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TOMATOES, TECHNOLOGY, AND OLIGOPSONY

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by

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Abstract

This paper draws on the theory of monopsony and oligopsony to develop an empirical test for the presence of the same in the situation where an exogenous shock on the relevant market may be observed. An application of this test is demonstrated for the tomato processing industry, where the exogenous shock is created by the introduction of mechanical harvesting technology. The results are remarkably consistent with oligopsonistic dominant firm-price leadership, and statistical tests suggest rejection of the null hypothesis of competition.

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1. Introduction

One of the most difficult problems facing economists is to determine from market data whether or not market power is being exercised. Textbook cases show very clearly how, for example, monopolists maximize profits with given cost and demand structures, but cost information is simply not adequately available in most practical problems to determine whether such pricing rules are operative. In lieu of such hard evidence, antitrust court cases have turned to more indirect evidence relating to use of information channels, timing of price movements, or unrelated evidence associated with legal technicalities. In the absence of rather abundant cost information, rigorous economic analysis accompanied by econometric investigatory possibilities, has thus had limited applicability.

The purpose of this paper is to demonstrate a case where empirical analysis of market behavior can lead to evidence favoring either competition or market power when cost or profit information cannot be measured directly. The necessary situation is one in which some major change has occurred in an exogenous force affecting the side of the market which is unquestionably competitive and where market data are observable both before and after the exogenous shift. If the questionable side of the market is competitive, its price-quantity relationship (supply or demand) should thus be unaffected, whereas market power would imply a shift in its price-quantity relationship. The properties of the implied shift are determined by the properties of the exogenous force, and a comparison of properties of the observed shift with the implied shift can provide evidence for or against the market power explanation.

The case of the tomato harvester provides such a possiblity. The introduction of the tomato harvester in California in the mid-1960s led to one of the most dramatic and interesting cases of agricultural mechanization on record. Without doubt, the harvester led to a substantial change in the structure of tomato supply as variable labor costs were replaced by fixed machine costs. Furthermore, processing tomato farmers in California switched from almost no machine harvesting to virtually complete machine harvesting in the very short period between 1963 and 1967 so there is only a three-year interim period in which one must consider other coincidental changes that may be partially responsible for observed shifts.

In the following section this paper begins by drawing on the theory of monopsony and oligopsony to demonstrate implied shifts in observed market phenomena when such structural change takes place. It is a simple matter for the reader to extend the analysis to the investigation of monopoly or oligopoly based on a structural shift in demand. Results from estimation of the California processing tomato market at the farm level are then presented and compared with theoretical implications associated with market power. The results are consistent in every respect with the implications of dominant-firm, price-leadership oligopsony on the part of tomato processors in California.[1]

2. Structural change with market power

Before examining the effects of a structural change on observed market behavior, one must consider characteristics of the structural change. For example, one would expect that adoption of the harvester would lead to a reduction in variable costs (associated with labor) and an increase in fixed costs (associated with machinery). This would supposedly lead to more inelastic short-run supply. That is, once fixed costs are sunken, tomato producers must operate at a level consistent with the capacity of their expensive capital equipment to recover fixed costs. Fixed costs cannot be adequately spread if output is reduced nor can output be easily increased without investing in additional costly capital equipment of a very lumpy nature.

Several conditions surrounding the processing tomato industry in California make this situation particularly acute. First of all, farmers who are large enough to spread the costs of mechanical harvesters profitably have found reliance on rental machines very risky. Tomatoes are a sensitive crop requiring urgency in harvesting whereas weather conditions have proven to make custom harvesting unreliable even when under contract because of associated queuing problems. These conditions are also partly responsible for the replacement of small tomato farms with larger ones which can efficiently use the technology and thus face similar ex ante production costs. A second factor which has tended to make farmers rely solely on high-fixed-cost mechanical technology is that both tomato varieties and processing and transporting equipment have been converted at the impetus of processors to accomodate mechanical technology and, in fact, discourage hand harvesting. For example, canners are no longer equiped to receive tomatoes in boxes as in the old hand harvesting days. If a grower were to use hand harvesting to increase production above his mechanical harvesting capacity in the short run, then he has to incure additional costs of obtaining his own boxes and transferring tomatoes from boxes to bins or bulk facilities.

To consider the effects of this change in technology on tomato producers, suppose the costs of preparing seed bed, planting, and raising a tomato crop to maturity are given by

$$TC^* = C_1(Q) + FC$$

where Q is tomato production and FC is fixed costs in the absence of mechanical harvesting technology. Since labor costs under hand harvesting methods occur at a constant rate per unit of production (within a season), say C_2 dollars/ton, harvest costs are $C_2 \cdot Q$. Thus, total production costs are

$$(1) \quad TC_0 = TC^* + C_2 \cdot Q = C_1(Q) + C_2 \cdot Q + FC .$$

Suppose, on the other hand, that machine harvesting technology is used in place of hand harvesting. Harvesting costs in this case may be reasonably represented by

$$HC = HFC + C_3(Q)$$

where HFC is fixed cost associated with the harvester and C_3 is fuel and operator cost. Hence, total production costs with mechanical technology are

$$(2) \quad TC_1 = TC^* + HFC + C_3(Q) = C_1(Q) + C_3(Q) + FC + HFC \; .$$

To examine the effect of mechanical technology on competitive producer supply, note that (1) and (2) imply short-run marginal costs of

$$(3) \quad MC_0 = C_1' + C_2$$

and

$$(4) \quad MC_1 = C_1' + C_3'$$

under hand and mechanical methods, respectively. Further note that, at the margin, mechanical costs are apparently smaller than hand harvesting costs at observed price levels, i.e., $C_3' < C_2$; otherwise partial hand harvesting methods would have continued at the margin or at least growers would have attempted to persuade processors to continue to receive hand-harvested boxes.[2] Assuming the usual cost curve shapes ($C_i' > 0$, $C_i'' > 0$, $i = 1,3$), the resulting implications are demonstrated in Figure 1. That is, at a comparable price, say P*, the short-run marginal cost or supply curve is further right and is more sharply increasing under mechanical technology than under hand methods (note that this holds if either $C_1'' = 0$ or $C_3'' = 0$ as well). Since quantity is also greater at the same price, the supply elasticity must thus be smaller under mechanical technology than under hand harvesting at comparable prices.

