UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURAL SCIENCES
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Econometric Analysis of Supply Response and Demand for Processing Tomatoes in California

Wen S. Chern and Richard E. Just

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CALIFORNIA AGRICULTURAL EXPERIMENT STATION

In this study an econometric model is developed to assess the effect of contracting on acreage and price determination in the raw tomato market and to estimate the impact of the tomato harvester on structural parameters of acreage response and demand for processing tomatoes in California.

Estimation is performed by utilizing both aggregate time series data for the 10 major counties and pooled county and time series data. The results for the aggregate model suggest that uncertainty and industry disequilibrium during the transition period of tomato harvester adoption have a distorting effect on elasticity estimates and, furthermore, that multicollinearity prevents a rigorous investigation of structural change.

In developing asymptotically efficient estimators for the pooled model, some major problems were encountered with ordinary simultaneous equations estimation methods. As a result, several alternative modifications of three–stage least squares techniques were developed for the study.

From the pooled estimation results, it is found that the tomato harvester has led to grower supply of processing tomatoes that is less elastic with respect to all the variable factor prices and competing crop prices which are investigated. A theoretical interpretation of these results based on a shifting of costs between variable (labor) and fixed (harvesting machinery) costs is given. It is also found that the demand–price relationship has become less elastic with the adoption of the tomato harvester. A theory of oligopsony is used to explain the observed shift in the demand–price relationship. Furthermore, a study of reduced–form equations indicates that the estimated impact of the harvester was to reduce both price and acreage, *ceteris paribus.* The theory of oligopsony also suggests that reduced supply elasticity has allowed the processing industry to exercise increased market power.

THE AUTHORS:

Wen S. Chern is an Economist with the Energy Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Richard E. Just is Associate Professor of Agricultural and Resource Economics and Associate Agricultural Economist in the Experiment Station and on the Giannini Foundation, University of California, Berkeley.

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ECONOMETRIC ANALYSIS OF SUPPLY RESPONSE AND DEMAND FOR PROCESSING TOMATOES IN CALIFORNIA

1. INTRODUCTION AND SUMMARY

Over the last two decades, California has been one of the most important states in producing processing tomatoes in the United States. In 1975, California produced 8.5 million tons of processing tomatoes which accounted for 87 percent of U. S. production.[1] The industry has also made a significant contribution to California's agricultural economy. Cash farm receipts from processing tomatoes in 1974 were $373 million, accounting for more than 25 percent of total receipts from all vegetable crops in the state.[2]

Tomato production in California has been highly mechanized.[3] The introduction of the tomato harvester in the 1960s represents one of the most dramatic achievements in agricultural mechanization. The adoption of the tomato harvester has drastically altered harvesting operations, and its impact on the economic structure of the California tomato industry cannot be ignored. Furthermore, the yield in California has been consistently higher than that in other states. As a result, there has been a gradual shift of major production areas for canning tomatoes from the Midwest (Indiana and Ohio) and East (New Jersey, Maryland, and Delaware) to California over the last 25 years.

An understanding of the economic structure of the California tomato industry in this evolving environment is essential for evaluating the performance of the industry and formulating proper agricultural policies. The specific objectives of this study are to investigate the economic trends of key variables in the California tomato industry, assess the effect of contracting on acreage and price determination in the raw tomato market, and estimate the impact of the tomato harvester on structural parameters of acreage response and demand for processing tomatoes in California.

In California, tomato production has been concentrated in 10 major counties which have accounted for more than 85 percent of the state's production in recent years. Yolo and San Joaquin Counties have been the two most important counties; together, they shared 30 percent of the total harvested acreage in 1975. The initial empirical analyses

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[1] Federal–State Market News Service, *Marketing California Tomatoes* (Sacramento 1975).

[2] California Crop and Livestock Reporting Service, *California Vegetable Crops, 1974–75* (Sacramento, 1975), 22p.

[3] Since tomatoes for fresh use are virtually excluded from this study, the term "tomato industry" will refer only to the processing segment unless "fresh" is otherwise specified. In California, tomato production for fresh use historically has been much less important than production for processing. In 1974, the acreage producing tomatoes for fresh markets was 28,700 acres compared with 249,800 acres of canning tomatoes.

are based on these 10 counties; and the more detailed analyses focus on 8 remaining counties after eliminating one which did not produce tomatoes before adoption of the harvester and another which, for the most part, does not operate under the predominant contractual agreement.

Acreage response and processors' demand relationships for processing tomatoes are explicitly derived from the neoclassical optimization model. Accordingly, in the econometric analysis, acreage response is expressed as a function of grower price, wage rates, price of ammonium nitrate fertilizer, average yield in the preceding three years, standard deviation of yields in the preceding three years, and lagged prices of competing crops. The demand for processing tomatoes is assumed to be functionally related to grower price, weighted January–March f.o.b. price of tomato products, total April 1 inventory of tomato products, and consumer disposable incomes. The structural model is completed by introducing a behavioral equation expressing acreage as a function of the quantity of tomatoes and expected yield.

Annual data over the 1951–1975 sample period are used for estimation. Two variants for estimating the structural model are attempted. The first version of estimation is accomplished by utilizing aggregate data for the 10–county total. The second variant is implemented by pooling county and time series data. The stochastic specifications and statistical problems differ between these two versions; consequently, different estimating procedures are used.

Aggregate Estimation

Consider first the aggregate model for the 10–county total. This portion of the study demonstrates an attempt to update the previous study by Chern covering the period 1951–1972.[1] In updating the models estimated earlier by Chern, it is shown that the estimates of many structural parameters in the acreage response equations are greatly altered as a result of adding three more observations in the postharvester period (1973–1975). In the updated models, among other things, the estimated price elasticity of acreage response is considerably higher when two–stage least squares (2SLS) and three–stage least squares (3SLS) are used. Furthermore, when ordinary least squares (OLS) is applied, all coefficient estimates except the one for grower price in the acreage response equation became statistically insignificant. A careful evaluation of these results suggests that uncertainty and industry disequilibrium during the transition period of tomato harvester adoption (1963–1966) may be distorting elasticity estimates.

To examine this possibility, the system of three equations is reestimated for 1951–1975 with the transition period excluded. Additional variables are also introduced for the preharvester period to investigate structural shifts in elasticities. The implication of these estimates further suggests that the tomato market may have indeed been operating under a peculiarly different structure during the transition period. Based on the results, it also becomes clear that the aggregate–model estimates may lead to quite distorted implications because of the multicollinearity that obtains when the transition period is eliminated.

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[1] Wen S. Chern, "Supply Response and Price–Demand Relationships for California Processing Tomatoes" (unpublished Ph.D. dissertation, Department of Agricultural Economics, University of California, Berkeley, 1975), 159p.

Pooled County and Time Series Estimation

The observations relating to the aggregate results motivate further study of pooled county data. First, it is generally the case that more efficient estimates are possible when disaggregated data are pooled appropriately as in the large class of error components models. Second, in updating the earlier results by Chern, it is apparent that the aggregate results are not stable as more observations are added, at least when the transition period is included.[1] In particular, the estimates of price elasticity of supply increase and estimates of both wage elasticity of supply and fertilizer price elasticity of supply decrease as observations beyond 1972 are added. This leads to a hypothesis that the structural effects of the tomato harvester were fairly comprehensive and that the effects of harvester–related phenomena become more dominant as more postharvester data are used. Since the number of observations was too restricted in the aggregate case to test the possibility of a general structural shift from before to after the adoption of the tomato harvester, the use of pooled county data was the only means of obtaining needed generality.

Results with the pooled model tend to confirm this hypothesis but also suggest another peculiarity. It is indeed found that the price elasticity of supply is lower in the postharvester pooled results than in the preharvester period, but the price elasticity of supply in *both* the pre– and postharvester periods appears to be lower than when the data from both periods, as well as the transition years, are included. Since the additional problem of specification error associated with the aggregate model does not exist in this model, this result apparently can be explained only by the omission of the transition period data in the pooled estimation (during which both hand and machine methods of harvesting were used). A more fundamental reason for this observation could be that the tomato supply was more volatile in the transition period, possibly because of decision–makers' uncertainty about the effects of the introduction of the tomato harvester.

From the pooled estimation results, it is found that the tomato harvester has led to grower supply of processing tomatoes that is less elastic with respect to all the variable factor prices and competing crop prices which are investigated. A theoretical interpretation of these results based on a shifting of costs between variable (labor) and fixed (harvesting machinery) cost categories is given. It is also found, however, that the demand–price relationship has become less elastic with adoption of the tomato harvester. This result may seem somewhat peculiar since, normally, the market for a factor of supply should have no impact on demand. Some possible explanations relate to coincidental changes in tastes and preferences toward necessity of tomato consumption and possibly in composition of processing costs. Recent rapid increases in costs of labor and capital may result in reducing the percentage of total processing costs due to cost of raw tomatoes. Marshall and Sato and Koizumi[2] have shown that "the demand for anything is likely to be less elastic, the less important is the part played by the cost of that thing in the total cost of some other thing, in the production of which it is employed." A casual examination of these and similar explanations, however, reveals that they do not fully explain the observed phenomenon.

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[1]*Ibid.*

[2]R. Sato and T. Koizumi, "Substitutability, Complementarity, and the Theory of Derived Demand," *Review of Economic Studies,* Vol. XXXVII(1), No. 109 (January, 1970), pp. 107–118.

Alternatively, assuming that this shift is truly related to the tomato harvester, a theory of oligopsony is developed which explains the observed shift in the demand–price relationship. Furthermore, a study of reduced–form equations indicates that the estimated impact of the harvester was to reduce both price and quantity. Normally, if only supply shifts (due to a change in some fixed factor use), price and quantity will vary inversely along the demand curve. As shown in this study, however, the observed results are consistent with the theory of oligopsony. Conversely, the several coincidental explanations (higher demand elasticity at higher prices, increased demand due to nutritional information, etc.) seem to be eliminated, given the downward effect on prices. Hence, the study concludes that the theory of oligopsony may indeed be relevant to the tomato processing industry and that reduced supply elasticity has allowed the processing industry to exercise increased market power.

Estimation Methodology

In developing asymptotically efficient estimators for the pooled model, some major problems are encountered with ordinary simultaneous equations estimation methods. Hence, it is necessary to digress to a considerable extent to develop appropriate estimation techniques. The pooled estimation problem is essentially one of seemingly unrelated simultaneous equations systems. Normally, 3SLS 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.

Two alternative modifications of 3SLS are developed for the case at hand. The first is termed ridge 3SLS since, as in ridge regression, it involves adding a ridge (a scalar times an identity) to a matrix which is singular (but the matrix is not the same one altered in ridge regression). The second method involves ad hoc imposition of constraints on the 2SLS covariance matrix of residuals (which is otherwise singular) to attain nonsingularity and existence of the corresponding 3SLS estimator. The latter approach, however, is not ad hoc in a theoretical sense but merely in a computational sense. For each ad hoc set of constraints, a true (or unconstrained) asymptotic estimate of the covariance of coefficient estimators can be obtained. Hence, a rigorous justification can be developed from the standpoint of computationally minimizing the covariance matrix of the coefficient estimator subject to computational existence. In both the ridge 3SLS and ad hoc cases, the modified 3SLS estimator is asymptotically unbiased; and it is not hard in either case to improve upon the (estimated) efficiency of 2SLS.[1]

2. THE CALIFORNIA PROCESSING TOMATO INDUSTRY

The purposes of this section are twofold: (1) to describe the structure of the California tomato industry and its historical trends, which are subjects of interest in themselves,

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[1]Since the theoretical material required to develop these estimators is more technical than the rest of the study and an understanding of these theoretical results is not absolutely necessary for the presentation of the pooled model results, the less–technical reader is advised to disregard "Theoretical Considerations in Pooling County Systems" in Section VI, *infra*, p. 57.

and (2) to provide important background materials for the theoretical and quantitative analyses in the sections that follow. More specifically, this section covers four major aspects which have characterized the tomato industry in the post–World War II period: production, processing, consumption, and cost structures.[1]

Tomato Production in California

An Overview

The California processing tomato industry is probably one of the most developed and dynamic sectors of the state's agriculture. The introduction of the tomato harvester in the early 1960s and its rapid adoption have transformed the industry into one of the most highly mechanized sectors in agriculture. More importantly, it has undoubtedly enhanced California's competitive position in tomato production.[2]

The growth of tomato production in California has been notable in the last two decades. Annual average production in California was only 1.3 million tons, accounting for 42.6 percent of the U. S. total during 1947–1951. It increased to 5.6 million tons or 82.6 percent of total output during 1972–1975. This phenomenal increase in tomato production resulted from increases in both acreage and yield as indicated in Tables 1 and 2.

