note that the w are vectors of exogenous supply shifters and typically contain other variables as well as input prices.

* Typically these models are transformed and these parameters are estimated as elasticities.

may allow the rejection of a particular behavioral structure² but not determination of one. However, the residual demand elasticity does answer the question of whether firms are able to exercise market power, and the methodology is quite appropriate to use in considering mergers of firms within an industry and the impact of other structural changes such as firm closures.

Finally, the advantages of a structural model in terms of behavioral analysis are diminished if the data are not available at the firm level. Often, when the input and cost data required to estimate a structural model are available, it is only in a highly aggregated form; and, under these circumstances, the conjectural parameter estimated is average industry behavior, which is not helpful when the analyst's interest is, for example, in discerning whether small and large firms behave differently. If price and quantity are available in disaggregate form, a residual demand estimation will provide some information about differences in ability to exercise market power. Estimated in aggregate form the structural model has primarily been used to provide an overall index of market power and to look at the impact of changes in market power over time.

A residual demand elasticity reveals the individual impact a firm's actions have, because it incorporates the impact it has on other firms and, thus, the market. If a firm is in a perfectly competitive market the residual demand flexibility is zero and the firm cannot affect the market. The residual demand model may also be applied to a group of firms. The Scheffman and Spiller analysis considered whether regional groups of firms were sufficiently independent with regards to competition from firms in adjoining regions to constitute a market. A significant residual demand price flexibility for the firms in a group indicates that the group's ability to exercise market power is not fully constrained by external competition. Thus, external competition does not mitigate the market power a merger of the firms would provide or the market power firms within the group could exercise collusively.

While the above discussion is presented in terms of market power over output price, the issues are unchanged in analysis of input market power, or, oligopsony rather than oligopoly.

²Baker and Bresnahan (1987) consider various models of market behavior in analysis of the brewing industry.

4. Residual Supply

The purpose of this paper is to present a spatial model through which monopsony power in a market for an input to processing may be analyzed. This model can be described as a residual supply model, and may be considered an extension of the residual demand models developed by Baker and Bresnahan (1985, 1987) and Scheffman and Spiller (1987). Residual supply is the supply of the input to a firm after rivals' demands have been accounted for.

The basic premise of residual supply may be viewed graphically in Figure 1. The two graphs present two hypothetical residual supplies. Total supply is the same in both graphs but the elasticity of demand for the input by firms outside of the production area is different. Residual supply on these graphs is simply the horizontal difference between total supply and outside demand—the demand by non-local processors.

The first graph shows a situation where outside demand is relatively elastic and by simply subtracting outside demand from total supply we obtain a residual supply which is approaching the horizontal or a perfectly elastic, competitive, supply curve. The reverse is true in the next graph, where outside demand is inelastic and hence residual supply is less elastic—providing an opportunity for the exercise of market power.

It is possible that demand by outside firms is fairly inelastic if their primary reason for obtaining raw product outside their own production area is (1) to spread production to reduce risk of uneven delivery, or (2) to obtain early or late production. However, if outside demand is elastic, an estimated residual supply would be elastic and local firms would not possess market power.

To estimate residual supply a model must incorporate the factors which influence processor demand, as well as those factors influencing farm supply. The model allows for the possibility of spatially-exercised market power by processors. The model has two purposes:

- (1) to illuminate the exercise of market power, or the potential for it, by processing firms, and
- (2) to provide a framework with which to analyze the impact of changes in processor concentration from mergers, plant openings, and plant closings.

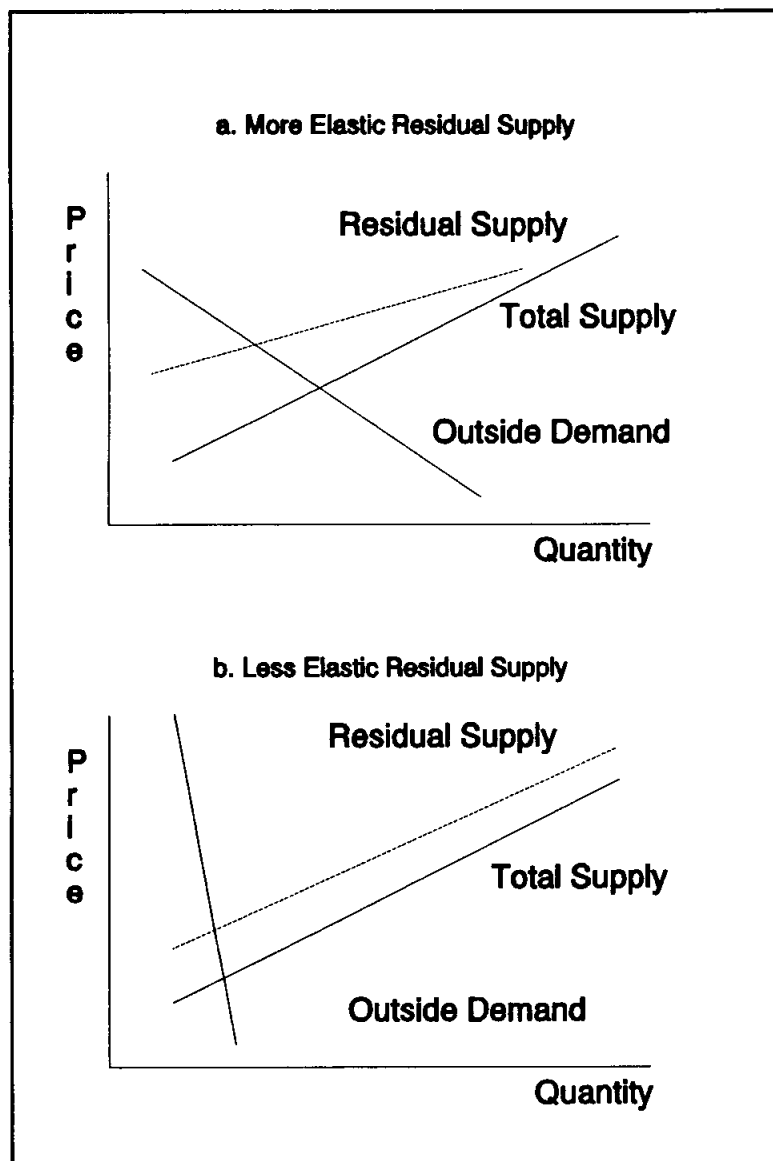


Figure 1 ILLUSTRATIONS OF RESIDUAL SUPPLY

In order to estimate residual supply it is necessary to develop a model which accounts for demand by processors and supply by growers in the area under consideration, as well as processor demand and farm supply in outside locations. The latter determines the position of the outside demand curve. The goal is to derive a residual supply function in which the quantity demanded at each price by outside processors has been substituted out of the equation. To achieve this goal we need a model which incorporates influences on processing firms' behavior and growers' behavior.

The next sections present the components of the model of residual supply. First, the factors influencing grower behavior are developed into the supply which faces an individual processor. Next, a model of processor behavior is developed for a typical processor of perishable agricultural products.