Consider now the case where processors exercise market power in the tomato market. To illustrate this case, suppose tomato consumption demand is competitive and represented by $\bar{D}$ in Figure 2. Suppose further that processing costs per unit can be represented by the vertical difference in $\bar{D}$ and D so that D would be the demand curve facing producers in the case

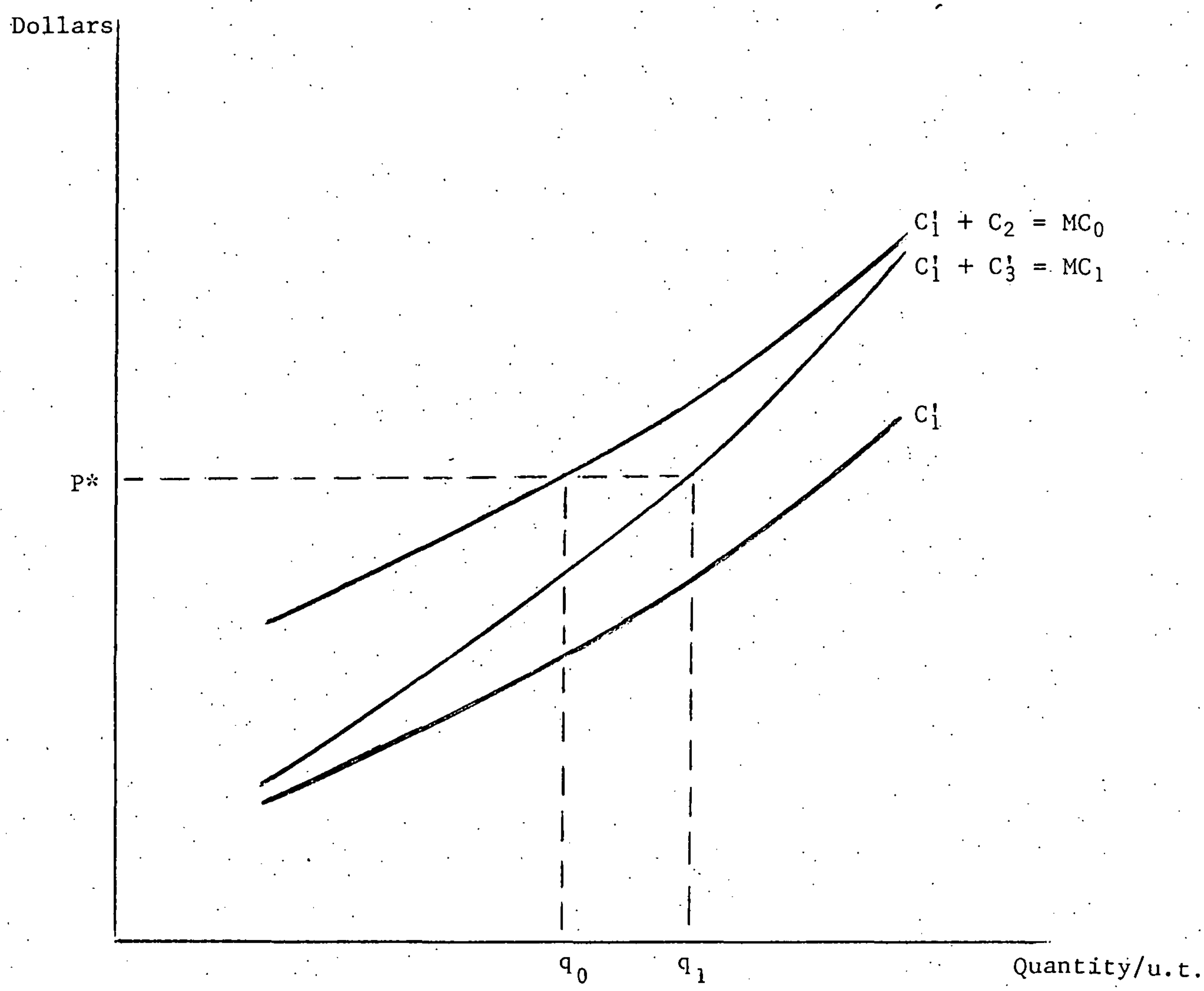

FIGURE 1. Shift in Cost Structure as Variable Costs are Replaced by Fixed Costs

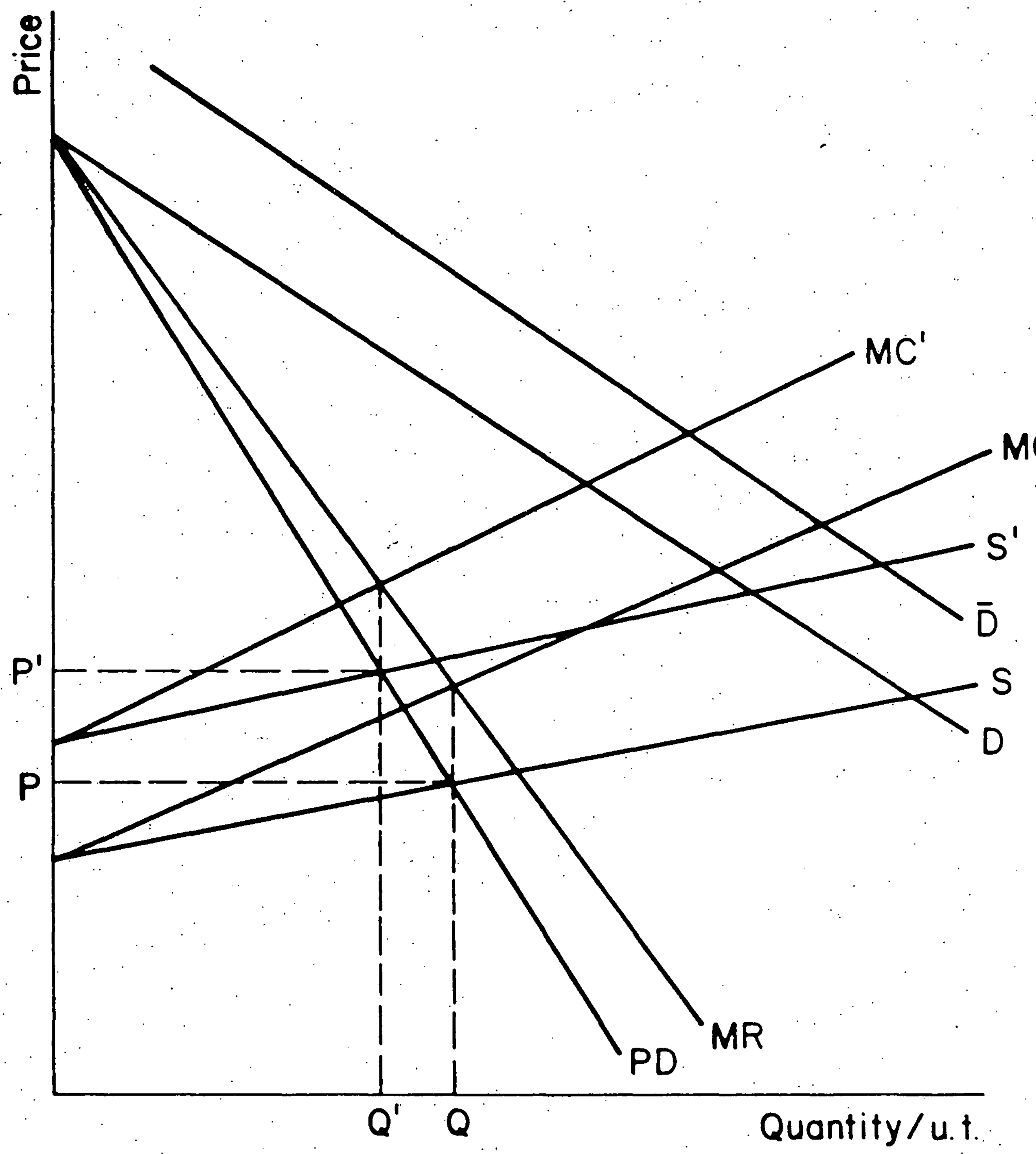

FIGURE 2. Perceived Demand Under Monopsony

of competition. Now to illustrate price and quantity determination in the monopsonistic case, suppose that supply changes from S to S'. Normally, with competition, the demand curve can be traced from price-quantity observations by varying supply while holding demand fixed. If a middleman-processor operates as both a monopoly and monopsony, however, he will maximize profits by equating his marginal revenue (MR) and marginal cost (MC in the case of S and MC' in the case of S'). Hence, the observed producer price and quantity, respectively, are P and Q in the case of supply S and P' and Q' in the case of supply S'. Continuing to vary supply, one thus traces out the "demand" curve PD perceived by producers. In this case, it is the PD curve that would be estimated econometrically by using producer prices and quantities. One can easily note also that a similar observation could be made if processors purchased monopsonistically but sold competitively. By simply reinterpreting the MR curve as the demand curve exclusive of processing costs (thus replacing D), the same arguments would again imply observation of PD rather than the true demand curve using producer prices and quantities.

Now consider the situation where supply becomes inelastic in response to tomato harvester adoption as in Figure 1. Suppose preharvester supply is represented by S_0 in Figure 3, and postharvester supply is represented by S_1. Thus, the relative positions of S_0 and S_1 are consistent with the explanation of Figure 1, i.e., supply shifts toward the right at prevailing prices. Now, where marginal revenue in the case of monopolistic selling (or demand exclusive of processing costs in the case of competitive sales) is represented by MR, the price and quantity would be P_0 and Q_0, respectively, in the preharvester period and P_1 and Q_1, respectively, in the postharvester period. Furthermore, upon noting that PD, MR, and D always converge at the price axis in Figure 2, it is clear that PD_0 would be the perceived demand in Figure 3 in the preharvester case, and PD_1 would be the perceived demand in the postharvester case. Clearly, from Figure 3, the slope of the perceived demand will always increase negatively as the slope of supply increases positively in the case of monopsonistic buying regardless of whether or not monopoly prevails in selling the processed goods.