Over the past two decades, the major production areas for canning tomatoes in the United States have shifted from the Midwest (Ohio, Indiana, and Illinois) and East (New

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[1]Considerable information in preparing this section was drawn from earlier studies:

Sidney Hoos and Frank Meissner, "California Canning Tomatoes: Economic Trends and Statistics," University of California, California Agricultural Experiment Station (Berkeley, 1952), 41p.

Sidney Hoos and R. D. Aplin, *California Canned Tomatoes: Analysis of F.O.B. Price Relationships,* University of California, Giannini Foundation Mimeographed Report No. 156 (Berkeley, 1953), 34p.

Sidney Hoos, *Tomato and Tomato Products: Economic Trends and F.O.B. Price Relationships,* University of California, Giannini Foundation Mimeographed Report No. 185 (Berkeley, 1956), 46p.

Norman R. Collins, Willard F. Mueller, and Eleanor M. Birch, *Grower–Processor Integration: A Study of Vertical Integration Between Growers and Processors of Tomatoes in California,* California Agricultural Experiment Station Bulletin 768 (Berkeley, 1959), 76p.

Their studies covered various periods prior to 1955. While dramatic changes have occurred in the last 20 years, it is believed that some fundamental features of the industry have remained unchanged.

[2]While the adoption of the harvester benefits the industry in general, it might hurt some parties in particular, such as farm workers, as pointed out by Andrew Schmitz and David Seckler, "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester," *American Journal of Agricultural Economics,* Vol. 52, No. 4 (November, 1970), pp. 569–577. However, it is believed that the social costs of technological innovation as such can only be measured more accurately when one knows the relevant supply and demand structure of the industry.

TABLE 1

Harvested Acreage and Production of Processing Tomatoes: California and the United States
Annual Average, 1947-1951 to 1972-1975

Calendar year	Harvested acreage			Production		
	California	United States	California share	California	United States	California share
	acres		percent	1,000 tons		percent
1947-1951	105,960	394,176	26.9	1,311.3	3,093.5	42.4
1952-1956	108,640	325,126	33.4	1,866.7	3,486.1	53.6
1957-1961	137,620	305,880	45.0	2,243.2	3,889.2	57.7
1962-1966	146,900	281,840	52.1	2,857.9	4,647.7	61.5
1967-1971	175,400	293,384	59.8	3,742.3	5,524.8	67.7
1972-1975	236,500	320,518	73.8	5,626.4	6,813.9	82.6

Sources:

For California, see California Crop and Livestock Reporting Service, *Tomatoes for Processing: Acreage, Production, and Value*, Final Reports (Sacramento, 1947, and selected annual issues).

For the United States, see U. S. Department of Agriculture, Statistical Reporting Service, *Agricultural Statistics, 1947* (1947 and subsequent annual issues).

TABLE 2

Yield of Processing Tomatoes: California, 14 Major States, Other States and United States, Annual Average, 1947-1951 to 1972-1975

Period	California	14 major states[a]	Other states	United States
	tons per acre			
1947-1951	12.36	6.51	3.33	7.88
1952-1956	17.08	7.66	5.03	10.70
1957-1961	16.28	10.05	6.66	12.76
1962-1966	19.54	13.45	8.82	16.52
1967-1971	21.54	15.39	9.55	18.98
1972-1975	23.79	14.30	12.78	21.26

[a]1947-1971: Includes Ohio, New Jersey, Indiana, Pennsylvania, Virginia, Michigan, Texas, Maryland, Florida, Illinois, New York, Utah, Delaware, and New Mexico.

1972-1974: Same as above, including Colorado and excluding Florida, Illinois, Utah, and Delaware.

1975: Same as 1972-1974, except including Delaware.

Sources:

1947 and 1948: U. S. Department of Agriculture, Bureau of Agricultural Economics, "Tomatoes--Commercial Crop for Processing: Acreage, Yield, Production, Season Average Price Received by Growers, and Value, 1947 with Comparisons," *Commercial Truck Crops*, TC-47:1230 [1239] (December, 1947); also, TC-48:1230 [1243] (December, 1948).

1949-1970: U. S. Department of Agriculture, Agricultural Marketing Service, *Vegetables for Processing: Acreage, Production, Value, by States, 1949-1955. Revised Estimates,* Statistical Bulletin No. 210 (May, 1957).

U. S. Department of Agriculture, Statistical Reporting Service, *Vegetables for Processing: Acreage, Production, Value, by States, 1954-1959. Revised Estimates,* Statistical Bulletin No. 299 (December, 1961); see, also, Statistical Bulletin 411 (August, 1967) and Statistical Bulletin No. 494 (September, 1972).

1971-1975: *Idem, Vegetables--Processing: Annual Summary. Acreage, Yield, Production, Value* (December, 1971, and subsequent annual issues).

York, New Jersey, Pennsylvania, Maryland, and Virginia) to California. This dramatic shift might be attributed to the sustained differences in yield and in the scale of operation of tomato growers between California and other states.

While tomato yields have steadily increased in all production regions over the last 28 years, California has maintained a substantially higher yield than any other tomato producing area. As shown in Table 2, the annual average yield during 1947–1951 was 12.4 tons per acre in California as compared to 6.5 tons in the 14 other major producing states. The yield in both areas has rapidly increased since then with California maintaining about the same absolute differential. The historical yield differences between California and the other minor producing states have been even greater.

Historical trends have shown that the size of farms growing tomatoes for all uses has been increasing, while the number of farms has been declining (Table 3). While there were 2,896 farms producing tomatoes in California in 1954, the number declined to 1,582 in 1969. Correspondingly, the average farm size increased from 32 acres to 111 acres. Similar trends with somewhat less drastic changes were also found in Ohio, New Jersey, and Indiana. Note that the average farm size in California has been much greater than that in other states. These sustained differences may result from the fact that California tomato growers tend to specialize in tomato crops, while eastern and midwestern growers are more likely to consider tomatoes a cash crop subsidiary to other crops.[1]

Comparisons of the historical trends of acreage, yield, and production between California and other tomato producing states are shown in Figure 1. In California and other states, acreage and yield have been subject to substantial annual fluctuation throughout the period 1948–1975. Consequently, production has also had a high year–to–year variation. In California, production reached 7.3 million tons in 1975, the highest peak in recorded history. The next highest years were 1974 with 5.8 million tons and 1968 with 4.9 million tons produced. These peaks of production all coincided with peaks in acreage.

It is obvious that the steady upward trend of production in California has resulted from the positive trends in both acreage and yield. In other states the declining acreage trend has offset the upward trend in yield. As a result, production has not maintained any significant trend.

Production Regions in California

Production of canning tomatoes has been centered in the San Joaquin and Sacramento Valleys. The 10 major tomato producing counties had 86 percent of total contracted acreage in the state during the period 1971–1975. Table 4 and Figure 2 provide identification of major counties.

In California, canning tomatoes are strictly distinguishable from tomatoes for fresh uses because they are different varieties and require different cultural practices. Among

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[1]Gordon A. King, Edward V. Jesse, and Ben C. French, *Economic Trends in the Processing Tomato Industry*, University of California, Giannini Foundation Information Series No. 73–4 (Davis, 1973), 130p.

TABLE 3

Number and Average Size of Tomato Farms[a]
California, Ohio, New Jersey, and Indiana
1954, 1959, 1964, and 1969

State and calendar year	Number of farms	Total acreage	Average size of tomato farm
			acres
California			
1954	2,896	92,896	32.0
1959	2,724	156,978	57.6
1964	1,883	159,183	84.5
1969	1,582	176,088	111.3
Ohio			
1954	4,714	18,314	3.9
1959	4,101	25,052	6.1
1964	1,625	24,146	14.9
1969	1,515	28,518	18.8
New Jersey			
1954	3,488	30,434	8.7
1959	2,299	20,044	8.7
1964	1,413	20,376	14.4
1969	1,178	19,961	16.9
Indiana			
1954	3,163	24,837	7.9
1959	2,787	25,399	9.1
1964	831	13,525	16.3
1969	665	17,142	25.8

[a]Also includes farms producing tomatoes for fresh market.

Sources:

U. S. Bureau of the Census, *U. S. Census of Agriculture: 1959*, Vol. 1, Counties, Part 48, California (1961).

Idem, Census of Agriculture, 1969, Vol. 1, Area Reports, Part 48, Section 2, County Data (1972).

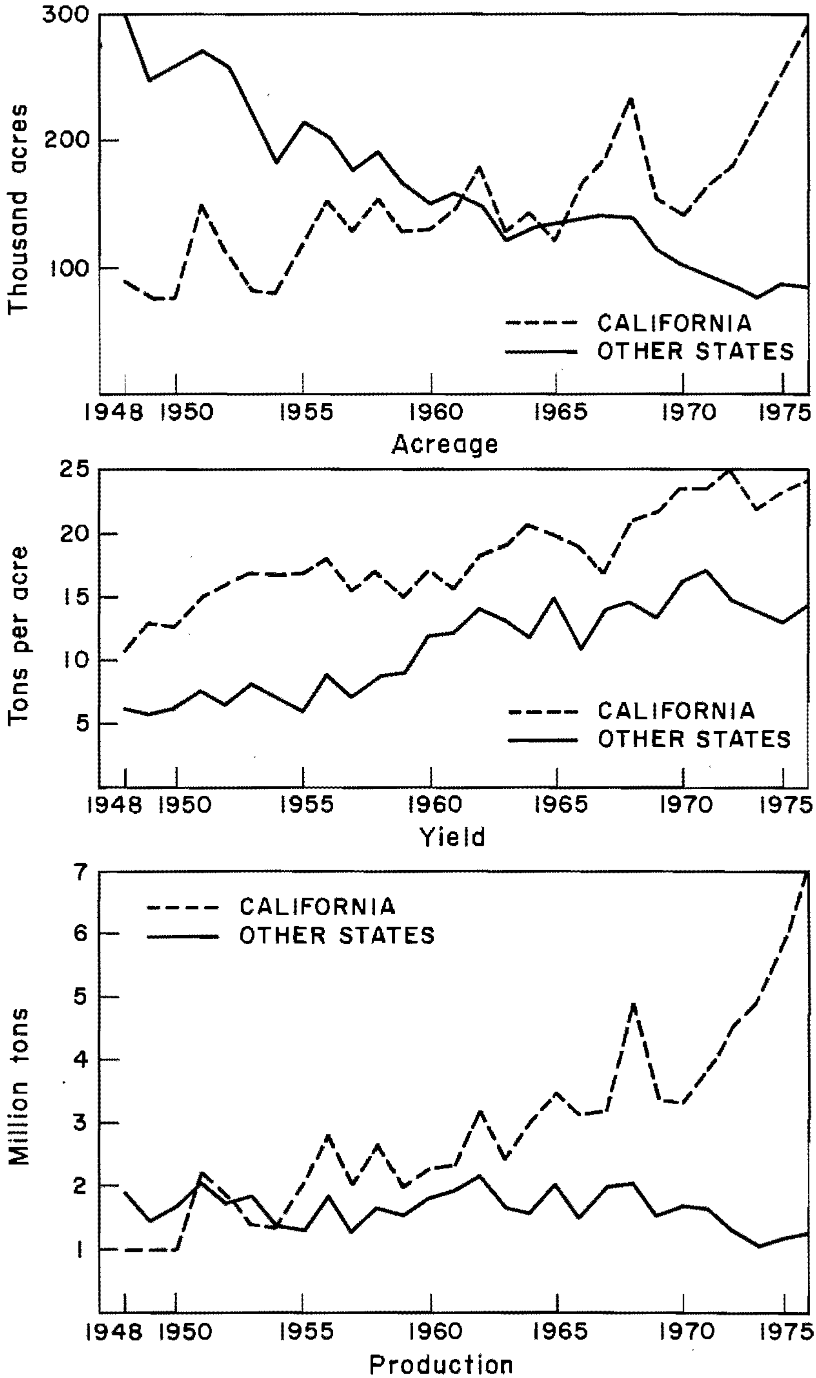

FIGURE 1. Acreage, Yield, and Production of Processed Tomatoes, California and Other States, 1948-1975

TABLE 4

Tomatoes for Processing and Fresh Use
10 Major Tomato Producing Counties, California
Annual Average, 1971-1975[a]

Identification	10 major tomato producing counties	1971-1975: Tomatoes for processing: Acreage	Tomatoes for processing: Percent of state total	Tomatoes for fresh use: Acreage	Tomatoes for fresh use: Percent of state total
1	San Joaquin	28,626	12.9	4,590	15.3
2	Yolo	50,334	22.7	*b*	
3	Fresno	36,956	16.7	1,236	4.1
4	Solano	17,920	8.1		
5	Sutter	18,388	8.3		
6	Sacramento	7,024	3.2	94	.3
7	Stanislaus	7,976	3.6	3,054	10.2
8	Merced	7,450	3.4	3,670	12.2
9	Santa Clara	7,786	3.5	108	.4
10	San Benito	8,340	3.8		
	10-county total	190,800	86.0	12,752	42.6
California		221,940		29,960	

[a]Calendar years; 1975 data preliminary.