5. Farm Supply

The multi-crop farmer maximizes profit given the prices of the crops produced, the costs of producing those crops, and, in the short run, fixed mechanical and managerial capacity. Thus, the grower faces a multi-product profit function:

$$\Pi_g = wR_g + \omega Q' - C_g(\theta, R, Q, E) - Z. \quad (1)$$

The price paid for the raw product to the processing industry is w , R_g is the amount of the processing input produced, ω is a vector of other output prices, Q is a vector of other outputs and $C_g(\theta, R, Q, E)$ is variable production costs, where θ is a vector of variable input prices, and E is the quantity vector of fixed inputs with Z as their cost. In a decision-making period the farmer maximizes profit with respect to R and Q given w , ω , θ and E . The supply of raw product, R , is thus influenced by all of these factors, and a supply response relationship derived from maximizing Equation 1 with respect to R and Q would include the exogenous factors in Equation 1. The supply response relationship is shown in Equation 2:

$$R_g = f(w, \omega, \theta, E). \quad (2)$$

Prices are exogenous to individual farmers. However, the aggregate raw product supply function facing the processor is affected by the nature of markets for agricultural inputs to

processing. There are a relatively small number of processors hypothesized to have some influence over raw product prices, and farmers within a local processor's sphere of influence may potentially contract to deliver to outside processors. A common practice in determining raw product price for fruits and vegetables is for processors to announce tonnage intentions and for agents to meet with growers to discuss potential tonnage allocations. For this reason, it is appropriate to handle farm supply in inverse or price dependent form. The price a processor must offer, therefore, depends upon the tonnage demanded, R_i , the tonnage demanded by other processors, R_n , and local supply shifters, ω_i , θ_i and E_i . Equation 3 is the residual supply to a firm located in Region i , which is affected by the factors influencing local farmers but also by the tonnage demanded by other processors, R_n :

$$w_i = f_i(R_i, R_n, \omega_i, \theta_i, E_i). \quad (3)$$

6. Processor Demand

The farm product is the critical factor in a food processor's decision-making and, due, for example, to the spatial nature of the firm's operating conditions, the processor may be able to exercise market power in its procurement. Other inputs to processing--including energy, labor, capital and packing materials, are considered to be obtained in a competitive market since they are used in many other sectors, both farm and non-farm. Other assumptions in the model follow.

- (i) Growers produce a homogeneous raw product, R , with productive acreage at a uniform density (d).
- (ii) Processors obtain raw product in a circular market, and pay for the transportation of the farm input to the factory, i.e., pricing is uniform.
- (iii) Processors' technology may be represented as quasi-fixed proportions. Output of the finished product $Q = \min\{\lambda R, h(X)\}$, with no substitution possible between the raw farm input, R , and the vector of non-farm inputs, $X = \{X_n, K\}$ where the X_n are non-raw

product variable inputs and K denotes fixed inputs.³

A processor's demand for the raw input is based upon the price received for output, the supply function for the raw input, and other input costs such as labor, energy, and packaging materials. Equation 4 represents the i^{th} processor's profit function:

$$\begin{aligned} \text{Max } \Pi_i = & p \min\{\lambda R_i, h(X_i)\} - w_i(R_i, R_n, \Theta_i) R_i \\ & - C_i(v_i, R_i, K_i) - F_i - t_f R_i \\ & - 2t_m R_i^{3/2} / 3d^{1/2} \pi^{1/2} \end{aligned} \quad (4)$$

The price the processor receives is p , and λ is the finished-to-raw product ratio. For example, it takes approximately 6 pounds of tomatoes to produce 1 pound of tomato paste. Thus, $\lambda = 0.17$ for tomato paste. The price paid for the raw product is w and it is represented as a function of $R_n = \{R_1, R_2, \dots, R_{i-1}, R_{i+1}, \dots, R_N\}$ which is raw product usage for the other $N-1$ firms in the industry, and R_i since the firm's market power is being tested. Local supply shifters are also included and are contained in the vector Θ_i . $C_i(v_i, R_i, K_i)$ is the processing cost function, where v_i is a vector of prices for the other variable inputs-- X_n , K_i is the fixed input or capacity, and F_i represents fixed costs of K_i . The last two terms in Equation 4 represent transportation costs for obtaining tomatoes from a circular area with d incorporating yield and density of the raw product acreage and t_f representing a per ton price for each load and t_m a per ton-per mile factor.⁴ The processor's problem is to choose the profit maximizing amount of raw product. Equation 5, the first order condition to Equation 4, is essentially the firm's behavioral equation. Arranged with $p\lambda$ on the left would give the marginal value product equal to marginal cost per unit of input condition.

³Understanding of future notation will be clarified by noting that prices are lower case Roman letters, quantities are in upper case Roman letters, price vectors are in Greek letters and vectors which are later combined for the purpose of simplification are in upper case Greek letters.

⁴The derivation of the transportation costs is found in French (1960).

$$\begin{aligned} \partial \Pi_i / \partial R_i &= p\lambda - w_i(R_i, R_n, \Theta_i) - \sum_{n=1}^N \frac{\partial w_i}{\partial R_n} \frac{\partial R_n}{\partial R_i} R_i \\ &\quad - \partial C_i(v_i, R_i, K_i) / \partial R_i - t_f - t_m R_i^{1/2} / d^{1/2} \pi^{1/2} \\ &= 0 \end{aligned} \quad (5)$$

As shown, the firm's level of R_i may affect w_i both through its direct impact and influences on R_n . While the preceding equation describes a firm which is competitive in a single output market, the model can be extended to multiple products and imperfect competition in output markets. The empirical analysis conducted in this paper is based on the assumption that processing tomato firms are competitive in their output markets, and thus we will not develop the model for imperfect competition in output markets although it is straightforward to do so.⁵ Given positive prices for R and X , and if firms are cost minimizing, then Q_i^j may be represented as $\lambda^j R_i^j$. The input price w_i depends on the sum of raw input use for all products and firms, so each element of R_n becomes $\sum_{j=1}^k R_n^j$, where $R_n^1, R_n^2, \dots, R_n^k$ denote individual product forms for the n th firm. The non-raw product costs for Firm i depend on $R_i^1, R_i^2, \dots, R_i^k$. Equation 6 is a generalization of Equation 4 to multiple products:

⁵If firms are imperfect competitors in output, the output prices p^j (see Equation 6) are no longer parametric but rather must be represented as functions of the output level produced, e.g., $p^j = p^j(Q^j)$ where $Q^j = \sum_{n=1}^N Q_n^j$. In this case the optimization process must take into account how expansion of raw product purchases and hence, output affects not only raw product price but also the processed product prices.