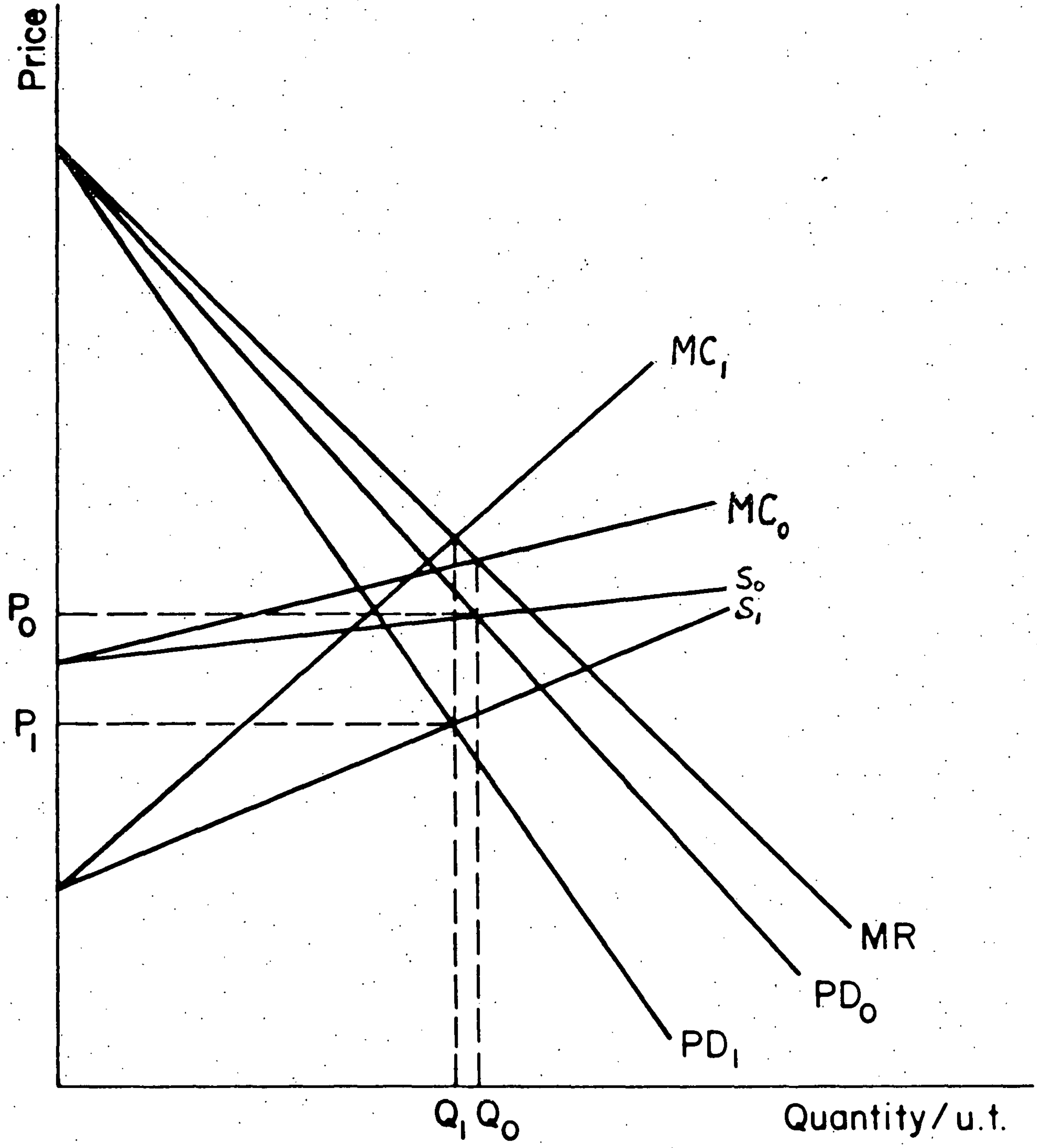

FIGURE 3. Effect of Technological Change Under Monopsony

To further generalize the arguments for the case at hand, suppose the tomato processing industry is oligopsonistic with dominant firm price leadership.[3] Oligopsonistic price leadership by a dominant firm may be described by Figure 4.[4] In this case, SS represents growers' supply of processing tomatoes, D_S represents demand for processing tomatoes by all processors except the dominant firm, and D_L represents demand for the dominant firm's processed tomatoes exclusive of processing costs. For simplicity, assume that the output market is segmented so that the effect of other firms on D_L need not be considered. Now under the leadership-firm hypothesis that all other firms adopt the leader's price for the growers' product, an excess supply to the dominant firm S'S can be constructed by horizontally subtracting D_S from SS. Where MC is the dominant firm's marginal cost associated with S'S and MR is the dominant firm's marginal revenue associated with D_L, the dominant firm's profits are maximized by equating MC and MR, thus purchasing quantity Q from growers at price P. Other firms would purchase Q' - Q from growers also at price P so that market price and quantity would be P and Q', respectively.

In this context it can be shown that the effects of technological change affecting producers would be qualitatively the same with oligopsonistic dominant firm price leadership as with monopsony. That is, if one traces price-quantity points generated by parallel shifts in supply (from S to S*), one can again develop the grower's perceived demand curve PD^o in Figure 5 which is the relationship estimated econometrically in place of the true demand curve. Similarly, one can trace the price-quantity points associated only with the dominant firm, PD*. Comparing Figure 5 with Figure 2, it is clear that PD* (rather than PD^o) is comparable to the perceived demand curve PD in Figure 2 under monopsony. Hence, all the qualitative conclusions surrounding perceived demand in Figure 3 noted above apply to PD* in Figure 5. Finally, it can be noted that, by construction, the perceived demand curve under oligopsony PD^o differs from PD* by a horizontal amount specified by D_S, the elasticity and location of which does not change as supply changes. The same qualitative conclusions associated with perceived demand in Figure 3 thus apply to perceived demand under oligopsonistic dominant firm-price leadership. Hence, the introduction of harvesting equipment which replaces variable costs with fixed