[b]Blanks indicate no data reported due to insignificant acreage.

Source: Federal-State Market News Service, *Marketing California Tomatoes* (Sacramento, 1971, and subsequent selected issues).

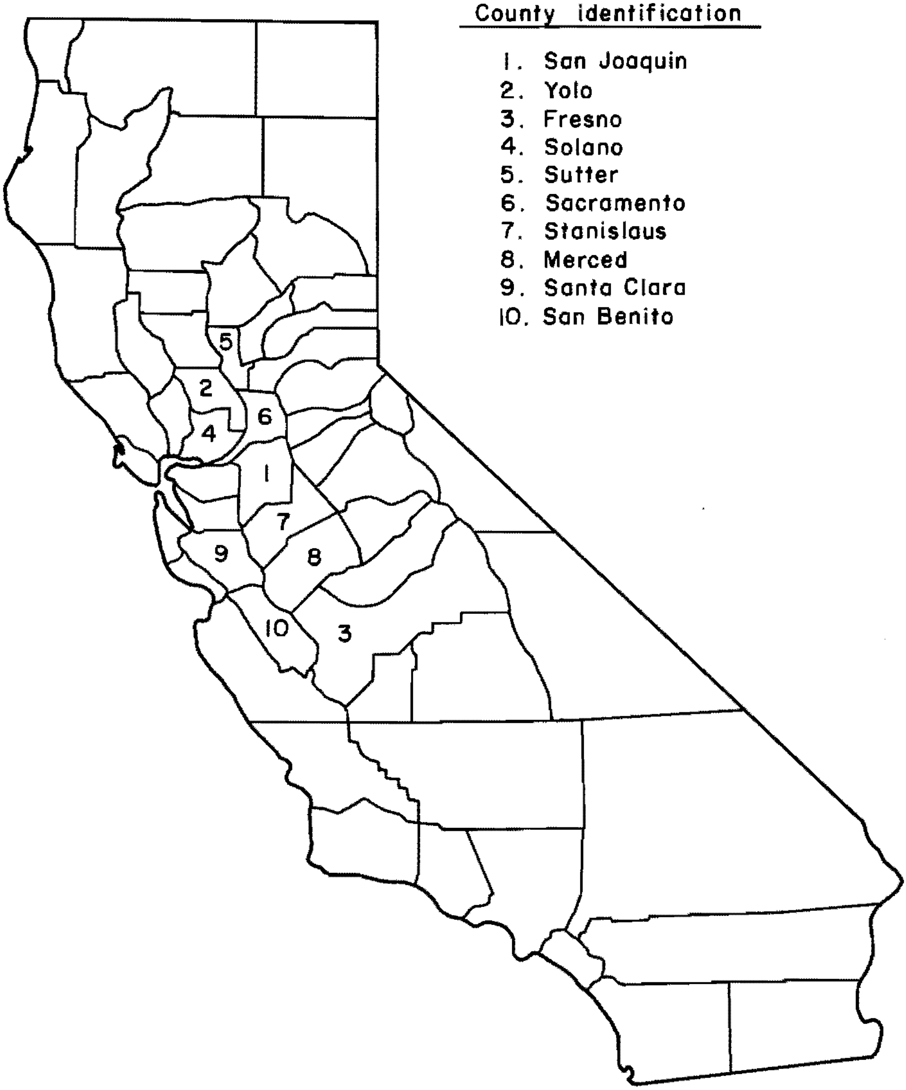

FIGURE 2. Identification of the Selected Major Processing Tomato Producing Counties

the 10 major counties, only San Joaquin, Merced, and Stanislaus have had significant acreage in producing tomatoes for fresh uses. Even in those three counties, the fresh tomato segment has been much smaller than that of processing tomatoes (Table 4).

In Figure 3 the historical trends of contract acreage and yield are shown for each of the selected 10 counties. Yolo and San Joaquin have been the two most important counties since 1948. While contract acreage has steadily increased in Yolo County, no significant increasing trend has prevailed in San Joaquin. It is noted that the annual variation appears to be very substantial in all 10 counties. Most counties show a significant trend in contract acreage except San Joaquin and Sacramento which even incurred a decline in recent years. The most rapid growth in acreage is found in Fresno and Merced Counties. While ranking first in 1975, Fresno was not even reported as an important county in 1951.

The shifts in production areas have been dramatic within the state. The most apparent instance is the change in Alameda County. It was ranked fourth in the state with 13,023 acres in 1945, and now less than 1,000 acres are from that county.[1] This drastic decline was undoubtedly due to urban expansion. On the other hand, the evident shift of acreage to Merced, San Benito, and Fresno Counties has probably resulted from canners' attempts to extend the harvesting season and the recent development of irrigation facilities in these areas.

Yield was also subject to substantial annual fluctuation throughout the period in every county. However, a general increasing trend is apparent in all counties. Undoubtedly, this increasing trend has resulted from the improvement of technology, adoption of new varieties, increasing use of fertilizer and pesticides, and improvement of irrigation.

Annual variation of acreage is expected to be highly correlated with changes in economic factors and likely to reflect various decisions which growers and processors made. On the other hand, the yearly fluctuation of yield might well be attributed to weather conditions and other uncontrollable random factors. Growers in different counties do not face an entirely similar environment even though they are relatively close to each other geographically in some cases. The soil, climate, and irrigation conditions are different. Also, growers in different counties adopt different crop rotation systems. This suggests that growers' response toward the changing environment in different counties might not be uniform. Therefore, it would be appropriate to measure these differences quantitatively in our estimation of acreage response.

Variety, Production Period, and Alternative Crops

Some understanding of general practices in the tomato industry is also useful. Two general types of tomatoes are produced in California: round and pear. Round tomatoes are utilized for all purposes and have comprised more than 95 percent of the crop in recent years. Pear tomatoes are used primarily in the manufacture of paste because they give a product of thicker consistency. In the past, pear tomatoes had a lower average

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[1] California Crop and Livestock Reporting Service, *California Vegetable Crops, 1945–46* (Sacramento, 1946); and *idem, California Vegetable Crops, 1975–76* (Sacramento, 1976), 22p.

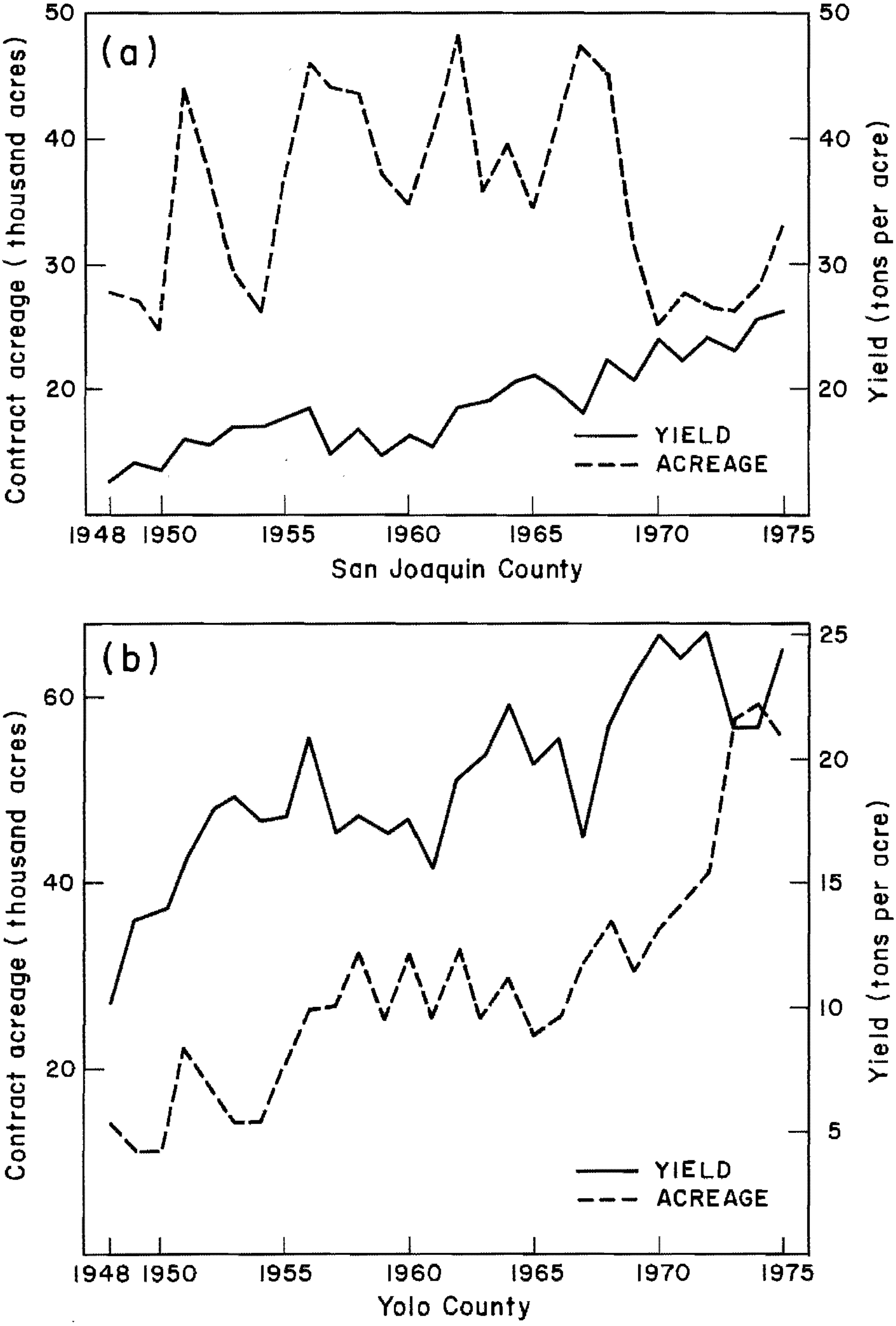
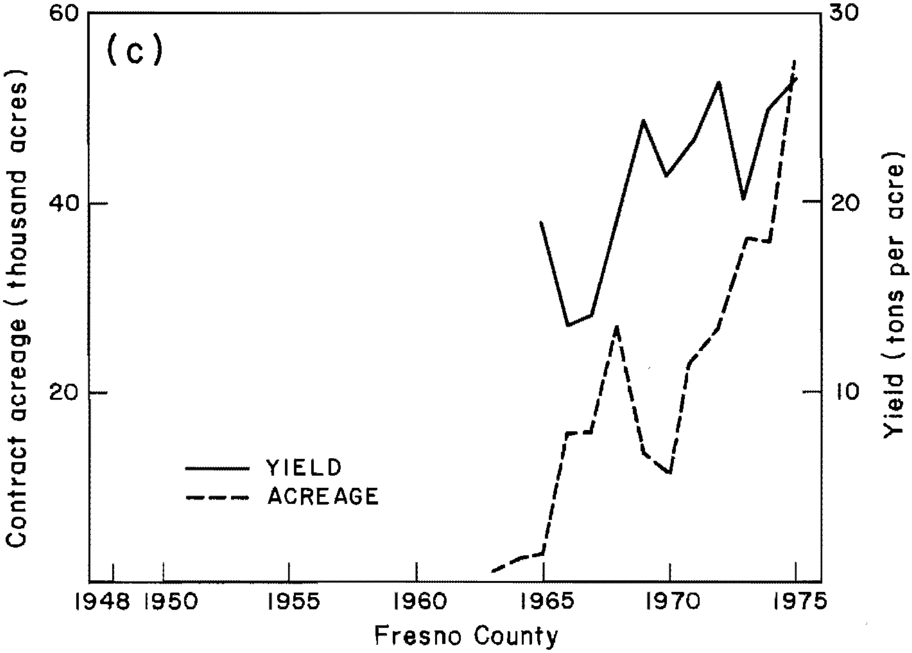
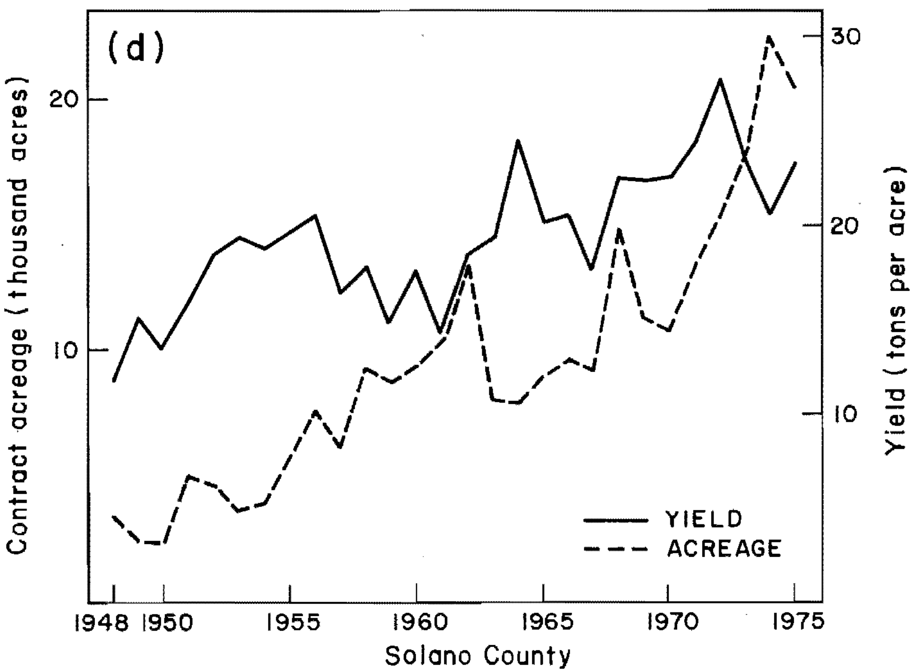
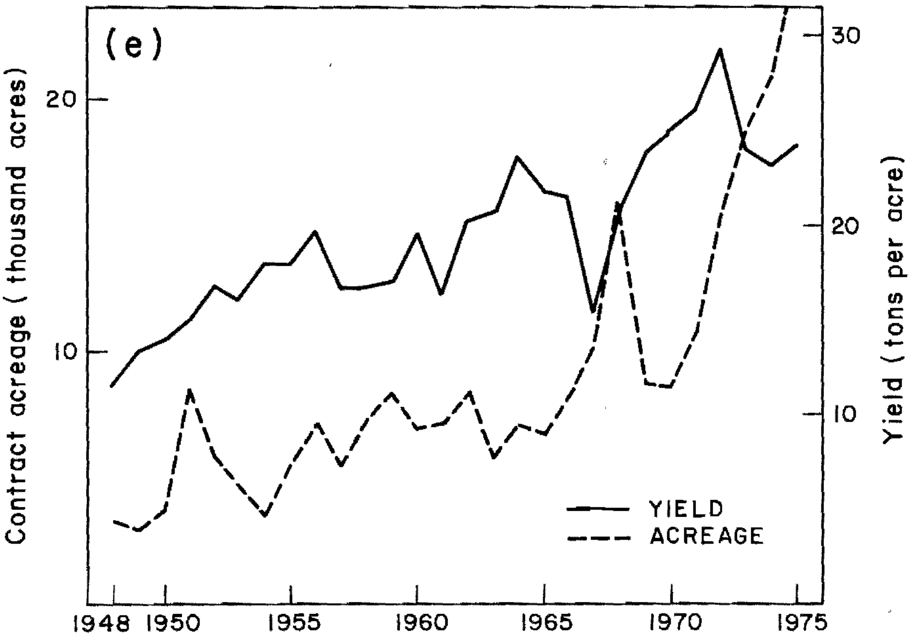