The major hurdle in extending the analysis to both imperfect output and input markets is not the theoretical development but, rather, the econometric application. In order to distinguish input from output market power, processed as well as raw product quantities would be needed. Identification of residual supply may also be complicated in these cases because output prices are no longer available to use as raw product demand shifters.

$$\begin{aligned} \text{Max } \Pi_i &= \sum_{j=1}^k p^j \lambda^j R_i^j - w_i(R_i, R_n, \Theta_i) \sum_{j=1}^k R_i^j \\ &\quad - C_i(v_i, R_i^1, R_i^2, \dots, R_i^k, K_i) \\ &\quad - t_f \sum_{j=1}^k R_i^j - t_m \left(\sum_{j=1}^k R_i^j \right)^{3/2} / 2/3 d^{1/2} \pi^{1/2}. \end{aligned} \quad (6)$$

Equation 7 is the multi-product analog of Equation 5 for each product j of the i th firm.

$$\begin{aligned} \partial \Pi_i / \partial R_i^j &= p^j \lambda^j - w_i(R_i, R_n, \Theta_i) - \sum_{n=1}^N \frac{\partial w_i}{\partial R_n} \frac{\partial R_n}{\partial R_i^j} R_i^j \\ &\quad - \partial C_i(v_i, R_i^1, R_i^2, \dots, R_i^k, K_i) / \partial R_i^j \\ &\quad - t_f - t_m R_i^{1/2} / d^{1/2} \pi^{1/2} = 0, \text{ for } 1, \dots, k. \end{aligned} \quad (7)$$

$R_i = \sum_{j=1}^k R_i^j$, is the aggregate volume of raw product purchased by the firm.

To depict the firm's aggregate raw product demand relationship, sum across the k first order conditions to obtain:

$$\begin{aligned} &\sum_{j=1}^k [p^j \lambda^j - MC_i^j] - k w_i(R_i, R_n, \Theta_i) \\ &\quad - k \sum_{n=1}^N \frac{\partial w_i}{\partial R_n} \frac{\partial R_n}{\partial R_i} R_i - k t_f - k R_i^{1/2} (t_m / d^{1/2} \pi^{1/2}) \\ &= 0, \end{aligned} \quad (8)$$

where $MC_i^j = \partial C_i / \partial R_i^j$ denotes marginal processing costs for the j th product.

Rearranging Equation 8 and dividing through by k obtains an expression which represents the i th firm's aggregate demand relationship for the raw product:

$$\sum_{j=1}^k [p^j \lambda^j - MC_i^j] / k - t_f - R_i^{1/2} (t_m / d^{1/2} \pi^{1/2})$$

$$= w_i(R_i, R_n, \Theta_i) + \sum_{n=1}^N \frac{\partial w_i}{\partial R_n} \frac{\partial R_n}{\partial R_i} R_i. \quad (9)$$

The left hand side of Equation 9 represents net marginal revenue product for the raw product averaged across the k product forms. In equilibrium this value must equal the marginal factor cost of R , which is represented by the right-hand side of Equation 9. Individual component demands, the $R_i^1, R_i^2, \dots, R_i^k$ can be expressed via the first order conditions (7) and solved once the form of the residual supply function facing this firm is known.

Equation 9 describes behavior for a firm which is able to exercise market power and, hence, adjusts its behavior accordingly. The next section describes methods to analyze the residual supply to a firm in the position described above. Section 7 develops residual supply facing a group of firms in which the goal is to analyze whether the firms in this regional group could exercise market power if they acted collusively or if firms within the group merged.

7. Derivation of Residual Supply for a Single Firm with Market Power

For purposes of illustration it will be assumed that only two growing regions and two processing firms exist. Region 1 will be the area under consideration. Analogous to Equation 3, Equation 10 is the inverse supply facing Firm 1, the local firm, and Equation 11 is supply to the non-local firm, or

$$w_1 = f_1(R_1, R_2, \Theta_1) \quad \text{and} \quad (10)$$

$$w_2 = f_2(R_2, R_1, \Theta_2). \quad (11)$$

The two supplies are interrelated, each containing the other's quantity of raw product demanded, as well as the vector of local supply shifters represented by Θ , including farm input prices, and competing crop prices.

Our goal is to solve for R_2 in equation 10 having accounted for those factors which determine equilibrium for

Firm 2. This goal can be achieved by simultaneously solving Equations 1 and Firm 2's aggregate demand relationship which from Equation 9 can be written as:

$$\sum_{j=1}^k [p^j \lambda^j - MC_2^j] / k - t_f - R_2^{1/2} (t_m / d^{1/2} \pi^{1/2})$$

$$= R_2 (\partial w_2 / \partial R_2 + (\partial w_2 / \partial R_1) (\partial R_1 / \partial R_2)) + w_2. \quad (12)$$

Solution of the system consisting of Equations 11 and 12 obtains a value for R_2 which is expressed in terms of R_1 and the exogenous variables which determine equilibrium for Firm 2:

$$R_2 = \hat{R}_2(R_1, \rho_2^1, \Delta_2, \Theta_2), \quad (13)$$

where all the exogenous demand shifters except the finished product price (i.e., the exogenous variables entering from the MC) are aggregated into a vector Δ_2 . ρ_2^1 is a weighted index of finished prices adjusted by each products finished-to-raw product ratios. Equation 13 is a quasi-reduced form which expresses the equilibrium value of R_2 in terms of R_1 and the exogenous variables; it is used to substitute for R_2 in Equation 10 as seen in Equation 14. Equation 15 omits the redundant notation in Equation 14,

$$w_1 = f_1(R_1, \Theta_1, \hat{R}_2(R_1, \rho_2^1, \Delta_2, \Theta_2)). \quad (14)$$

$$w_1 = f_1(R_1, \Theta_1, \rho_2^1, \Delta_2, \Theta_2). \quad (15)$$

Equation 15 is the residual supply facing Firm 1. Outside demand has been accounted for through appropriate inclusion of the factors determining equilibrium for the outside processor. If demand by the outside processor for the local product is very elastic, the parameter on R_1 in Equation 15 will be insignificant; i.e., Firm 1 faces a nearly flat residual supply elasticity. Obviously, R_1 and w_1 are determined simultaneously and, thus, estimation must take place in conjunction with Equation 16 the demand relation for Firm 1, which, in turn, is adapted from Equation 9,

$$\begin{aligned} & \sum_{j=1}^k [p^j \lambda^j - MC_1^j] / k - t_1 - R_1^{1/2} (t_w / d^{1/2} \pi^{1/2}) \\ & = R_1 (\partial w_1 / \partial R_1, \Theta_1, \rho_2^\lambda, \Delta_2, \Theta_2) / \partial R_1 \\ & + (\partial w_1 / \partial R_2) (\partial R_2 / \partial R_1) + w_1. \end{aligned} \quad (16)$$

R_2 has been substituted out and redundant notation is omitted in Equation 16. Equations 15 and 16 comprise a system of simultaneous equations in which the only endogenous variables are the quantities and prices of the local firm's raw product. Identification of residual supply requires a variable which enters and shifts the demand relationship but not the residual supply. Residual supply, Equation 15, is identified if Equation 16 contains a variable not contained in Equation 15. This condition will be satisfied if, for example, some product produced by firm one is not produced by Firm 2 or if a cost shifter in Δ_1 is not in Δ_2 .

If Equation 15 is estimated in log-linear form,

$$\ln w_1 = a + \eta_1^R \ln R_1 + b_1 \ln \theta_1 + c_2 \ln \rho_2^\lambda + d_2 \ln \Delta_2 + b_2 \ln \theta_2, \quad (17)$$

then the inverse residual price elasticity of supply, otherwise known as the residual price flexibility, $(\partial w_1 / \partial R_1) (R_1 / w_1)$, is simply the parameter η_1^R .