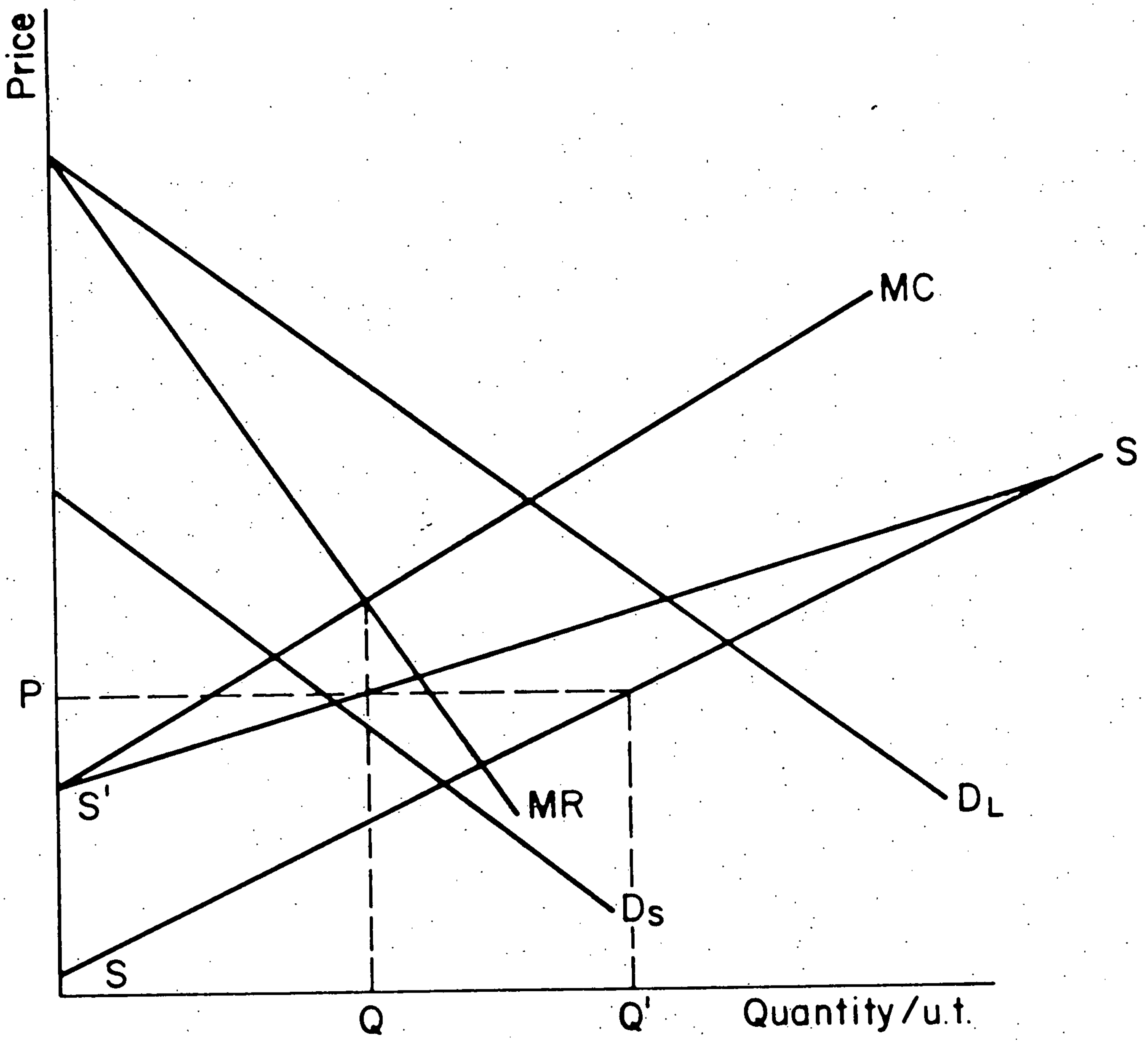

FIGURE 4. Price Determination Under Oligopsony

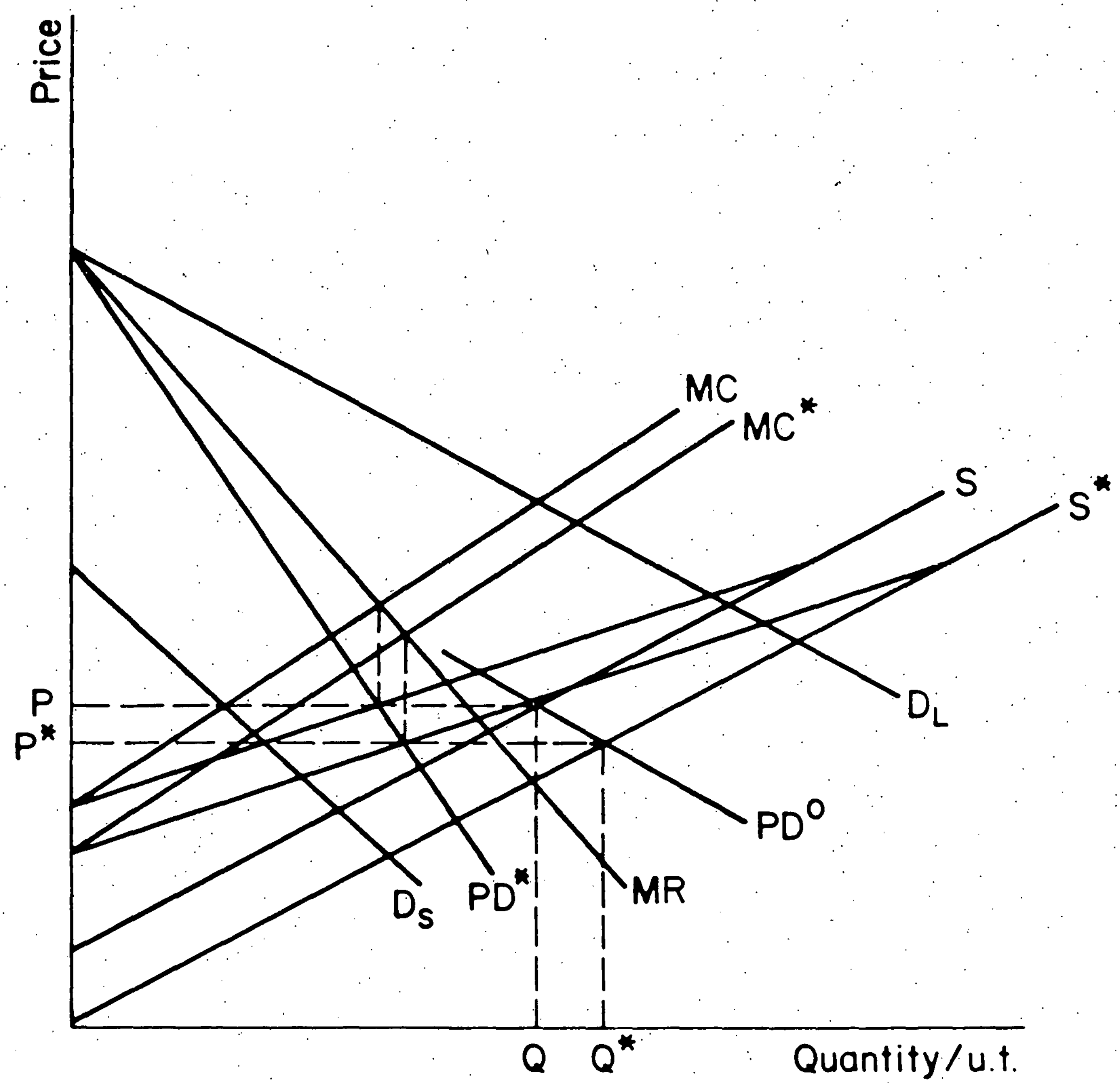

FIGURE 5. Perceived Demand Under Oligopsony

costs and, as a result, shifts supply to the right and toward inelasticity would have the following effects. First, the perceived demand (the estimated econometric demand) would be shifted downward and become more steeply sloped. This shift, in conjunction with the supply shift, would cause the equilibrium grower price to fall, while the effect on production may be either positive or negative. Finally, because price falls, the size of the market associated with nondominating firms would increase along D_S, while the size of the market controlled by the dominant firm may or may not increase (as in the case of the monopsonistic firm in Figure 3).

By comparison with the case of competition in processing tomato demand, one would expect alternatively the same shift in supply. However, the structural change in supply would not cause a shift in perceived (or estimated) demand; furthermore, while price would thus fall, the quantity would definitely increase in contrast to the uncertain outcome above.

While the above diagrammatic discussion presents the crux of the intuition of this paper, a somewhat more formal mathematical derivation can strengthen or verify the qualitative conclusions. To allow simple tractability, suppose first-order Taylor series approximations are invoked so that supply can be represented by

$$(5) \quad Q_0 = a_0 + a_1 P , \quad a_1 > 0 ,$$

where Q_0 is quantity supplied and P is price; demand by the dominant firm or colluding share is

$$(6) \quad Q_1^d = b_0 - b_1 P , \quad b_0, b_1 > 0 ,$$

where Q_1^d is the associated quantity demanded; and demand by other firms is

$$(7) \quad Q_2 = c_0 - c_1 P , \quad c_0, c_1 > 0 ,$$

where Q_2 is the associated quantity demanded by other firms. In this context, excess supply to the dominant or colluding share is

(8) $Q_1^s = Q_0 - Q_2 = a_0 - c_0 + (a_1 + c_1)P \equiv \alpha_0 + \alpha_1 P$,

where Q_1^s is the quantity supplied to the colluding share, $\alpha_0 = a_0 - c_0$, and $\alpha_1 = a_1 + c_1$. Profits for the colluding share are

$$\pi = (P^d - P^s)Q_1$$

where P^d is a function of Q_1 following equation (6),

(9) $P^d = (b_0 - Q_1^d)/b_1$,

and P^s is a function of Q_1 following equation (8),

(10) $P^s = (Q_1^s - \alpha_0)/\alpha_1$.