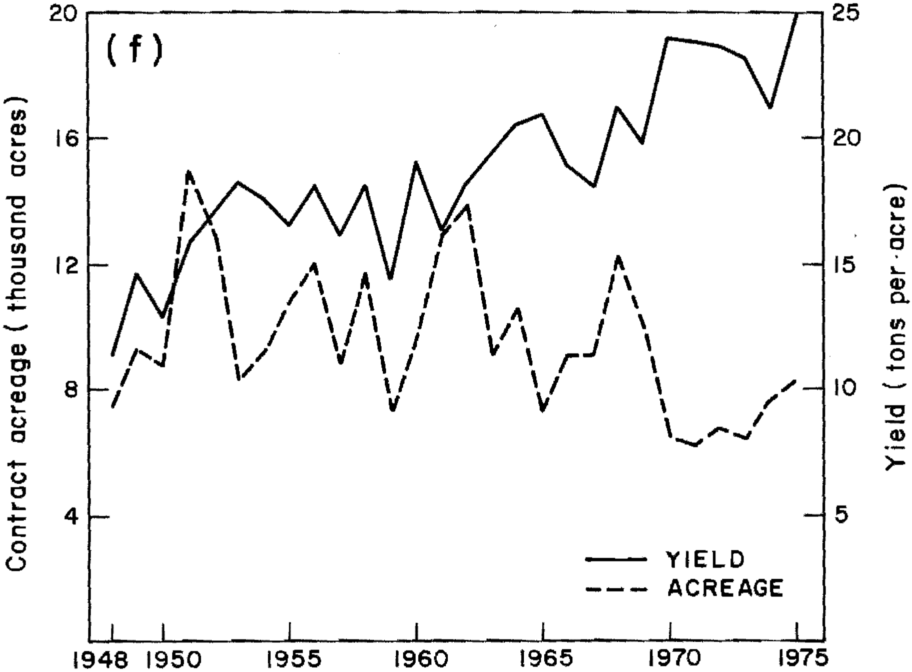
FIGURE 3. Contracted Acreage and Yield of Processing Tomatoes, by Counties in California, 1948–1975


(c)
60
40
20
30
20
10
Contract acreage (thousand acres)
Yield (tons per acre)
YIELD
ACREAGE
1948 1950 1955 1960 1965 1970 1975
Fresno County

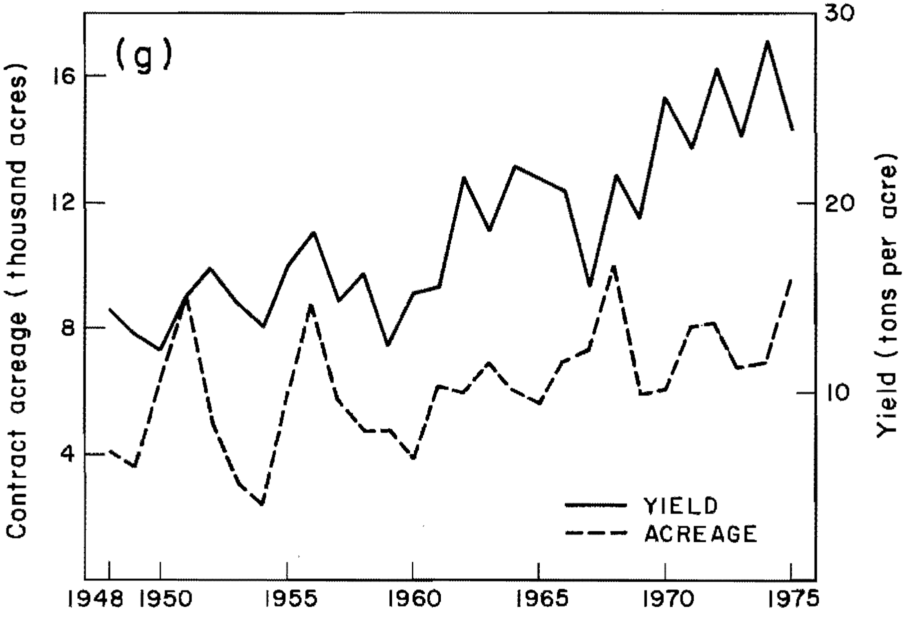

(d)
20
10
30
20
10
Contract acreage (thousand acres)
Yield (tons per acre)
YIELD
ACREAGE
1948 1950 1955 1960 1965 1970 1975
Solano County