Equation 14 is fundamentally unchanged by allowing R_n , which had only the single element R_2 in the derivation--because of the assumption of only two firms, to include possible additional elements R_3, \dots, R_N . The full interpretation of η_1^R may then be seen. This interpretation may be more completely understood by first expanding Equation 14 to account for additional competing processors and then examining the decomposed price flexibility:

$$\begin{aligned} w_1 &= f_1(R_1, \Theta_1, R_2(R_1, \rho_2^\lambda, \Delta_2, \Theta_2), \\ & R_3(R_1, \rho_3^\lambda, \Delta_3, \Theta_3), \dots \\ & R_N(R_1, \rho_N^\lambda, \Delta_N, \Theta_N)) \end{aligned} \quad (18)$$

To decompose the flexibility, first, totally differentiate the function f_1 omitting all terms that are unaffected by R_1 :

$$\begin{aligned} dw_1 &= (\partial f_1 / \partial R_1) dR_1 + (\partial f_1 / \partial R_2) (\partial R_2 / \partial R_1) dR_1 \\ &+ (\partial f_1 / \partial R_3) (\partial R_3 / \partial R_1) dR_1 \\ &+ \dots + (\partial f_1 / \partial R_N) (\partial R_N / \partial R_1) dR_1 \end{aligned} \quad (19)$$

To convert this expression to an elasticity, divide Equation 19 by dR_1 and multiply by R_1 / w_1 and where appropriate by R_i / R_i . Then, rearranging obtains:

$$\eta_1^R = (\partial w_1 / \partial R_1) (R_1 / w_1) + \sum_{i=2}^N (\partial w_1 / \partial R_i) (R_i / w_1) (\partial R_i / \partial R_1) (R_1 / R_i).$$

or

$$\eta_1^R = \eta_{11} + \sum_{i=2}^N \eta_{1i} \epsilon_{i1} \quad (20)$$

Equation 20 shows that the residual supply price flexibility, η_1^R , contains the direct supply flexibility, $\eta_{11} = (\partial w_1 / \partial R_1) (R_1 / w_1)$. It also contains the cross price flexibilities, $\eta_{1i} = (\partial w_1 / \partial R_i) (R_i / w_1)$, and the reaction function⁶, $\epsilon_{i1} = (\partial R_i / \partial R_1) (R_i / R_i)$. So, though the estimated parameter, η_1^R , includes both the direct and indirect affect of R_1 on w_1 , it is not possible to discern the reaction function, which would be estimated parametrically as a conjectural elasticity in a conjectural variations or structural model. The idea behind Figures 1.a and 1.b can be interpreted using the last equation. The residual supply curve is the remainder from total supply to firm 1, after the reactions of rivals are taken into account as indicated in Equation 17. The parameter η_1^R encompasses the elasticity of non-local demand via the right hand term.

To examine the components of residual elasticity more fully, consider that in this type of market it is most reasonable to

⁶As discussed in footnote 1 this parameter is often termed the conjectural elasticity but, because it is an observed outcome rather than the firm's conjecture, terming it a conjectural elasticity is somewhat misleading.

expect that ϵ_{i1} is negative⁷ because the $\partial R_i/\partial R_1$ is expected to be negative. This expectation follows from the idea that if Firm 1 increases demand for the raw product then the price will rise and the non-local firms will desire less of it; i.e., the assumption is that outside demand slopes downward. The most interesting case in raw product market power may be to consider Firm 1's advantage in dropping the quantity of raw product demanded. The greater the absolute value of ϵ_{i1} , the more Firm 1 will have to decrease R_1 to achieve a decline in w_1 . This result can be seen in Figure 1.a. On the other hand, the smaller is ϵ_{i1} (the steeper is outside demand—as portrayed in Figure 1.b), the greater the raw product price drop will be for Firm 1.

8. Residual Supply for a Group of Firms

In many instances it is necessary to consider whether a merger within a group of firms will create an opportunity to exercise market power. This consideration is the basis for the model developed by Scheffman and Spiller (1987), whose premise is: if a group of firms faces a downward sloping residual demand, then a merger in the group may enable the firms to exercise market power by facilitating collusion. For the model developed here an upward sloping residual supply in the group of firms' input market implies the same result.

This scenario is the one considered in the subsequent analysis of the processing tomato market. The market power available to a regional group of firms which may merge or may act collusively is considered.

It can be shown that estimation of the residual supply equation is unchanged by extending the analysis to consider a group of firms (Durham, 1991). What may be changed is whether price-taking behavior by individual firms will be assumed. If it is, then the input demand relationship is simply marginal value product equal to the market price.

Analysis of a spatially-derived oligopsony power is possible using either the individual firm or a grouped firm model with or without competitive behavior assumed. If local groups of

⁷It is conceivable that $\partial R_i/\partial R_1$ could be non-negative. A processing firm may be unwilling to lose a grower to another firm and, hence, increase or at least maintain the original quantity demanded in the face of a price increase by a rival.

processing firms are able to influence the price paid in their production region, the residual supply flexibility found in estimating Equations 15 and 16 provides a test of the latent market power in the region or, equivalently, the power that a merger of the firms in the area would allow. The implications of a significant residual supply flexibility are most relevant in considering firm mergers and providing an impetus for closer analysis of market power in industries showing significant potential for such behavior. Comparison of results between regions of greater and lesser processor concentration should prove illuminating in this regard.

While a single firm estimation would provide a clear test of market power if the firm did face a significant upward sloping residual supply, finding a significant residual supply elasticity among a group of firms sharing the same input market area indicates that the firms could benefit from collusive behavior, which becomes a greater and greater possibility as firm numbers shrink. The residual supply elasticity tells us how much power the firms would have if they acted collusively. Analysis of the residual supply equations shows us that either the model developed for the firm or the group gives the same estimates of residual supply. Thus, our assumption that the group of firms acts competitively in the input market does not affect the estimation of residual supply.

9. Processing Tomato Industry

Processing tomatoes are grown in a fairly wide range in California and even into Arizona along the Colorado River. Processing tomatoes are purchased only by processing firms, because the varieties developed for processing do not have the properties desired in fresh tomatoes. Processor's use a uniform pricing scheme (Greenhut, Norman and Hung, 1987), that is they pay transportation costs and the price a grower receives from a particular plant/firm is not differentiated by distance⁸ from the plant. Co-operative processors handle about 15% of production, and a bargaining association exists which claims about 70% grower membership.

⁸There are a few firms who differentiate price by locale. This appears to be occasioned by the higher or lower risk encountered by grower's in those locales for production during a particular time period.

The co-operative processors do not have open membership or acreage. There are about 22 firms (including co-operatives) processing tomatoes in California in 1989. This is a smaller number than might be observed casually because firms with the same parent company are counted as one firm. There are about 40 plants, and plant size varies widely. The growers' association does not practice quantity control.