If the colluding share enjoys market power (monopoly) in its output market, then it will recognize P^d as a function of Q_1 as in (9); on the other hand, if the colluding share is composed of a number of firms which perhaps compete with others in their output market, then they may behave competitively and not consider P^d as a function of Q_1 in maximizing profits. Suppose these cases are represented respectively by $k = 2$ and $k = 1$. Then first order conditions for maximization of π imply

(11) $$Q_1 = \frac{b_0\alpha_1 + b_1\alpha_0}{k\alpha_1 + 2b_1}$$

and, hence, substituting into equation (10) the raw product price is

(12) $$P^s = \frac{b_0\alpha_1 - k\alpha_1\alpha_0 - b_1\alpha_0}{k\alpha_1^2 + 2b_1\alpha_1} .$$

Now substituting (12) into (7) and adding to Q_1 in (11) obtains the equilibrium quantity traded

$$(13)\quad Q_0 = Q_1 + Q_2 = c_0 - c_1 \frac{b_0\alpha_1 - k\alpha_1\alpha_0 - b_1\alpha_0}{k\alpha_1^2 + 2b_1\alpha_1} + \frac{b_0\alpha_1 + b_1\alpha_0}{k\alpha_1 + 2b_1} .$$

Note that at the raw product level, the price in (12) and quantity in (13) are the observed market variables. Of course, the corresponding supply curve is given by equation (5); both the price in (12) and quantity in (13) always fall thereon. The corresponding perceived demand curve for producers can be determined by considering the locas of price-quantity points traced out by shifting supply. Consider, for example, shifting a_0 to determine the perceived demand specified by

$$(14)\quad Q_0 = d_0 - d_1 P^s .$$

Differentiating both P^s and Q_0 in (12) and (13) with respect to a_0 and taking the ratio obtains

$$(15)\quad d_1 = -\frac{\partial Q_0}{\partial P^s} = c_1 + \frac{b_1\alpha_1}{k\alpha_1 + b_1} > 0 ;$$

hence, substituting (12), (13), and (15) into (14) and solving yields

$$(16)\quad d_0 = c_0 + \frac{b_0\alpha_1}{k\alpha_1 + b_1} .$$

These same solutions for d_0 and d_1 are, of course, obtained if the above process is repeated differentiating with respect to a_1 rather than a_0.

Now consider the implications of a change in technology on the perceived demand curve. Following the implications of equations (3) and (4), the change in technology causes a_0 to increase and a_1 to decrease since competitive producer supply represents short-run marginal cost. The perceived demand curve does not depend on a_0 but

$$\frac{\partial d_0}{\partial a_1} = \frac{b_0 b_1}{(k\alpha_1 + b_1)^2} > 0$$

$$(17)\quad \frac{\partial d_1}{\partial a_1} = \frac{b_1^2}{(k\alpha_1 + b_1)^2} > 0 \ .$$

Hence, the decrease in a_1 leads to a decrease in d_1, the slope of the perceived demand curve.

Now consider further the effects on coefficients of other determinants of demand. Suppose a determinant X in demand is considered in a first order Taylor series approximation so that

$$b_0 = b_{00} + b_{01} X$$

$$c_0 = c_{00} + c_{01} X \ .$$

Substituting in equation (16) thus obtains

$$(18)\quad d_0 = d_{00} + d_{01} X$$

where

$$d_{00} = c_{00} + \frac{b_{00}\alpha_1}{k\alpha_1 + b_1}$$

$$d_{01} = c_{01} + \frac{b_{01}\alpha_1}{k\alpha_1 + b_1}$$

so that differentiation implies

$$(19)\quad \frac{\partial d_{01}}{\partial a_1} = \frac{b_{01} b_1}{(k\alpha_1 + b_1)^2}$$

which is of the same sign as the coefficient of the determinant. Note also that d_1 does not depend on the determinant in a first order sense and a_0 does not affect d_{01}. Hence, the effect of the change in cost structure is to reduce the coefficient of X in absolute value (a decrease in a_1 moves d_{01} toward zero) thus verifying the earlier heuristic discussion of the effects of the change in cost structure. Furthermore, upon considering small changes in cost structure and taking the first order Taylor series expansions around initial values, the approximation becomes exact if supply and demands have continuous first derivatives.

3. An econometric model of the California processing tomato market

To demonstrate empirical application of the above framwork, consider the California tomato processing market where the introduction of the mechanical tomato harvester apparently caused a major shift in cost structure as discussed earlier. Using pooled data from the eight major processing-tomato producing counties in California (San Joaquin, Yolo, Solano, Sutter, Sacramento, Stanislous, San Benito, and Santa Clara), consider estimation of supply and (perceived) demand in both the preharvester period, 1951-1963, and the postharvester period, 1967-1975, following the simple supply-demand model

$$Q_i = S(P_i, Y_i, D_i, F, G_{t-1}, W_i, C)$$

$$Q_i = D(P_i, I, R, C)$$

where both relationships follow linear form as in the framework above and

Q_i = purchased processing tomato quantity in county i (1000 tons)

P_i = processing tomato grower price in county i (dollars per ton)

Y_i = processing tomato expected yield in county i -- a three-year moving average (tons per acre)

D_i = standard deviation of yields in county i -- over three preceding years (tons per acre)

F = fertilizer price for California (dollars per ton)

G_{t-1} = lagged grain sorghum price in California (dollars per bushel)

W_i = June harvesting labor wage rate in county i (dollars per hour)

V = April 1 inventory of processing tomatoes in California (24/303 million cases)

I = U.S. disposable personal income (billion dollars)

R = January-March weighted average of tomato-product prices (dollars per unit)

C = set of dummy variables indicating county specific shifts in the two relationships.

For a detailed discussion of the data and the associated sources, see Chern and Just (1978). The general specification of the quantity supply equation follows rather standard econometric practice for agricultural crop production aside from the contracting considerations. To account for the dominance of contracting in California grower-processor relations, the current rather than lagged processing tomato price appears in the supply equation.

To interpret this model in the context of the analytical model above, note that the first equation corresponds to (5) where a_0 is a function of various determinants of supply while the second equation corresponds to (14) where d_0 is a function of determinants of demand following equation (18).

Before proceeding to the estimates, a few additional remarks about the estimation method are required. That is, in the case where grower price is exogenous to the system, the sets of county equations (of which there are eight) can be appropriately treated as sets of seemingly unrelated regression equations in Zellner's terminology. Zellner (1962) has proposed a corresponding Aitken generalized least-square estimator which is asymptotically more efficient than ordinary least squares (OLS). The use of such an approach in combining cross-section and time series data has been investigated extensively by Balestra and Nerlove (1966), Nerlove (1971), and Maddala (1971) for the case where each cross-sectional unit is described by a single equation rather than a simultaneous system.

The pooled estimation problem here, however, is essentially one of seemingly unrelated simultaneous equations systems. Normally, the three-stage least squares (3SLS) approach applied to such a set of simultaneous equation systems is sufficient to attain asymptotic efficiency. However, when the number of time series observations is small compared with the number of cross-sectional units (counties), as in this case, the ordinary 3SLS estimator does not exist. That is, there are only, say, T observations on each covariance; the rank of the covariance matrix estimate based on two-stage least squares (2SLS) can be no greater than T, while its order is 16 (two equations for each of eight counties). Hence, the covariance matrix estimate is singular (T < 16) for both estimation periods, 1951-1963 and 1967-1975 (Chern and Just provide further explanation). For this reason and to avoid unnecessary complication, the estimates are derived by 2SLS; the results are reported in Table 1.