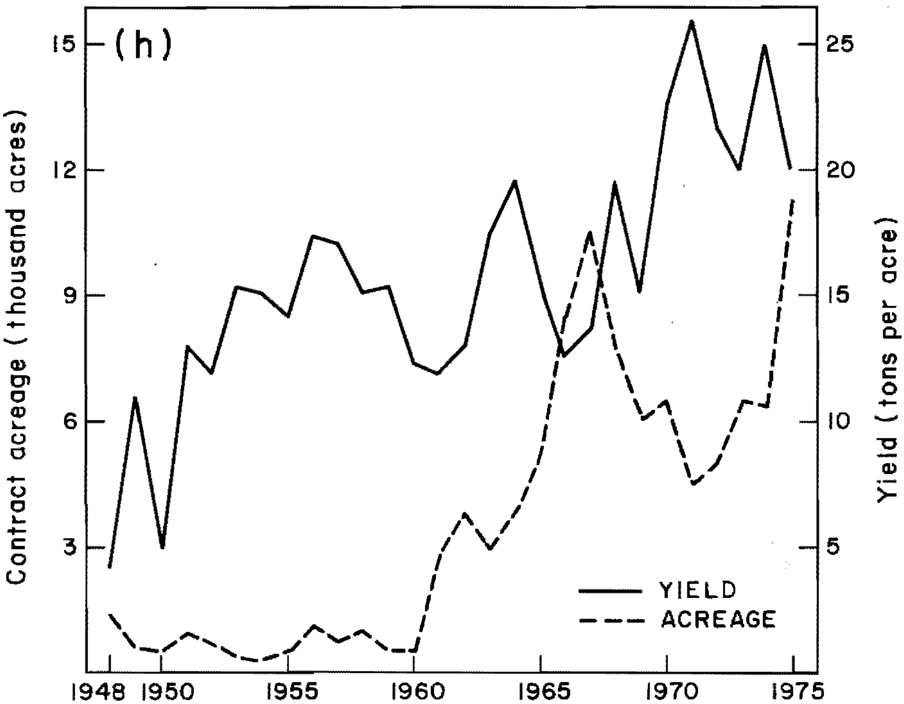
Sutter County



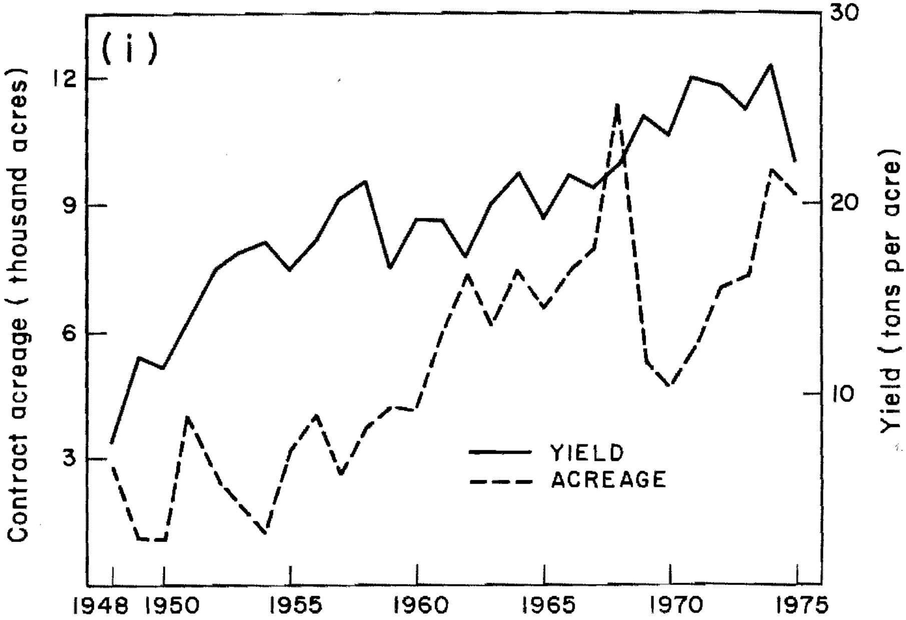
Sacramento County



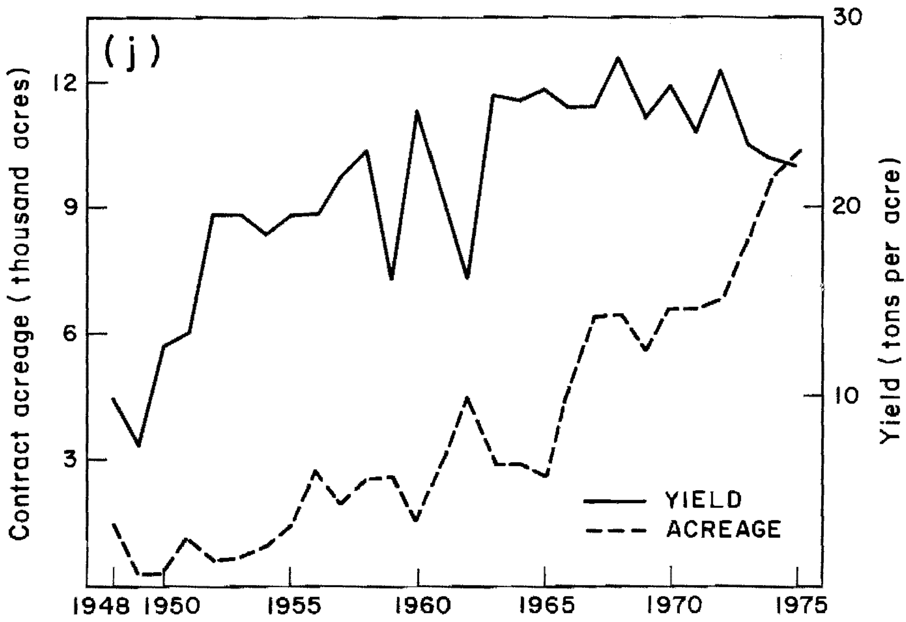
Stanislaus County



Merced County



Santa Clara County



San Benito County

yield but received a higher price than round tomatoes. Data regarding this differentiation are no longer available for recent years. Therefore, no attempt is made to treat these two varieties separately in the analysis.

The canning tomato is an annual crop. In California it is generally planted during February through May and harvested during July through November, with the most active harvesting occurring from August 20 to October 10. The production season in the Midwest and East is generally earlier in the year. Tomatoes are usually harvested in the summer in these areas. In Texas and New Mexico, canning tomatoes are produced in the late spring or early summer. The relatively late planting and harvesting in California are probably of some advantage to the state's growers and processors. With some knowledge of the supply conditions in other states, adjustments can possibly be made in harvesting and processing the current crop.

Alfalfa hay, sugar beets, and grain sorghum are probably the three most important alternative crops for tomato growers. These crops were often grown in a rotation system in some counties. While the degree of freedom for the grower to raise other crops might play an important role in his decision making, the generalization of an alternative crop is fairly difficult. For example, more than 100 crops are grown in San Joaquin County, and it is impossible to single out one or two crops as the most common alternative crops to processing tomatoes.

Grower–Processor Relations

Contracting (or forward buying) has been an effective means for grower–processor integration. Virtually all tomatoes for processing are now produced under contracts. One apparent purpose of contracting is to reduce uncertainty for both growers and processors. As previously indicated, California tomato growers are highly specialized and commercialized. Canning tomatoes are grown solely for the processing market. Since the number of canners is small (during the 1970s, the number of firms in California has numbered in the twenties), growers have to sell their products to one of only a few local canners. The constraint in plant capacity tends to make the market for their products more restrictive than in a situation where they can sell their products in the fresh market as well. It is, therefore, desirable for growers to assure a market for their products before growing the crop.

On the other hand, processors need a stable supply of raw tomatoes to maintain efficient operation of their plants and to preserve the market for their final products. Furthermore, without contracting, processors cannot have controls over the quality of raw tomatoes and the time schedules of delivery. The latter is especially important because tomatoes are perishable products. Thus, processors have a vested interest in stabilizing supply conditions through contractual arrangements.

Of course, a contractual arrangement does not guarantee the greatest possible income to the two competing groups in any optimal sense. As observed by Collins, Mueller, and Birch, the prices received by growers depend on the relative bargaining position of growers *vis–à–vis* canners.[1] It is the relative market power of the participants and not the mere

[1]Collins, Mueller, and Birch, *op. cit.*

existence of a vertically integrated relationship that is the crucial determinant of grower and processor income.

Although specific terms in a contract may differ somewhat among canners, they generally include the following items:

1. *Price provisions.* One of the most important terms is price per ton specified in all contracts. In addition to this contract price, most contracts contain a provision on payment tolerance which specifies the maximum allowable damaged fruit due to worms, mold, rot, insects, and other imperfections. Most canners allow 5 percent general defects.

2. *Quantity provisions.* All contracts specify the number of acres committed by the grower. The standard terms also specify that growers deliver all tomatoes harvested from the contracted acreage. Sometimes, canners modify this provision by stating the maximum tonnage per acre the canner is required to accept during the season.

3. *Delivery schedule.* Most contracts specify the times during which products may be delivered, the maximum daily or weekly tonnage per acre, and the latest date at which products will be accepted.

4. *Variety and strain specification.* All contracts specify the variety of tomatoes to be grown. Some also require that seeds be purchased from the canner. The restriction on variety is for controlling both maturity date and product quality.

5. *Other provisions.* Other common terms include hauling allowance, bin rental, time of payment, grading of products, and requirements for several cultural practices such as pest control.

Historically, most contracts have been finalized during the period December to March prior to the beginning of each season. This arrangement of raw product procurement is also common in midwestern and eastern states.

Contracting thus gives both growers and processors the opportunity to negotiate price and other contract terms in advance. Since growers can, in principle, turn down any unacceptable price offered by processors, the contract price is theoretically determined by both parties. In reality, however, the processor may exercise its oligopsonistic power. The notion of contracting is the basis upon which various pricing hypotheses are formulated for the empirical model later.

After a contract is made, contract price becomes fixed. Consequently, risk is greatly reduced for both growers and processors. The contractual arrangement can also help maintain the stability of tomato supply. Since the risk associated with price expectation is eliminated under this legal arrangement, it seems reasonable that price risk is not an important factor affecting response in the empirical model for the grower.

Tomato Processing in California

Canned Tomatoes and Tomato Products

The important forms in which California processed tomatoes are marketed are as follows: canned whole tomatoes, tomato juice, paste, sauce, catsup, and puree. Generally, catsup, juice, and canned whole tomatoes are sold exclusively through wholesalers and retailers to consumers. On the other hand, tomato paste, sauce, and puree have major outlets in manufacturing industries as ingredients for other food products.

An understanding of the historical trends of pack for various tomato products is severely restrained by data limitations. Data on the pack of sauce, hot sauce, and paste in consumer can sizes have not been available since 1961. Also, published data on the pack of catsup since 1968 have included only No. 10 and larger can sizes. The discussion here is confined to the five major products for which complete adjusted data series are available.

In California, the growth of pack has been very rapid from 1951–1956 to 1967–1972 for all products except tomato juice, for which the increase was not significant (Table 5). In other states, the packs of all tomato products except for catsup have declined. During this period, California's share increased drastically in the pack of canned tomatoes (from 40 to 70 percent) followed by tomato puree (from 56 to 85 percent). Tomato paste has been primarily a California product.

Tomato paste ranked first in terms of the utilization of raw tomatoes. In the 1971–72 season, 24 percent of raw tomatoes were used for making paste; canned tomatoes, 11 percent; tomato juice, 7 percent; catsup, 13 percent; and puree, 4 percent. The remaining 40 percent of raw tomatoes were used for hot sauce, chili sauce, consumer sizes of canned tomato paste, and others for which data are not available. The distribution of raw tomato tonnage among these products has varied from year to year.[1] This variation may result from the changes in demand and inventory situations.

Tomato Processing Plants and Firms in California

Most processing plants practice a multiple–production operation, both in the sense that they process more than one tomato product and that they process products other than tomatoes. A recent study by King *et al.* shows that more than 85 percent of 51 tomato processing plants packed one or more products other than tomatoes in 1972.[2] They found also that 60 percent of processing plants packed at least five different tomato products. In contrast, tomato processing plants in the Midwest and East tend to specialize in one or two tomato products.

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[1]Detailed data on utilization of raw tomatoes have been compiled and adjusted, but they are not reported here because they are too lengthy and are not to be used in the econometric analysis.

[2]King, Jesse, and French, *op. cit.*

TABLE 5

Pack of Tomato Products: California and Other States
Annual Average, 1951-52 to 1955-56 and 1967-68 to 1971-72

Period	Tomato products									
	Canned		Juice		Puree		Paste		Catsup	
	California	Other states	California	Other states	California	Other states	California	Other states	California	Other states
	millions of 24 No. 303 equivalent cases									
1951-52 to 1955-56	12.7 (40)[b]	18.7 (60)	14.4 (36)	25.5 (64)	3.2 (56)	2.5 (46)	5.8 (100)	[a]	8.5 (45)	10.6 (55)
1967-68 to 1971-72	27.7 (70)	11.7 (30)	17.5 (46)	20.5 (54)	7.4 (85)	1.3 (15)	12.6 (100)		21.1 (46)	31.8 (54)

[a]Blanks indicate insignificance.

[b]Figures in parentheses denote percentages.

Source: Canners League of California, *Reports of Packs and Stocks of Various Tomato Products* (Sacramento, December, 1951-1956, and 1967-1972).

The number of tomato processing firms declined from 57 in 1955 to 28 in 1972.[1] Since tomato production has rapidly increased in the state, the average size of the firm has increased. The average firm size, in terms of raw tomatoes procured, was 1.75 million tons in 1972 as compared to 35,000 tons in 1955. The average plant size would be somewhat smaller because of the existence of multiple–plant firms.

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, the four largest plants (all likely to be located in California) manufactured 25 percent of the total output of tomato products in the United States, while the share for the eight largest plants was 35 percent in 1965.[2] Converting to acreage equivalents, the average plant size was 17,084 acres for the four largest plants and 10,681 acres for the eight largest plants.

The increasing concentration of tomato processing among fewer firms has important implications for the structure of the tomato market (the number of California tomato canners has fallen more than 50 percent over the last 20 years). For example, price may be determined by one or a few dominant firms, and competition may be reduced in negotiating for contracts. Indeed, some experts believe that a single firm continually has been 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.[3]

Consumption and Imports and Exports of Tomato Products in the United States

Consumption

As shown in Table 6, per capita consumption of canned whole tomatoes and tomato juice has been relatively steady with very little change over the last two decades. For catsup, chili sauce, paste, and puree, an increasing trend can be traced out. If all products are combined, the increasing trend becomes more apparent. Calculated in fresh equivalent basis, the per capita consumption of all tomato products was 55.4 pounds in 1974 as compared to 41 pounds in 1951, an increase of 35 percent during the 23–year period. Aggregate consumption would, of course, have a much greater increasing trend as population has steadily increased.

Imports and Exports

The United States imports substantial quantities of canned tomatoes, paste, and sauce. It also exports many tomato products to other countries. During 1971–72, total imports

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[1] *Ibid.;* also, see Collins, Mueller, and Birch, *op. cit.*

[2] U. S. National Commission on Food Marketing, *Organization and Competition in the Fruit and Vegetable Industry,* Technical Study No. 4, 1966, p. 182.

[3] For a further discussion, see *infra,* pp. 89–96.