The majority of processing tomatoes are harvested from July through September though some areas may harvest as early as the end of May or as late as November. Weather conditions determine the percentage of tomatoes ripe for harvest simultaneously, so that the production costs per unit of output rise in cooler weather. Rainfall, due either to the damage it causes to the tomatoes or because it interferes with harvesting, essentially has the same impact in that it causes supply to shift inward.

10. Data and Econometric Model

Historical data are available only at the county level, but the residual supply model must differentiate between locally-grown tonnage which is processed locally, and tonnage which is "exported" to more distant firms. Since 1985 data allowing this differentiation have been collected by the Processing Tomato Advisory Board in the form of inspections records, which include the tomato condition, and the soluble solids level for each load of tomatoes. Permission was obtained to access these data in the form of regionally aggregated groups of firms/plants, which are located on Figure 2. The base data are collected on a truckload by truckload basis. For the purposes of the study these were summed into weekly observations primarily because delivery arrangements between firms and growers are conducted on a loads per week basis. Between 67 and 87 observations occur for six different regional groups.

Prices are taken from booklets published by the California Tomato Grower's Association (CTGA). The booklet published by the CTGA lists prices on a firm by firm basis including premium levels for early and late season and for quality factors such as soluble solids and good condition, as well as the rates for quantity deduction. Both price premiums and deductions for poor tomatoes are based on the sampling done at the inspection station. For each group a major firm's pricing scheme is chosen to represent prices in that group. Because

pricing schemes are not available for all years for all firms, there is an element of necessity in this selection of pricing scheme.

Two criteria are equally important in selection of a price schedule. One is to select one of the largest firms in terms of tonnage processed for which complete pricing information is available, and the other is to choose a firm which appears to be typical of its group. Generally, the pricing schemes between firms in a group are comparable. If not, the assumption is made that the largest has the most influence. Base prices within groups do tend to move together and deductions rates are almost always the same. Soluble solids premiums do sometimes vary by firm, generally, because they process different products. Continuous solids premiums are preferred over high/low premiums for the purpose of analysis, since the latter have little effect on prices in using the weekly average of soluble solids levels. Late season premiums may not be offered by all firms but are incorporated if some plant in the group uses them since that will be the firm still receiving tomatoes. Just and Chern's (1980) study used county level prices. These prices lose a great deal of the information available in the CTGA booklet. They are also of limited accuracy since the data are gathered from the survey of a small number of farmers in each county, and cannot reflect late season or quality premiums. Also, the county prices reflect total supply and not residual supply.

For those groups where the price growers receive is affected by the soluble solids levels of tomatoes, it, too, is an endogenous variable because growers may influence the level by their cultural practices. The soluble solids level is the only quality variable included in the demand equation, and it is only used in those groups where premiums for soluble solids are paid by the majority of processors in the group and for the entire period of study. In other groups premiums/penalties, if paid, are paid only for extremely high/low levels of soluble solids rather than for each incremental improvement. Because the data used in this study are developed from total weekly deliveries, quality levels reflect the weekly average for the factor and do not reach the high extremes for which the price is affected in these groups.

The use of weekly data had considerable impact on the estimation procedure. The processor attempts to schedule continuous delivery of the raw product while arranging transportation as efficiently as possible. In so doing the processor considers the relative availability of local and more distant raw product production and how weather patterns affect production.

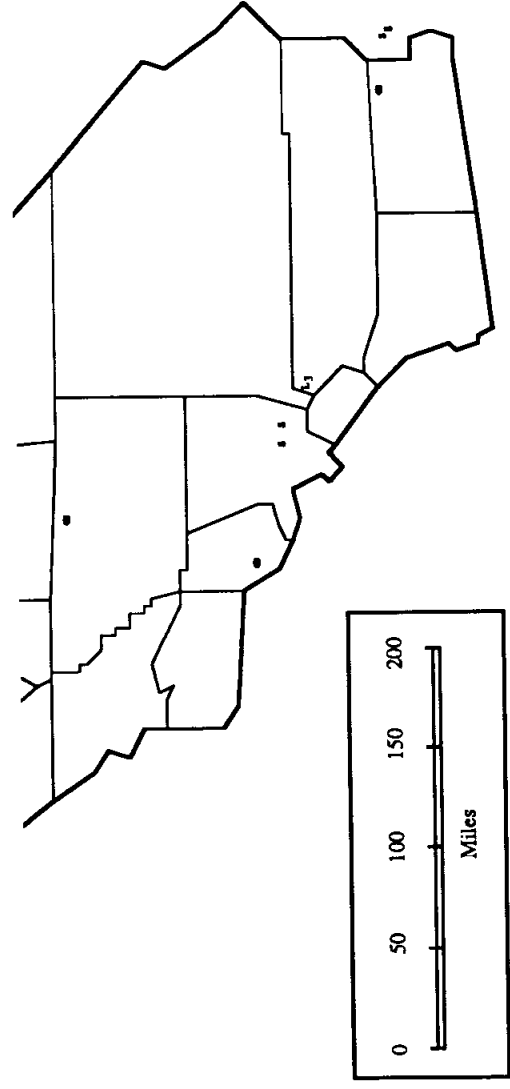
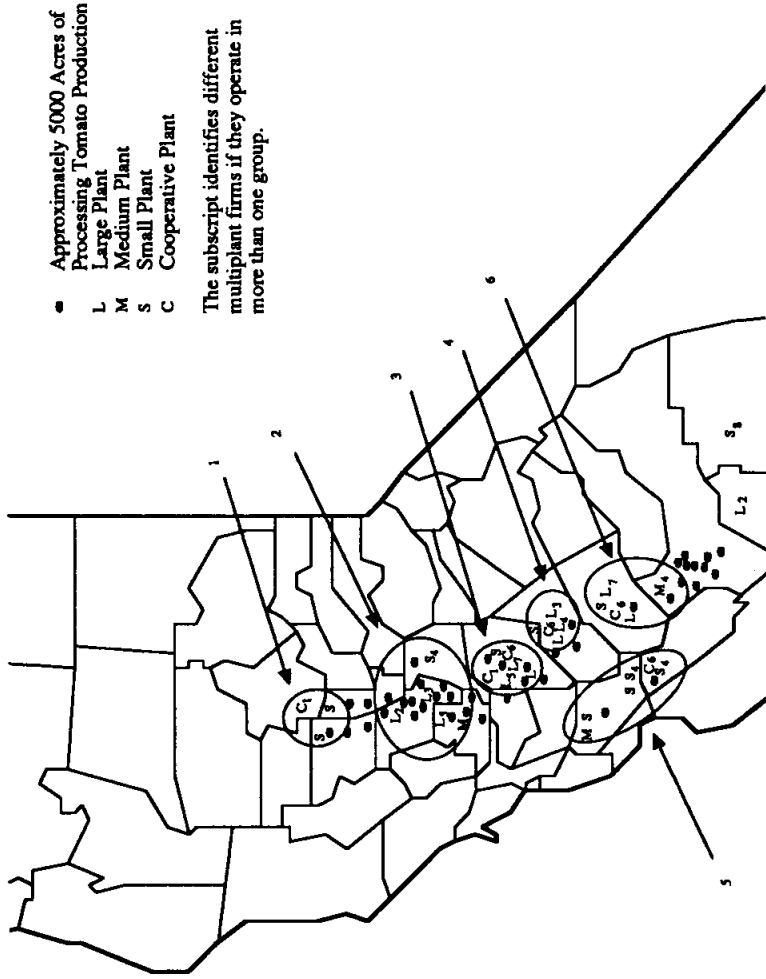


Figure 2 PROCESSING PLANT AND PRODUCTION LOCATIONS

As a result a plant may operate though all the raw product it uses is coming from non-local production areas. The pattern of operation is unlikely to be followed precisely on a year to year basis because, if a greater amount of overall production is desired, the number of weeks of delivery may be extended in all regions as well as increasing amounts delivered on a weekly basis. The decision process which governs the number of weeks in which a processor will desire input from a particular area is not observable directly, though we may hypothesize that the factors which enter into this decision include the factors which affect timing of production—such as weather, and the amount of total production desired—such as output prices.