4. The impact of the tomato harvester on supply

For the purposes of investigating the competitive versus noncompetitive aspects of the effects of the tomato harvester, the differences in the pre- and post-harvester cases of Table 1 can be analyzed statistically. Since the estimates are generated by different sets of observations, the estimators are independent in the absence of serial correlation. Hence, one can easily determine the statistical significance or test the hypothesis of equality versus inequality of corresponding coefficients. Asympototically, the marginal distribution of each coefficient estimator in, say, period k, k = 1, 2, is normal with mean μ_k, and standard deviation σ_k, where σ_k is estimated by the reported standard deviation. With independence, one thus finds

$$s = \frac{\hat{\mu}_i - \hat{\mu}_j}{\sqrt{\sigma_i^2 + \sigma_j^2}} \mathrel{\dot{\sim}} N(0, 1) \qquad i \neq j$$

under the hypothesis of equality of corresponding coefficients. Using pooled estimation methods and the above hypothesis-testing approach with i corresponding to 1967-75 and j corresponding to 1951-63, Table 2 is developed to consider the significance of structural changes due to the tomato harvester by determining the significance of structural change on each coefficient individually.[5]

Table 1. Estimated Grower Supply and Demand for Processing Tomatoes in California[a]

	Preharvester Period 1951-1963		Postharvester Period 1967-1975	
Variable	Supply	Demand	Supply	Demand
Constant	227.20 (339.53)	-405.89 (62.21)	-353.94 (190.52)	-95.83 (80.61)
P_i	11.72 (4.12)	-14.17 (5.71)	3.91 (1.48)	-3.31 (4.01)
Y_i	9.89 (5.10)		15.39 (8.08)	
D_i	-6.53 (11.11)			
F	-2.12 (2.28)			
G_{t-1}	-91.08 (45.34)			
W_i	-334.77 (155.24)			
I		.698 (.115)		.137 (.146)
R		131.56 (32.11)		45.61 (28.74)
R^2	.92	.94	.87	.88

[a]Numbers in parentheses are estimated standard errors. Note that estimates of coefficients of dummy variables associated with individual counties are not reported.

The results in Table 2 add substance to the substantial structural change (with the introduction of the tomato harvester) suggested by Table 1. The supply equation results imply a significant structural change of the type suggested by equations (3)-(4) and Figure 1. A significant change in the slope of supply consistent with Figure 1 is attained at the 3.7 percent level (note that the one-sided sense is appropriate). It should also be noted that the wage rate which is quite significant in the preharvester results (Table 1) attained a wrong sign with some significance, thus suggesting misspecification, when included in the postharvester case (not reported); this result is also consistent with the argument related to equations (3)-(4) and Figure 1. The absence of D_i, F, and G_{t-1} in the postharvester case suggests also some further change in C_1'; each of these variables resulted in wrong-signed own coefficients (although insignificant) when included in the postharvester case. But the D_i and F coefficients also do not attain much significance in the preharvester case and, more importantly, the observed structural shift of the price coefficient is sufficient to validate the supply shift suggested by Figure 1.

5. A change in perceived demand structure: implied oligopsonistic market structure

Table 2 also suggests a consistent structural change (across coefficients) for the income elasticity as well as the grower and product price elasticities of demand. Furthermore, these shifts are fairly significant. In the context of competition, such a shift or any change in demand is hard to explain as an impact of the tomato harvester. That is, the tomato harvester is a factor of supply and does not serve as a determinant of demand; under competition the harvester should affect price and quantity only through the supply curve. Consider alternatively, however, the monopsonistic-oligopsonistic implications of Figures 2 through 5. In these noncompetitive market structures, a shift in the perceived (or estimated) demand toward inelasticity is exactly what one would expect.

To further consider this possibility objectively, each of the standard normal statistics associated with demand in Table 2 may be regarded as a

Table 2. Significance of the Structural Impact of the Tomato Harvester, 1951-63 Versus 1967-75

Equation	Coefficient	Statistic for test of coefficient equality	Asymptotic significance
Supply	P_i	-1.78	.037
Demand	P_i	1.56	.059
	I	-3.02	.001
	R	-2.00	.023

separate test statistic for a null hypothesis of competition versus an alternative hypothesis of monopsony-oligopsony. According to the monopsony-oligopsony theory culminating in equations (17) and (19), the effect of the supply shift discussed above should be to drive each of the demand coefficients toward zero whereas under competition they would be unchanged. In this context, the 3 statistical tests lead to rejection of competition in favor of monopsony-oligopsony in every case at the 16 percent level (again the one-sided sense is appropriate), and two of the three tests imply rejection at a 2.3 percent level. The observed shifts thus appear to be consistent with the noncompetitive theory of this paper.

A further interesting check on the results is possible, however. That is, the competitive case, as explained earlier, should lead to a reduction in price but an increase in quantity as a result of the structural supply shift associated with the tomato harvester. The noncompetitive cases discussed above, however, imply a reduction in price, but the quantity produced can shift in either direction. Thus, if by chance conditions are such that some quantities fall in the noncompetitive case, then the evidence is in favor of monopsony-oligopsony. To investigate these possibilities, the reduced-form equations corresponding to Table 1 were derived (not reported) and, using mean data, the impact of the tomato harvester on prices and quantities was computed by comparing predictions of the two models. That is, to determine the impact of the tomato harvester on quantity and price after compensating for the effects of other coincidentally varying factors of supply and demand, Table 3 has been developed by applying reduced forms corresponding to Table 1 to the average data point for the 1951-1975 period.

The price impacts in Table 3 are entirely consistent with both the competitive and noncompetitive cases; in every county the price has fallen as a result of tomato harvester adoption. The quantity impacts, however, are interesting in that some county acreages increased while others decreased. According to competitive theory, the structural shift in supply associated with the tomato harvester should lead to lower price but increased production. The results in Table 3 are thus not supportive of the competitive theory.

Table 3. Impacts of the Tomato Harvester Holding Other Factors Constant[a]

County	Impact of Mechanization: Price ($/ton)	Impact of Mechanization: Quantity (1000 tons)
San Joaquin	-39.68 (-67)	-43.50 (-6)
Yolo	-39.58 (-66)	433.36 (+79)
Solano	-38.82 (-65)	99.7 (+41)
Sutter	-37.61 (-63)	124.4 (+56)
Sacramento	-40.61 (-68)	-113.7 (-38)
Stanislaus	-38.31 (-65)	-36.3 (-17)
Santa Clara	-35.52 (-60)	-15.3 (-8)
San Benito	-31.77 (-53)	10.32 (+7)

[a]Numbers in parentheses represent percentage changes.