TABLE 6

Per Capita Consumption of Tomato Products: United States, 1948-1974

Calendar years	Tomato products: Canned, whole	Catsup and chili sauce	Paste and sauce	Pulp and puree	Juice[a]	Total tomato products
	processed weight, pounds					fresh equivalent, pounds
1948	4.4	2.2	2.3	.5	3.9	32.6
1949	4.7	2.5	2.2	.6	4.2	34.0
1950	5.1	2.7	2.4	.7	4.7	37.6
1951	4.9	2.5	3.3	.8	4.4	41.0
1952	4.1	2.8	2.7	.9	4.8	38.6
1953	4.5	2.7	2.9	.8	5.2	40.2
1954	4.6	2.8	2.7	.5	4.8	38.2
1955	4.5	3.0	3.3	.7	4.5	41.0
1956	4.6	3.1	3.3	.9	4.3	41.6
1957	4.6	3.3	3.2	.7	5.0	41.7
1958	4.6	3.5	3.4	.7	4.4	42.3
1959	4.6	3.6	3.5	.7	4.8	42.8
1960	4.6	3.8	3.8	.7	4.7	43.7
1961	4.8	3.9	3.7	.8	4.6	44.2
1962	4.6	4.1	3.9	.8	4.7	45.0
1963	4.6	4.3	4.0	.8	5.4	46.5
1964	4.5	4.6	3.9	.8	4.5	45.0
1965	4.5	5.0	3.9	.8	4.7	45.9
1966	4.6	4.8	4.2	1.0	4.4	47.6
1967	4.6	4.7	5.0	1.0	4.2	51.0
1968	4.9	9.8		1.1	4.0	50.4
1969	4.9	10.1		1.0	4.1	51.3
1970	4.8	10.1		1.0	4.1	51.3
1971	4.9	9.9		1.0	3.9	50.4
1972	5.1	10.2		1.1	3.7	52.0
1973	5.8	11.3		1.1	3.3	56.2
1974[b]	5.0	11.3		1.2	3.6	55.4

[a]Tomato juice and other vegetable juices: 94 percent of reported per capita consumption.
[b]Preliminary.

Sources:

1948-1959: U. S. Economic Research Service, *Food Consumption Prices Expenditure*, Agricultural Economics Report No. 138 (1968), Tables 20 and 22.

1960-1974: *Idem*, *Food Consumption Prices Expenditure: Supplement for 1974*, Agricultural Economics Report No. 138 (1976), Tables 20 and 22.

of canned tomatoes amounted to 141 million pounds in processed weight, while the exports of this product were 17.8 million pounds.[1]

Exports of paste, puree, catsup, and chili sauce have declined, while imports of canned tomatoes, paste, and sauce have increased during the last two decades. Italy has been the major supplier of canned tomatoes until recently when it lost some of its share to Spain. For tomato paste and sauce, Portugal and Spain have recently replaced Italy as the major exporters to the United States.

Canada has been the single most important receiver of U. S. exports of tomato products. During 1971–72, Canada imported 17 million pounds of canned tomatoes from the United States which accounted for 94 percent of the total U. S. export of this product. Canada also accounted for 78 percent of U. S. exports of puree, 30 percent of tomato juice, and 19 percent of catsup and chili sauce during the same period.

California has contributed most of the U. S. exportation of processed tomato products. During 1962–1965, California supplied all paste, puree, and sauces and about 50 percent of canned tomatoes and tomato juice exported from the United States.[2] Data are not available for recent years, but it is expected that California's contribution to U. S. exports of tomato products has increased as a result of its increasing share of tomato production.

Analysis of Costs in Production, Processing, and Marketing

The average cost for producing canning tomatoes was about $550 per acre in 1969 as shown in Table 7. The detailed cost components are also shown in this tabulation. Total costs are about equally divided into three major categories: (1) cultural (preharvest), (2) harvesting, and (3) investment overhead costs. Labor costs appear to be the single most important item accounting for more than 28 percent of total costs. Costs for fertilizer application, insect control, and irrigation together shared 17 percent of total costs.

Before the introduction of the mechanical tomato harvester in mid–1960, tomatoes were harvested by hand. The cost components of hand harvesting should be different from those of mechanical harvesting. Parsons showed that mechanical harvesting reduces harvesting costs dramatically.[3] As calculated by the 1965 enterprise cost studies, the average cost per ton by mechanical harvesting was $9.84 as compared to $27.07 in San Joaquin County and $17.19 in Yolo County by hand harvesting. King, Jesse, and French conducted a regression analysis based on the sample cost studies for various counties over the period 1951–1973.[4] By expressing total harvesting costs per acre as a function of time, yield,

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[1]All statistics related to imports and exports cited here are obtained from the U. S. Economic Research Service, *U. S. Foreign Agricultural Trade Statistical Report: Fiscal Year* (selected issues).

[2]California Crop and Livestock Reporting Service, *Exports of Agricultural Commodities Produced in California: Calendar Year, 1962–1963* (Sacramento, 1964, and subsequent years).

[3]Philip S. Parsons, *Cost of Mechanical Tomato Harvesting Compared to Hand Harvesting*, California Agricultural Extension Service, AXT–224 (Berkeley, 1966), 9p.

[4]King, Jesse, and French, *op. cit.*

TABLE 7

Costs of Tomato Production with Machine Harvesting: Yolo and San Joaquin Counties[a]
1969-70 and 1970-71

Item	1969-70[b] Yolo County		1970-71[c] San Joaquin County	
	Cost of tomato production	Percent of total	Cost of tomato production	Percent of total
	dollars		dollars	
Cultural costs				
Fertilizer (starter and sidedress)				
Labor	0.94	0.2	[d]	
Fuel and repairs	1.27	0.2		
Materials	12.30	2.3	36.50	6.1
Weed and insect control				
Labor	1.12	0.2	1.13	0.2
Equipment for Application	1.04	0.2	12.68	2.1
Materials	41.86	7.7	35.66	6.0
Irrigation				
Labor	18.38	3.4	18.04	3.0
Water	15.33	2.8	16.88	2.8
Others				
Labor	27.46	5.0	45.18	7.6
Fuel and repairs	17.77	3.3	24.97	4.2
Materials	15.50	2.8	11.25	1.9
Miscellaneous	45.39	8.3		
Total cultural costs	198.36	36.4	202.29	34.0
Harvesting costs				
Labor	104.62	19.2	116.21	19.6
Fuel, repairs, etc.	27.05	5.0	36.82	6.2
Miscellaneous	38.77	7.1	26.16	4.4
Total harvesting costs	170.44	31.3	179.19	30.2
Management costs	28.75	5.3	32.20	5.4
Investment costs (overhead)	147.69	27.0	180.72	30.4
Total costs per acre	545.24	100.0	594.40	100.0
Total costs per ton	23.70		25.84	

[a]Based on yield of 23 tons per acre.

[b]This cost study, based on 160 acres of machine-harvested tomatoes, is assumed to be part of a 1,000-acre multicrop farming operation.

[c]Based on an 800-acre farm, with 300 acres in tomatoes (rented land).

[d]Blanks indicate negligible amounts.

Sources:

Melvin P. Zobel and Philip S. Parsons, "Tomato Costs of Production: Yolo County--1970," Agricultural Extension Service, University of California (Yolo County, 1970), 5p.

Ray C. King, "Sample Costs to Produce Direct-Seeded Tomatoes in San Joaquin County" (Stockton, 1971).

and harvesting method, they estimated that the use of the harvester reduces harvesting costs by $5.43 per ton.

The latter estimate represents an average cost saving for all counties over the study period. Thus, it is not quite comparable with Parsons' estimates for a particular year (1965) because cost per ton depends crucially upon yield per acre, and yield fluctuates over time. However, both studies show substantial cost saving in harvesting as a result of using the tomato harvester.

Cultural and harvesting costs for the periods before and after the adoption of the tomato harvester are compared in Table 8. From this limited sample, it is found that, while harvesting costs have declined with mechanization, cultural costs have increased notably. In San Joaquin County, cultural costs accounted for about 25 percent of total production costs during the hand–harvesting period; this increased to 36 percent in 1973 when mechanical harvesting completely replaced handpicking methods.

Use of the tomato harvester, however, represents a substantial capital investment in place of variable costs associated with labor. For example, in 1969 the total required investment for a single–machine operation was $43,000 ($23,500 for the harvester, $2,000 for two trailers, $10,000 for the tractor, $6,000 for a forklift, and $1,500 for washing equipment).[1] Furthermore, the harvester lasted for only five years (annual depreciation was $4,600 for a salvage value of $500). Finally, costs of harvesters have increased substantially in recent years. With the development of electronic color sorters (reducing hand sorting on the machine), it is not uncommon to hear of costs associated with a single harvester exceeding $140,000. Such shifts from variable (labor) to fixed (capital) costs can lead to important structural changes in supply; these shifts are investigated and discussed at some length in the later empirical section.

The structure of processing cost components is more complicated than production costs. Different tomato products have to go through different manufacturing processes. While complete information regarding the cost variation among different products is not available, a specific cost study for canned peeled tomatoes was provided by the U. S. National Commission on Food Marketing.[2] The detailed cost components are summarized in Table 9. Raw material costs constitute only a small proportion of total processing expenses——17 percent.

The distribution of the consumer dollar is further shown in Table 10. Tomato growers received only 16 percent of the consumer dollar for canned tomatoes. On the other hand, more than 50 percent of the consumer dollar was allocated to processors and 25 percent to wholesalers and retailers. This is, of course, typical for most processed agricultural products.

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[1]Melvin P. Zobel, "Machine Harvest Costs: Tomato——1969, Yolo County," Agricultural Extension Service, University of California (Woodland, 1969), 12p. (Mimeographed.)

[2]U. S. National Commission on Food Marketing, *op. cit.*

TABLE 8

Comparison of Cultural and Harvesting Costs
Yolo and San Joaquin Counties, Selected Years

Calendar year	Yolo County			San Joaquin County		
	Cultural costs	Harvesting costs	Total costs[a]	Cultural costs	Harvesting costs	Total costs[a]
	dollars per acre					
1957	[b]			115.8 (25)[c]	210.0 (46)	457.8 (100)
1958	101.2 (26)	196.0 (51)	383.5 (100)			
1961	139.7 (29)	239.1 (50)	474.5 (100)			
1962				122.9 (24)	249.6 (48)	519.7 (100)
1970	161.8 (30)	213.0 (39)	545.2 (100)			
1973				267.3 (36)	242.0 (33)	726.7 (100)

[a] Includes overhead costs.

[b] Blanks indicate no estimates available for those years.

[c] Figures in parentheses denote percentages.

Source: Gordon A. King, Edward V. Jesse, and Ben C. French, *Economic Trends in the Processing Tomato Industry*, University of California, Giannini Foundation Information Series No. 73-4 (Davis, 1973), pp. 70 and 71.

TABLE 9

Cost of Canning Peeled Tomatoes: California, 1964
24 No. 303 Cans (Standard) With Added Juice

Cost item	Canning peeled tomatoes: Weighted average cost[a] (dollars per case)	Canning peeled tomatoes: Percent of total costs
Raw products[b]	0.455	17.3
Cans	0.730	27.8
Containers and supplies[c]	0.171	6.5
Direct labor[d]	0.495	18.9
Variable overhead[e]	0.177	6.7
Specific selling cost[f]	0.168	6.4
Standby and programmed expenses[g]	0.430	16.4
Total costs[h]	2.626	100.0

[a] Weighted by the data reported from 17 firms.

[b] Grower price and those acquisition costs and credits which are directly variable with production.

[c] Cases, labels, and direct supplies.

[d] For receiving and preparation, special preparation, canning, processing, and warehouse.

[e] General service labor; employee benefits; royalties; and fuel, power, and water.

[f] Freight, delivery, brokerage, cash discount, and swells.

[g] Field overhead, superintendent and indirect labor, factory burden, financial, administrative, and general selling.

[h] Imputed interest on equity capital not included.

Source: U. S. National Commission on Food Marketing, *Organization and Competition in the Fruit and Vegetable Industry,* Technical Study No. 4 (Washington, D. C., 1966), p. 202.

TABLE 10

Distribution of the Consumer Dollar for Canned Tomatoes, 1964[a]

Item	Canned tomatoes	
	Distribution	Percent of total
	cents	
Grower	2.6	16.3
Processor	9.0	56.2
Wholesaler	1.2	7.5
Retailer	2.8	17.5
Transportation	0.4	2.5
Total	16.0	100.0

[a]Based on 16 cents paid for a No. 303 can (standard) of canned tomatoes.

Source: U. S. National Commission on Food Marketing, *Cost Components of Farm-Retail Price Spreads for Foods*, Technical Study No. 9 (Washington, D. C., 1968).

3. SUPPLY AND DEMAND FOR ACREAGE: AN ECONOMIC ANALYSIS OF CONTRACTING

In this section a theory of contracting is developed to show theoretically how acreage and price (paid to growers) might be determined in the raw tomato supply market. It is hoped that the model captured, at least in a rough way and without serious distortion, some of the essential features of the actual decision–making processes of growers and processors. The results derived in this section provide the basis for the econometric formulations.

A Static Economic Model

As noted previously, most processing tomatoes have been produced under contractual arrangements in California. The open market (or noncontracted) acreage amounted to less than 5 percent of total harvested acreage in most years during the period 1948–1975.[1]

[1]Appendix Table 1, *infra*, pp. 102–106.