Zero observations in the dependent variable, due to the processing patterns described above, cause difficulties in econometric estimation as well. Correction of the econometric problem is fortunately also a solution to the modeling problem.

It was Tobin (1957) who first recognized that ordinary least squares estimation of a truncated dependent variable led to biased and inconsistent estimates. Work by Olsen (1980) and Greene (1981) indicated that the bias is proportional to the probability of a limit observation. This observation led to a two step procedure (Amemiya, 1974) in which the probability of an observation being zero or positive is calculated in a probit regression as the inverse Mills' ratio and is used as an instrument in the second step ordinary least squares regression. The inverse Mills' ratio is the ratio of the probability density function to the cumulative density function of the standard normal as evaluated from the probit regression parameters⁹. The estimation in this study is more complicated than the ordinary least squares correction described because a set of simultaneous equations is being estimated and one of them has a dependent variable (quantity demanded) censored by unobservable latent variables. The method undertaken here is based on Lee's 1978 adaption of Amemiya's (1974) procedure to multiple equations, which Lee has shown to be more asymptotically efficient than other estimators.

⁹The use of the inverse Mills' Ratio may be understood intuitively by examining the conditional expectation of a truncated dependent variable Y_i :

$$E(Y_i | Y_i^* > 0) = bX_i + E(\varepsilon_i^* | Y_i^* > 0) = bX_i + E(\varepsilon_i | \varepsilon_i^* > -bX_i),$$

and if $\varepsilon_i^* \sim N(0, \sigma^2)$ then $E(\varepsilon_i | \varepsilon_i^* > -bX_i) = \sigma \lambda_i$, where λ_i is the inverse Mills' ratio.

For a detailed description of the econometric procedure undertaken in this analysis see Durham (1991).

A three step procedure is followed in estimating residual supply. The procedure is briefly reiterated here. In the manner described above, the first step is a probit estimation in which the dichotomous decision by firms to contract for tomatoes in their local growing region in a particular week is estimated as a function of weather variables and finished product prices. The Mills' ratios calculated from this regression are used as instruments in the second step to account for the bias introduced by a zero observations of the quantity variable. In the second step raw product price and locally processed raw product production are regressed on all exogenous variables including the Mills' ratios. In the final stage, the residual supply and input demand relationships are estimated using the estimated prices and quantities from the previous stage as instruments. Due to the time-series nature of the data and the inherent ebb and flow of a harvest season, autocorrelation is tested for and is not rejected, using Durbin-Watson tests. The autocorrelation parameters are made on a year to year basis because of the gap between observations at the end of one year's growing season and the beginning of the next. In essence a weighted two stage least squares procedure is undertaken which has been preceded by an accommodation for the properties of the censored regression equation.

Separate estimations were performed for six regional groups of firms. For three of the groupings it was also necessary to estimate a third equation, which accounts for the fact that in these regions a majority of the processors pay a premium for the soluble solids level of the tomatoes. The soluble solids level of the tomatoes is thus an endogenous factor in the input demand equations. The composition of the six regional groups of tomato processing firms may be observed in Figure 2.

11. Results

The residual supply equations are estimated in price dependent form for two reasons: one, because the processes leading to equilibrium in this market are initiated by tonnage intentions and, two, because the statistical testing of the price flexibility is clear in this form. A price flexibility of zero indicates an infinite price elasticity or that a group of firms does not have the ability to exercise market power on a regional basis. A

positive price flexibility indicates that a group of firms acting collusively can exercise an influence on the price they have to pay for tomatoes. Clearly, a test of the significance of the coefficient on tonnage in the inverse residual supply equation provides the best test of the potential for market power.

The effect of tonnage on raw product price was found to be positive in all but one instance and was significant in three groups. In the single case where the estimated tonnage coefficient is negative, the effect is very small and not significantly different from zero.¹⁰ Because the level of production varies widely among the groups, it is not particularly useful to interpret the magnitude of the coefficient on tonnage and, thus, these coefficients are converted into price flexibilities and discussed in that form.

The primary focus of this paper is to test the hypothesis that processing firms in California have the potential to exercise market power in the procurement of tomatoes in the immediate vicinity of their plant. Adjunct to this hypothesis is that groups of firms who are at greater distances from rivals should face more flexible (less elastic) residual supplies. To examine these hypotheses the inverse residual supply equations have been estimated.

In considering the impact of mergers the Department of Justice 1984 Merger Guidelines delineate an anti-trust market as one which can effect a "small but significant" price change above the competitive level. Earlier guidelines, which were more specific, indicate that an antitrust market is one in which the residual demand or supply elasticity, as estimated from a linear model, is less than 10 (Scheffman and Spiller, 1987, p. 131). For a price flexibility an anti-trust market would be indicated for a value greater than 0.10. Under that benchmark mergers of firms whose joint residual demand price flexibility was greater than .10 would be subject to scrutiny as merger partners.

Table 2 presents the price flexibilities of residual supply. Price flexibilities for two of the groups is greater than 0.10.

¹⁰This case occurred in Group 4, where a major processor withheld permission to include the data for their firm. Omission of its data clouds interpretation of the Group 4 results, but note that the firm's omission effectively treats it as an outsider, making a flat residual supply for the remaining firms a quite plausible outcome.