Turning to the monopsonistic-oligopsonistic theory of this paper, however, one finds that the Table 3 results are sensible. In this case, as suggested earlier, price should fall but production may either increase or decrease. Thus, the estimated impacts in San Joaquin, Sacramento, Stanislaus, and Santa Clara counties support only the noncompetitive theory rather than the competitive theory. And, of course, the remaining cases raise no contradictions.

Yet a further check on the validity of these results is possible. That is, one might question whether the observed structural change is really due to the tomato harvester or some other phenomena. If the structural shift is due to other factors, the change could have really occurred sooner or later than the partition of the data selected above which coincides with tomato harvester adoption. To check this possibility, the analysis was repeated varying the sample partition and the three-year excluded period forward or backward one year at a time. This exercise revealed that the greatest significance for the supply shift was actually obtained one year later than that used above with a test statistic of -2.09 (2 percent significance) rather than the -1.78 obtained in Table 2. The partition actually used ranked second in significance. With respect to the observed (perceived) shift in demand, the significance was higher in a uniform sense one or two years earlier than the portion actually used although the greatest significance on the change in an individual coefficient (a statistic of -3.2) was obtained for the income coefficient one year later using a partition of 1951-1964 versus 1968-1975. Finally, the highest uniform significance over all the test statistics reported in Table 2 was obtained with a partition one year earlier, 1951-1962 versus 1966-1975; in this case the smallest absolute statistic was 1.66 instead of the (second ranking) 1.56 in Table 2. The sensitivity analysis thus showed that the greatest significance of structural change occurred for the most part within one year of the partition selected for this study on the basis of observed tomato harvester adoption. Furthermore, the partition selected on *a priori* grounds results in almost as much significance as those with highest significance. Thus, the sensitivity analysis is quite supportive of the conclusions already drawn above.

6. Historical interpretation of results

The results thus far have an interesting interpretation in the light of historical events surrounding the California processing tomato market. For example, it is interesting to observe that the number of tomato processing firms has declined from 57 in 1955 to 28 in 1972.[6] Since tomato production has rapidly increased in the state, the average size of the firm has thus increased. The average firm size, in terms of raw tomatoes procured, in fact rose from 35,000 tons in 1955 to 1.75 million tons in 1972. According to a survey reported jointly by the U.S. Department of Agriculture and the National Canners Association to the U.S. National Commission on Food Marketing (1966), the four largest plants (all probably located in California) manufactured 25 percent of the total output of tomato products in the United States in 1965, while the share for the eight largest plants was 35 percent. Furthermore, concentration may well be higher than these statistics indicate since large firms own more than one plant.

The increasing concentration of tomato processing among fewer firms suggests important implications for the structure of the tomato market, particularly in light of the above empirical results. For example, greater opportunities exist for determination of price by one or a few dominant firms, thus reducing competition in negotiating for contracts. Collins, Mueller, and Birch (1959) have, in fact, observed that most tomato processors appear to follow price leadership in California. Furthermore, some experts consulted in the course of this study believe that a single firm has been continually the dominant tomato canner during the past 20 years and that dominance was exercised in the form of price leadership even in the 1950s when more firms existed. Thus, an examination of events and opinions in the industry tend to confirm the statistical results favoring oligopsony with dominant firm price leadership (monopsony is questionable since there are obviously several processing firms operating in the market).

7. Conclusions

The empirical results of this paper for the California processing tomato market are remarkably consistent with dominant-firm-price-leadership oligopsony. The results suggest that supply shifted exactly as one would expect with the tomato harvester displacing labor; this effect is statistically significant. Likewise, (perceived) demand became more inelastic; every estimated coefficient reflects a decrease in elasticity. Finally, prices and quantities have also behaved exactly as oligopsonistic theory suggests. Prices have fallen in every case (after removing the effect of exogenous forces), while qualitative impacts on quantities have been observed in both directions rather than the single direction implied by competition.

Of course, other explanations of the results obtained here, which may have had a more casual relationship with the adoption of the tomato harvester, must also be considered. For example, popular opinion appears to regard tomato consumption as more of a necessity in recent years (for nutritional reasons) than it had previously. Presumably, however, this explanation could only account for reduced demand elasticities and not for the apparent leftward shift in demand; on the contrary, such an explanation would imply a rightward shift.

Another possible explanation of a more causal nature relates to varietal changes in tomatoes that were made to accommodate the harvester. These varietal changes led to more efficient tomato processing because of higher solid content in tomatoes. But again, on the contrary, this change would, *ceteris paribus*, lead to increased demand for raw processing tomatoes, whereas the estimates indicate reduced perceived demand.

Finally, another explanation for structural change in demand relates to increased processing costs. Apparently, in this case, however, there could be no direct causation associated with the tomato harvester since the tomato harvester actually led to a more efficient tomato. But processing costs could have increased during the transition period because of coincidental increases in costs of other processing inputs. As indicated earlier, such changes should lead to less elastic grower demand for processing tomatoes as well as leftward shift in demand. This explanation is, thus, more consistent with the observed results even though no causal corroboration is offered by the model. Furthermore, the sensitivity analysis of the data partition suggests that any such change of this nature must have coincided almost exactly with tomato harvester adoption rather than following a general long term trend or occurring more decidedly at a different time during the sample period. Thus, such an explanation seems unlikely. Since data were not available on processing costs, this possibility could not be further investigated empirically.

With respect to the validity of conclusions, however, one should bear in mind that each of the statistics associated with demand in Table 2 provides a valid test in a classical statistical sense of the null hypothesis of competition (asymptotically). And these statistics imply rejection of competition. Hence, the weight of the evidence is as substantial as one could expect in any econometric analysis subject to the usual phenomena of specification error.

Footnotes

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[1]One can also note that the results are consistent with either oligopolistic or competitive supply by processors.

[2]In the context of this discussion, however, marginal costs under mechanical technology may be increasing more sharply (as the ensuing discussion indicates); hence, at sufficiently high prices, some hand harvesting may become economically feasible. For example, the MC_0 and MC_1 curves in Figure 1 may cross at higher prices.

[3]The specific case of dominant firm price leadership is examined here because of evidence of its existence in the California processing tomato market (see the discussion below).

[4]A similar case for oligopolistic price leadership is presented by Cohen and Cyert (1965), pp. 241 and 242.

[5]It is interesting to consider the possibility of developing a single test statistic for the hypothesis of imperfect competition but this would require estimated covariances between the supply and demand equation which are not easily obtainable with 2SLS. Furthermore, the text would involve inequality of two vectors of coefficient estimates and would thus require weights for individual coefficients in order to derive a simple test statistic. Since assignment of these weights would either be arbitrary or require a four dimensional sensitivity analysis, Table 2 will suffice for the purposes of this paper.

[6]See Collins, Mueller, and Birch (1959), and King, Jesse, and French (1973).

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