The analysis of contracting in this study deals with the determination of acreage and price within the structure of the raw tomato market. Theoretically, acreage and price are determined by supply and demand which can be derived from growers' and processors' profit–maximization conditions. A profit–maximization model is then employed to derive the acreage supply and demand functions. A static model is first developed without considering the formulation of expectations of yield and product prices.

Variables are defined as follows:

A = acreage to be contracted

Y = yield per acre

Y^* = expected yield

$Q = AY$ = quantity produced from contracted acreage

$Q^* = AY^*$ = expected quantity to be produced

P_c = price per ton of raw tomatoes

and

P_j^* = expected price of final product j.

Supply of Acreage

Suppose that the growers' objective is to maximize profit subject to technological and contractual constraints where the production function is defined by

$$Q = Q(A, X_1, X_2, X_3)$$

where

X_1 = labor

X_2 = fertilizer (and other materials)

and

X_3 = capital.

It is assumed that all marginal products are nonnegative, and Q is a strictly concave function (at least in the econometrically relevant region). It also will be useful to consider the corresponding unit production function,

$$Y = \frac{Q}{A} = Y\ (A,\ X_1,\ X_2,\ X_3).$$

The properties of the unit production function are qualified as follows. In the case that Q is a Cobb–Douglas function exhibiting decreasing returns to scale, Y will have a negative first derivative with respect to A; that is to say, greater acreage will imply smaller yield per acre. Using the unit function formulation, for a given A, Q is determined by Y. Hence, the unit production function can also be treated as an identity in Y, Q, and A.

The costs are further specified as

$$C = w_0 A + w_1 X_1 + w_2 X_2 + w_3 X_3$$

where w_0, w_1, w_2, and w_3 are, respectively, input prices for A, X_1, X_2, and X_3.

The profit function can then be expressed as

$$\Pi_g = P_c Q - C.$$

The problem is to maximize Π_g subject to the following constraints:[1]

$$Q \leqslant Q^*,\ A \geqslant 0,\ \text{and}\ X_i \geqslant 0 \qquad i = 1,\ 2,\ 3.$$

The Lagrangian function for the maximization problem is

$$L_g = P_c Q - C + \lambda\ (Q - Q^*),$$

and the associated Kuhn–Tucker conditions for a maximum are:[2]

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[1]The first inequality is imposed because bumper restrictions (growers cannot deliver more than the specified tonnage) are generally used, and the observed Qs were actual quantity marketed rather than production.

[2]Michael D. Intriligator, *Mathematical Optimization and Economic Theory* (Englewood Cliffs, N. J.: Prentice Hall, Inc., 1971), 508p.

$$
\begin{aligned}
&(P_c + \bar{\lambda}) \left(\frac{\partial \bar{Q}}{\partial A} \right) - w_0 \leq 0 \\
&(P_c + \bar{\lambda}) \left(\frac{\partial \bar{Q}}{\partial X_i} \right) - w_i \leq 0 \\
&\left[(P_c + \bar{\lambda}) \left(\frac{\partial \bar{Q}}{\partial A} \right) - w_0 \right] \bar{A} = 0 \\
&\left[(P_c + \bar{\lambda}) \left(\frac{\partial \bar{Q}}{\partial X_i} \right) - w_i \right] \bar{x}_i = 0 \\
&\bar{Q} - Q^* \leq 0 \\
&\bar{A} \geq 0 \\
&\bar{X}_i \geq 0 \qquad i = 1, 2, 3
\end{aligned}
\tag{1}
$$

where bars denote variables, functions, and derivatives evaluated at the maximum.[1] Assuming all inputs are actually used, *i.e.*, $\bar{A} > 0$ and $\bar{X}_i > 0$ for all i, the conditions reduce to

$$
\begin{aligned}
&(P_c + \bar{\lambda}) \left(\frac{\partial \bar{Q}}{\partial A} \right) - w_0 = 0 \\
&(P_c + \bar{\lambda}) \left(\frac{\partial \bar{Q}}{\partial X_i} \right) - w_i = 0 \\
&\bar{Q} - Q^* = 0 \qquad i = 1, 2, 3.
\end{aligned}
\tag{2}
$$

Noting $Q^* = AY^*$, one can derive the solutions for A and the X_i's from (2):

---

[1]Under strict concavity of Q and an additional "constraint qualification," these conditions define a global maximum; see *ibid.*

$$A = A\ (P_c,\ w_0,\ w_1,\ w_2,\ w_3,\ Y^*)$$
$$X_i = X_i\ (P_c,\ w_0,\ w_1,\ w_2,\ w_3,\ Y^*) \qquad i = 1,\ 2,\ 3. \tag{3}$$

Equation (3) says that the optimal use of various inputs is a function of raw tomato price, all input prices, and expected yield. These are generally termed the input demand functions. Our major interest for econometric analysis is in the equation for acreage, namely,

$$A^s = A^s\ (P_c,\ w_0,\ w_1,\ w_2,\ w_3,\ Y^*). \tag{4}$$

Equation (4) can be viewed as the derived demand function with respect to w_0. It can also be treated as a derived supply function of acreage with respect to P_c. In general, it can be termed the acreage response equation.

Derived Demand for Acreage

Let us now consider the processors' demand for acreage in tomato contracting. As noted in the last section, there are few processors in the industry. It is, therefore, plausible to consider that the processors may procure raw tomato supply in a so–called oligopsonistic market. The equilibrium conditions for an oligopsonistic entrepreneur are, in general, difficult to derive because the reactions of his rivals enter his decisions and may be difficult to predict. Fortunately, the situation in the tomato industry seems more straightforward. Informal interviews with growers in this study confirmed an earlier observation by Collins, Mueller, and Birch that most processors follow leadership pricing as a policy.[1] In leadership pricing, one firm takes the initiative in making price changes for the entire industry. As a result of this practice, most processors view price as given in negotiating a contract with growers. The focus in this section is on the behavior of price–taking processors. The effect of the price leader on the industry will be discussed later.

The price–taking processor is faced with a two–stage decision process. First, he has to determine the total quantity of raw tomatoes which will maximize his profit. Then he has to estimate the acreage needed according to his expectation of yield.

Suppose all processed products can be measured in proportion to the raw tomatoes utilized, that is,

$$V_j = r_j\ Q_j$$

---

[1]Collins, Mueller, and Birch, *op. cit.*

where

V_j = quantity of the *j*th processed product

r_j = product transformation ratio for the *j*th product

and

Q_j = quantity of raw tomatoes used for project j.

Assume, further, that the processing cost function for the *j*th product is given by

$$S_j = S_j(V_j) = S_j(r_j Q_j)$$

where S_j is net of the cost of purchasing raw tomatoes. The processors' expected profit function at the time of contracting can then be formulated as[1]

$$\Pi_p = \sum_{j=1}^{k} P_j^* r_j Q_j - \sum_{j=1}^{k} S_j(r_j Q_j) - P_c \sum_{j=1}^{k} Q_j.$$

The first–order condition of profit maximization with respect to the Q_j's gives

$$P_c = r_j P_j^* - r_j S_j'(r_j Q_j) \qquad \text{for } j = 1, ..., k. \tag{5}$$

The second–order condition is satisfied if $S_j''(r_j Q_j) > 0$ which holds under the assumption of increasing marginal cost. Equation (5) indicates that, at equilibrium, the processor would demand the quantity Q_j for project j at which the marginal cost of processing equals the difference between the prices of raw and processed products. From this first–order condition, one can derive the demand function for raw tomatoes as

$$Q_j = Q_j(P_c, P_j^*, r_j) \qquad j = 1, \ldots, k. \tag{6}$$

In order to obtain comparative static results, one can differentiate equation (5) with respect to P_c and P_j to show that

---

[1]The profit function is formulated differently here than in the previous section. Expressing the cost function in terms of output level, it is implicitly assumed that the cost–minimization conditions have been achieved for each level of output. The purpose here is only to find the optimal output level where previously the purposes were to find the input levels. However, the formulation here serves the objective in deriving the demand for acreage. All relevant input prices in tomato processing could well be included in the acreage demand equation as in the preceding section.

$$\frac{\partial Q_j}{\partial P_c} = \frac{-1}{r_j^2 S_j''(r_j Q_j)} < 0$$

$$\frac{\partial Q_j}{\partial P_j^*} = \frac{1}{r_j S_j''(r_j Q_j)} > 0$$

under the usual conditions. The total demand for raw tomatoes is simply the sum of Q_j's. This can be expressed as

$$Q^d = \sum_{j=1}^{k} Q_j = Q^d (P_c, P_1^*, \ldots, P_k^*, r_1, \ldots, r_k) \tag{7}$$

where $r_1, \ldots, r_k$ are fixed parameters in the equation.

In order to make contracts with growers, the processor first has to decide on a specific acreage. If yield were known with certainty at the time of contracting, one could derive acreage directly by computing $A^d = Q/Y$. In the stochastic case, however, acreage must be derived according to the yield expectation as $A^d = Q/Y^*$ where Y^* is the expected yield. More generally, it can be expressed as

$$A^d = A^d (Q^d, Y^*). \tag{8}$$

Equation (8) is the derived demand for acreage. The only behavioral element in determining acreage from the optimal quantity is the formulation of yield expectation. Several hypotheses regarding the processors' yield expectation will be discussed later. By consolidating the two stages of the decision process, the demand for acreage can be written as

$$A^d = A^d (P_c, P_1^*, \ldots, P_k^*, Y^*; r_1, \ldots, r_k). \tag{9}$$

All comparative static results derived above also apply to equation (9). In this formulation, equation (9) serves two important uses. It is a factor demand function with respect to P_c and also a product supply function with respect to the P_j^*'s.

Market Equilibrium and Price Determination

The supply and demand functions derived in the previous section are the decision rules which growers and processors must follow in order to maximize their profit. But the price paid to growers, P_c, is treated as given for both growers and processors. One would like to know how this price is determined in the raw tomato supply market.

As noted earlier, the pricing policy in the California tomato industry is a kind of leadership pricing. Stigler has noted two general cases of price leadership: (1) the dominant firm leadership and (2) the barometric firm hypothesis.[1] In the former case, a dominant firm sets the price while the minor firms buy what they wish at that price. Price leadership in the other case refers to the existence of a firm that conventionally announces price changes first (which are usually followed by the other firms in the industry) even though that barometric firm may not occupy a dominant position. Depending on the type of price leadership, the price may be set competitively, monopsonistically, or somewhere in between.

Suppose the industry supply and demand curves can be derived by summing up the supply and demand curves of all individual growers and processors. The competitive leadership price will then be set at aggregate supply and demand equilibrium just as in the competitive market. If the leadership firm acts like a monopsonist, the ordinate of any point on the supply curve of the factor denoted by SS in Figure 4 would be the average cost per unit of the factor to the firm. The firm would then equate the demand curve, DD, and the marginal factor cost curve, MM (not the average cost curve), in order to maximize its profit. As shown in Figure 4, P_p is the competitive price and P_m is the monopsonistic price. The actual leadership price would be at some level in between. If the demand curve was more inelastic than in Figure 4, the difference between P_p and P_m would be smaller.

Figure 4 also shows that monopsony leads to the utilization of a smaller quantity of raw tomatoes at a lower purchase price than a competitive market. These results hold regardless of whether the market for processed tomato products is competitive or monopolistic.[2]

It is interesting to see how a monopsonistic firm behaves within a static optimization model. Recall that previously it was assumed that P_c is fixed for processors in making a contract decision. In a monopsonistic situation, the leadership firm is facing an upward sloping supply curve which can be expressed as $P_c = P_c(Q) = P_c(A)$. Consider a simple case of one processed product with its price P and the product transformation ratio r. The expected profit function of the leadership firm thus becomes

$$\Pi_p = P^*rAY^* - S(rAY^*) - P_c(A)\,AY^*$$

which is a function of A.[3] The first–order condition gives

$$rP^* - rS'(rAY^*) = P_c(1 + \epsilon)$$

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[1]George J. Stigler, "The Kinky Oligopoly Demand Curve and Rigid Prices," *Journal of Political Economy,* Vol. 55, No. 5 (October, 1947), pp. 432–449.

[2]Kalman J. Cohen and Richard M. Cyert, *Theory of the Firm* (Englewood Cliffs, N. J.: Prentice–Hall, Inc., 1965), 406p.