Table 2 RESIDUAL SUPPLY PRICE FLEXIBILITIES, PRICE ELASTICITIES, AND CONFIDENCE INTERVALS

Group	(1)	(2)	(3)	(4)		(5)	(6)	(7)
	Price Flexibilities η	Elasticities $\epsilon = 1/\eta$	Variance of η	Lower	Upper	90% Confidence Intervals	1987 % of Local Use	% of Total Utilization Locally Produced
1	.1105	9.05	.00917	-.0470	.2680		35	80
2	.0417	23.98	.00080	-.0049	.0883		43	52
3	.0379	26.42	.00190	-.0152	.0605		35	15
4	-.0069	-144.69	.00008	-.0221	.0082		22	11
5	.0180	55.49	.00006	.0054	.0307		55	16
6	.1163	8.6	.00204	.0420	.1906		29	53

These flexibilities are evaluated at the mean of tons and raw price for observations in which tons are non-zero. Monte Carlo studies performed by Dorfman, Kling, and Sexton (1990) support the use of a first-order Taylor series expansion to develop variance and confidence intervals for the point flexibility estimates. Upper and lower bounds for a 90% confidence interval on the price flexibilities are based on the following variance formula¹¹:

$$\text{Var } \eta_R = \frac{\bar{R}^2}{\bar{w}^2} \text{Var}(b_R) + \frac{b_R^2 \bar{R}^2}{\bar{w}^2} \text{Var}(\bar{w}) - \frac{2b_R \bar{R}^2}{\bar{w}^4} \text{Covar}(b_R, w)$$

The covariance term is very small and assumed to be zero in these calculations. Examination of these flexibilities shows them to be small though significantly different from zero in three instances. As hypothesized, the flexibility of residual supply increases with distance from competitors. This result is evident in comparing a group's flexibility to its location on the map of California in Figure 2. The more spatially isolated groups in the study are Group 1 and Group 6, which both have measured flexibilities greater than 0.10. Groups closer to the center have lower flexibilities.

The residual supply flexibilities should tell us whether the firms in a group would be able to influence their raw product price if they acted collusively. Groups 3, 5, and 6 have a price flexibility which is significantly greater than zero; i.e., the 90% confidence¹² interval does not include zero. Group 1's flexibility, though it is the second highest, is insignificant. There are fewer observations for Group 1 (13 to 20 less than all other groups) because the plants in this group operate for fewer weeks than others. In addition, they operate more consistently over the season than other groups and, thus, have a low variation in tonnage. Because the variance of tonnage, $\text{var}(R_1)$, is low, the variance of the estimated flexibility is high. Group 2, with the

third highest flexibility value, has the second smallest number of observations in the sample, and with a confidence interval of 86% the lower bound on its flexibility would remain above zero.

When local processors purchase the majority of their input locally (Column 7), they have higher flexibilities. This result is not surprising since these firms have less need to compete in neighboring regions for production. In 1987 Groups 1, 2, and 6 purchased over 50% of their tonnage locally. This condition appears to override the possible importance of the percentage of the local production the resident group uses as a factor influencing the residual supply flexibility. Group 5, despite the fact that it uses the highest percentage of the locally produced tonnage among the groups, must obtain the majority of its total processed tonnage non-locally which may explain its low flexibility. A number of points may be made by comparing these numbers and observing the relationship of each group in spatial terms. Group 6 has the advantage of encompassing Fresno County which has the largest, as well as longest, period of production in the state. This group has the highest price flexibility, despite having one of the smaller percentages of local use. By examining the map one may observe that any user of Fresno production must pay to ship the tomatoes a greater distance than Group 6 firms must. More distant firms are unlikely to interfere with the equilibrium price paid by firms in Group 6, especially as their use of production from Group 6 is primarily in the off season of production in their own locale.

Table 3 provides estimated coefficients, t-statistics, and R^2 statistics for the six inverse residual supply equations. In general, the other results of the residual supply estimation are as expected. The remaining variables included in the residual supply equation fall into 2 categories: variables affecting grower supply (including weather and farm input prices), and variables influencing rival processor's demand for the raw product, which include supply characteristics for their local area.

Careful analysis was undertaken to determine the variables influencing grower supply. This testing included determination of the primary competitors for acreage in the various growing regions. Value per acre of competing crops was originally included in all estimations but was eliminated when found insignificant. The decision to drop these variables was also made by Just and Chern (1980) for the period after adoption of

¹¹Confidence intervals are based on the asymptotic normality of η_R , $\eta_R \pm 1.645 \text{var}(\eta_R)^{1/2}$.

¹²This conclusion is unchanged for a 95% confidence interval.

Table 3 RESIDUAL SUPPLY EQUATIONS

		Group					
		1	2	3	4	5	6
(1)	Tons	.000247 (1.15)	.000033 (1.47)	.000065 (2.75)	-.000047 (-0.75)	.000059 (2.35)	.000139 (2.57)
(2)	Avg. Temp.	-.39296 (-1.58)	-.03897 (-1.36)	-.00781 (-0.19)	-.00245 (-0.61)	-.19163 (-1.43)	-.28604 (-3.51)
(3)	Lagged Rain	1.8477 (1.74)	1.5606 (1.09)	2.8788 (4.55)	-1.0625 (-0.77)	-1.0729 (-1.43)	1.7828 (0.75)
(4)	Harvest Wage	11.183 (2.94)	2.9491 (1.38)	6.5908 (7.47)	7.4733 (8.10)	5.6452 (5.86)	1.8862 (-0.91)
(5)	Fuel Index	-0.0440 (-0.67)	-0.0734 (-1.03)	0.0410 (1.02)	-0.1113 (-3.79)	0.1581 (3.18)	-0.0347 (-0.48)
PPI Finished							
(6)	Product Price	-0.1695 (-1.03)	0.28527 (3.67)	0.17879 (9.88)	0.24158 (6.71)	0.09534 (6.77)	0.07120 (1.14)
(7)	Plant Indicator	35.66 (2.00)		1.321 (0.73)	-20.12 (-2.49)	-0.981 (-0.37)	
(8)	Rival's Soluble Solids	-0.9355 (-1.03)	-3.5577 (-1.59)		0.2767 (0.36)	-.0747 (-1.11)	
(9)	Rival's Mills' Ratios			-0.8505 (-2.06)			-0.7025 (-1.40)
(10)	Stock/Move	-162.79 (-2.26)	11.31 (1.00)	5.31 (1.00)	-5967 (-2.87)		2.87 (0.22)
(11)	Cans & Labor Index	2.522 (1.13)	0.656 (1.26)	0.220 (0.50)	-2.686 (-2.60)	0.237 (1.10)	-0.0283 (-0.06)
(12)	Trans. Serv.	6.260 (2.63)	0.456 (0.84)	0.410 (1.13)	3.015 (4.40)	0.270 (1.71)	1.340 (2.44)
(13)	Constant	-560.64 (-1.77)	-157.02 (-2.56)	-121.16 (-3.43)	107.17 (1.05)	-65.61 (-2.39)	-8.470 (-0.14)
(14)	R ² (adj)	.67 (.61)	.70 (.65)	.92 (.90)	.89 (.87)	.76 (.73)	.77 (.73)

the mechanical harvester for processing tomatoes. With the elimination of alternative crop values there are no regional differences between variables affecting grower supply.

The estimated coefficients and t-statistics for variables affecting grower supply are in rows (2) – (5), and coefficients generally have the expected sign when significant. Average temperature accounts for the progression of the harvest season. Growers plant more tomatoes for harvest as temperatures rise. Thus, the supply function should shift outward; i.e., for a given quantity, a lower price is necessary. Though not always significant, the temperature variable does have the expected negative sign. Rainfall should have the opposite affect, causing an inward shift in supply—a higher price for the same quantity of tomatoes. In only one instance is this contradicted by a significant negative sign which appears for Group 5.

The variables in rows (4) and (5) in Table 3 represent grower production costs; and, thus, both are expected to have a positive relation to w —as production costs increase growers will require a higher price for any level of production. With only one exception the lagged harvest wage coefficient has the expected positive sign, and the non-positive coefficient is insignificant. FUELI, an index of the price of diesel fuel, is intended to measure the price of the energy input to growers but is often of the wrong sign. This result appears to have its root in the inclusion of the transportation services index (Col. 12) which enters residual supply as one of the parameters affecting outside demand. This variable, which is included to account for processing firms' transportation costs, has an unexpectedly positive coefficient; it may be reflecting farm level energy costs more accurately than FUELI, which was taken from a national index.

Rows (6) through (12) represent variables which enter residual supply through outside firms' demand. The first is the producers' finished price index (PPI) for neighboring groups. As outside firms' finished product prices rise, their level of demand will increase. Collinearity between price indexes for the different groups is severe enough that in effect the output price index represents a state level variable included for each region's demand. Each region's actual index is used for estimation in the second stage. The finished product price index has the expected positive sign for all groups except Group 1 and, in this case, it was insignificant.

Two plant openings and one closure took place during

the period of this analysis. A firm indicator or dummy variable was constructed which takes on a value of one when the relevant firm is open and, hence, is expected to shift the region's raw product demand curve outward. As the additional plant increases capacity in its region, it may increase quantity and price of the raw product, which can, in turn, affect its neighbor's market and, thus, residual supply. The only firm indicator variable which supports this idea is the one entering Group 1's residual supply from Group 2 with a significant positive sign. The plant dummy for Group 3 accounts for both the closure of a plant to the south (Group 4) and the reopening of one to its north (Group 2). The firm dummy in Group 4's and Group 5's residual supply pertains to the opening of a plant in Group 6. The reasons for a negative sign on these last two variables are not clear but may have alternate explanations in consideration of the fact that this plant is owned by the same firm as two others, one of which is in Group 5.

Rivals' soluble solids level or SLB (Row 8) could decrease demand for neighbors' product as it increases the preference for one's own: these coefficients are negative as expected but not significant in residual supply. This relationship is somewhat complicated, since it implies SLB should be negative in residual supply though positive in own demand.

The sign of the Mill's ratios (Row 9) which are calculated from the Probit regressions, enter residual supply when a group provides the alternate location of production for an outside region, are negative as expected. The Mill's ratio enters Group 3's (San Joaquin County) residual supply from its southern neighbor who receives production from San Joaquin county when local tonnage is not being used.

Row 10 represents the ratio of January stocks of canned tomatoes to the preceding year's movement of canned tomatoes between January and July. The January stock level is relevant because this is the time when processing tonnage intentions are usually announced. The expected sign of Stock/Movement is negative because if stock levels are high relative to expected use, firms will expect carryover to be high for those products and decrease upcoming production levels. In all cases, when its effect is significant it does have the expected sign.

Rows (11) and (12) represent operating costs for the processing firms and, thus, are expected to have a negative effect on raw input demand. Row 11 is an index combining can prices and processing labor wages. It is negative in the single instance

in which it is significant. TRANSI, which is an index for transportation services, does not have the expected sign. These last two variables change only on an annual basis and it is not surprising that with only 5 years of data it is impossible to resolve their influence on residual supply. Further, as noted above, TRANSI may be picking up the influence of fuel costs on grower supply.

For the reasons of space the input demand, and soluble solids, equations are not discussed in this paper, though the variables which affect the former are described due to their entrance into the residual supply equation.¹⁵ Because identification of the residual equation in this type of approach is generally critical, some discussion of the input demand results is, however, relevant. Two variables were found to significantly impact input demand and, thus, identify residual supply. The first of these is regional changes in capacity via plant openings or closings. The second identifier is the Mills' Ratio estimated from probit estimation to determine the decision of operating a plant from local production and to thus correct for the bias introduced by zero observations of the dependent variable. This variable can be taken to indicate the probability that the firms in a group will demand local production during a week of operation. This means that the relationship to demand is, of course, positive. The Mill's ratio was not calculated for groups which had one or

¹⁵Neither Baker and Bresnahan (1987) nor Scheffman and Spiller (1987) present the equivalent equation (firm supply) for their residual demand estimations. Presumably, they do not because of the ambiguous meaning of this equation, and the estimation in those papers is an instrumental variables rather than two-stage least squares approach. To the extent that firms are currently acting competitively, as is assumed in Scheffman and Spiller's model, then a quasi-reduced form for the input demand equation may be estimated as $R_j = R_j(w_j, \rho_j^A, \Delta_j, MR_j)$ where R_j is the locally grown raw product used by firm j , w_j is its price, ρ_j^A and Δ_j are the processing firms output prices and cost shifters, and MR_j is the Mills' Ratio. The demand relationship thus estimated represents a typical aggregate input demand. If firms are not acting competitively then all variables which enter residual supply via outside firms enter the demand relationship and the meaning of the estimated parameters becomes ambiguous. Additionally, it will be difficult to identify the demand relationship unless firms are more distinctly separate in space and exogenous factors shift supply in regions distinctly. Fortunately, as discussed earlier, the econometric estimation and interpretation of residual supply remains the same in either circumstance.

less week's of operation with only non-local tonnage. In each input demand equation one or both of these variables was significant and enabled identification of the residual supply equation.

12. Conclusions

This paper develops and applies a model which may provide a useful addition to empirical models analyzing market power. The objectives of this research were first, to extend models recently developed for analysis of market power in output markets to analysis of markets for agricultural inputs, and second, to examine the potential for imperfect competition in the market for processing tomatoes.

Many other agricultural products have the same processing concentration and transportation considerations which make the processing tomato market a candidate for the exercise of input market power. The model constructed in this research is appropriate for analysis of these types of markets and it appears to meet the purpose for which it was constructed. It may provide a useful alternative to the empirical models derived from Appelbaum.

The results show that the potential for the exercise of market power due to spatial factors in the processing tomato market in California is limited. However, two regions, which include aggregates of firms in Colusa, Sutter, and Yuba Counties, and of firms in Merced and Fresno Counties, show residual supply price elasticities less elastic than those implied by the Department of Justice previous 5% rule for anti-trust markets. This ruling implies a price elasticity of 10 or a price flexibility of 0.10 when estimating the parameter from a linear model. Price flexibilities for these regions are both above 0.10, indicating that these markets would bear examination if plants within them considered merging.

In general, though, the results imply that rivalry between neighboring markets is adequate to make them competitive. Spatial models of competition as summarized in the recent book by Greenhut, Norman, and Hung (1987), therefore, appear to be somewhat deficient since, by construction, these spatial models assume that no market overlap occurs. In the processing tomato market overlap is the rule, and occurs for two primary reasons. One is to obtain production before or after one's own region is in its most productive period. The second is to spread production

to ensure against localized shortfalls in delivery. The assumption of non-overlapping markets is seen to be incorrect for the agricultural market analyzed in this study, and the assumption appears to be critical in determining the extent to which market power can occur. Casual observation suggests that many other spatial markets also overlap to some extent. Thus, spatial theory needs to be expanded to account for inter-regional competition, and conclusions about the implications of spatial factors for imperfect competition need to be re-evaluated.

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