[3]For purposes of illustration and convenience, the acreage–quantity identity, *i.e.*, Q = AY*, has been used in formulating the expected profit function. By consolidating the two decision stages, acreage instead of quantity becomes the only decision variable.

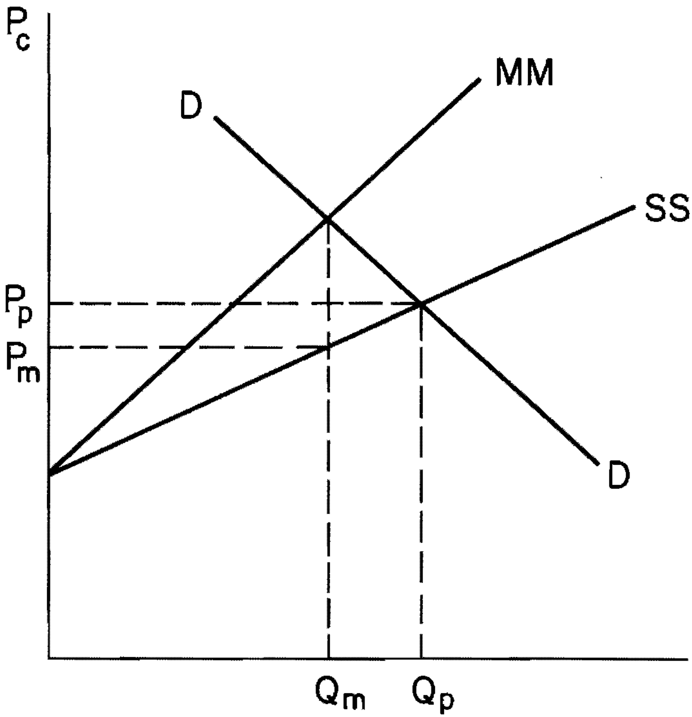

FIGURE 4. A Comparison of Monopsony and Competition

where

$$\epsilon = \frac{dP_c}{dA} \frac{A}{P_c}$$

is the price flexibility with respect to contract acreage ($\epsilon > 0$ for an upward–sloping supply curve). This condition can be rewritten as

$$P_c = \frac{r}{(1 + \epsilon)} [P^* - S' (rAY^*)].$$

It is then obvious that P_c in the monopsonistic situation is discounted by a factor ϵ and is therefore smaller than what would obtain in the competitive situation. This result is, of course, consistent with what was previously shown in Figure 4.

By way of implication for econometric model development for the aggregate market, the above discussion implies that both price and quantity are endogenously determined under both the competitive and monopsonistic situations. That is, while the leadership firm's actions may be exogenous to other processors, they are endogenously determined in the aggregate market.

A Complete System

The foregoing analysis has derived the behavioral equations describing growers' and processors' decision processes. By consolidating the static results obtained in equations (4), (7), and (8), the raw tomato market can be systematically described by a set of three equations:

Acreage response: $A^s = A^s (P_c, w_0, w_1, w_2, w_3, Y^*)$ (10)

Demand for Raw Product: $Q^d = Q^d (P_c, P_1^*, ..., P_k^*; r_1, ..., r_k)$ (11)

Quantity and Acreage Relation: $A^d = A^d (Q^d, Y^*)$ (12)

where all variables are defined previously. At equilibrium, $A^s = A^d$.

Although the acreage response function was derived from a single–product production function, it is possible to adopt a multiproduct production function. But the treatment of a multiproduct production function would substantially complicate the theoretical model without adding substantively to the model. The multiproduct case has similar results except that the prices of competing crops are introduced in the acreage response function.

Treatment of Unobservable Variables

One important aspect regarding expectations of yield and product prices has been neglected in our static model. It is noted that the expected yield and expected product prices in the system (10)–(12) are not observable at the time when growers and processors are negotiating for a contract. It is therefore necessary to know how growers and processors form their expectations.

Uncertainty and Expectation of Yield

It seems reasonable to hypothesize that the grower and processor formulate their yield expectations according to past yields. A naive expectation model is

$$E\ (Y_t \mid Y_{t-1},\ Y_{t-2},\ \ldots) = Y_{t-1} \tag{13}$$

or

$$E\ (Y_t \mid Y_{t-1},\ Y_{t-2},\ \ldots) = f\ (Y_{t-1}).$$

That is to say, the grower or processor simply takes last year's yield as a prediction of yield for the coming year. Or, more generally, the expectation of this year's yield is a function of yield in the last year.

There is, of course, no reason why the grower and processor use just the last year's information in forming their expectations. A more general formulation might be given by

$$E\ (Y_t \mid Y_{t-1},\ \ldots) = \sum_{i=1}^{n} \lambda_i Y_{t-i}, \qquad n = 2,\ 3,\ \ldots \tag{14}$$

where λ_i's are some weights to be specified and $\Sigma\lambda_i = 1$.

The problem, of course, is that the formulation of expectations is not directly observable. In order to link expected value to realized value, Nerlove used the well–known adaptive expectation model by which the yield expectation relation can be expressed as[1]

$$Y_t^* - Y_{t-1}^* = \gamma\ (Y_{t-1} - Y_{t-1}^*)$$

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[1]Marc Nerlove, "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," *Journal of Farm Economics,* Vol. XXXVIII, No. 2 (May, 1956), pp. 496–509.

where Y^*_t is the expected normal yield and γ is the coefficient of expectation ($0 < \gamma < 1$). By repeated substitution, one obtains the geometrically declining lag formulation,

$$Y^*_t = \gamma \sum_{i=1}^{\infty} (1 - \gamma)^{i-1} Y_{t-i}. \tag{15}$$

Nerlove's expectation model can be easily applied to the case of one independent variable in the supply response equation. But when there are many independent variables, the reduced–form equation will become very complicated.

Behrman proposed a possible extension of Nerlove's model by expressing the change in expected yield as[1]

$$Y^*_t = Y^*_{t-1} = c_0 + \gamma (Y_{t-1} - Y^*_{t-1}) + c_1 (R_{t-1} - \bar{R})$$

where R is the annual rainfall and $\bar{R}$ is the normal average rainfall. That is, to obtain the expected yield for the *i*th period, the expected yield for the previous period is adjusted not only for the deviation of actual from expected yield in the previous period but also for abnormalities in the rainfall which affected the actual yield. He did not empirically test this expectation hypothesis because of the lack of the number of observations for estimating the large number of parameters involved.[2] To simplify the matter, he used time trends to approximate farmers' aggregate expectation of future yields. The expected yield is then given by

$$Y^* = d_0 + d_1 T + d_2 T^2$$

where T is the time trend variable.

None of the above formulations of yield expectation can be accepted or rejected on *a priori* grounds. Furthermore, the number of independent variables in (10)–(12) is fairly large; hence, degrees of freedom are critically small for Nerlove's formulation. The simpler expectation's mechanisms in equations (13) and (14) are thus used for the empirical purposes of this study. It is also assumed that the grower and processor have the same expectation of yield.

While making yield predictions, the grower is subject to making errors of prediction. The grower might incur large losses because of a large random deviation in yield. The fact that the grower has to make decisions in an unsure environment is called uncertainty or risk.

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[1] Jere R. Behrman, *Supply Response in Underdeveloped Agriculture: A Case Study of Four Major Annual Crops in Thailand, 1936–1963* (Amsterdam: North–Holland Publishing Company, 1968), p. 167.

[2] Since he was more interested in price than yield, a similar formulation of price expectation was adopted in his supply response study.

The effects of risk and uncertainty on economic behavior have been well recognized. McCall pointed out:[1]

> "Almost every phase of economic behavior is affected by uncertainty. The underlying determinants of supply and demand have significant stochastic components. Consequently, it is imperative that relative prices [and some other variables] be regarded as random variables. . . . [Furthermore,] a deterministic economic theory does not provide an adequate explanation of those fundamental behavioral responses to a stochastic environment."

The model treatment of uncertainty has been developed in the decision–making framework based on the principles of expected utility maximization. In the theory of the firm, the application to perfect competition has been attempted by Baron[2] and Sandmo.[3] The deterministic static results under imperfect competition have been reexamined under the uncertainty situation by Dhrymes,[4] Hadar and Hillinger,[5] Baron,[6] Leland,[7] and others. Their analyses have, in one way or another, derived optimal decision rules which differ from those reached in deterministic static models. Unfortunately, the results of these theoretical developments are still far from being econometrically relevant or empirically testable, particularly in aggregate market analysis.

The difficulties of dealing with uncertainty in empirical analyses arise largely from lack of knowledge of the relevant probability distributions. But the mean–variance criterion

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[1]John J. McCall, "Probabilistic Microeconomics," *Bell Journal of Economics and Management Science*, Vol. 2, No. 2 (Autumn, 1971), p. 404.

[2]David P. Baron, "Price Uncertainty, Utility, and Industry Equilibrium in Pure Competition," *International Economic Review*, Vol. 11, No. 3 (October, 1970), pp. 463–480.

[3]Agnar Sandmo, "On the Theory of the Competitive Firm Under Price Uncertainty," *American Economic Review*, Vol. 61, No. 1 (March, 1971), pp. 65–73.

[4]Phoebus J. Dhrymes, "Restricted and Unrestricted Reduced Forms: Asymptotic Distribution and Relative Efficiency," *Econometrica*, Vol. 41, No. 1 (January, 1973), pp. 119–134.

[5]J. Hadar and C. Hillinger, "Imperfect Competition with Unknown Demand," *Review of Economic Studies*, Vol. 36(4), No. 108 (October, 1969), pp. 519–525.

[6]Baron, "Demand Uncertainty in Imperfect Competition," *International Economic Review*, Vol. 12, No. 2 (June, 1971), pp. 196–208.

[7]Hayne E. Leland, "Theory of the Firm Facing Uncertain Demand," *American Economic Review*, Vol. 62, No. 3 (June, 1972), pp. 278–291.

has been widely adopted in measuring risk and uncertainty.[1] This criterion appears to be appropriate for application in this study. Following Behrman's formulation, which is a simplification of Just's model, this can be achieved by introducing the variance (or standard deviation) of past yields in addition to the expected yield as another variable in the acreage supply response equation.

Expectation of Product Prices

On the processor side, prices of processed tomato products are factors affecting the processors' demand for raw tomatoes. Although these prices are not observable at the time of contracting, information on current prices and inventory conditions could be used for predicting future prices. Also, information on projected consumer incomes for the coming season is usually available. Therefore, it seems plausible to assume that

$$P_j^* = f\ (R_1,\ \ldots,\ R_k,\ I_j,\ M)$$

where

R_j = current price of the *j*th product

I_j = inventory at the time of contracting

and

M = projected consumer income.

The importance of risk terms for product prices is not investigated because product prices are relatively certain due to the contracting system of marketing.

4. ECONOMETRIC VARIABLES

The preceding conceptual analysis has derived fundamental functional relationships in the context of the California tomato economy. Empirical implementation of the

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[1]J. Tobin, "Liquidity Preference as Behavior Towards Risk," *Review of Economic Studies*, Vol. XXV(2), No. 67 (February, 1958), pp. 65–86.

Behrman, *op. cit.*

Richard E. Just, *Econometric Analysis of Production Decisions with Government Intervention: The Case of the California Field Crops*, University of California, Giannini Foundation Monograph No. 33 (Berkeley, 1974), 98p.

Idem, "An Investigation of the Importance of Risk in Farmers' Decisions," *American Journal of Agricultural Economics*, Vol. 56, No. 1 (February, 1974), pp. 14–25.

Richard E. Just and Rulon D. Pope, "On the Relationship of Input Decisions and Risk," in *Risk and Uncertainty in Agricultural Development*, ed. J. Roumasset, J. Boussard, and I. J. Singh (forthcoming).

conceptual economic structure is, of course, subject to data availability; and whether estimation is successful or not depends upon the appropriateness of the statistical methods as well as the quality of data and the extent to which the simplified conceptual model reliably reflects reality.

Not all economic variables identified thus far have data available. For some unobserved variables, however, it is possible to adopt plausible approximate measures to reflect the characteristics which unobserved variables portray in theoretical analysis; in other cases such variables simply have to be omitted from empirical analysis. On the other hand, some variables are observed at the county level. The availability of county data enables us to conduct our empirical analysis at different aggregation levels. Before proceeding with statistical estimation, it is useful to discuss the specific variables used in the econometric analyses.

Acreage

Acreage is one of the most important variables to be explained in the model. Both contract acreage and open market acreage could be considered. Historically, however, the open market acreage has amounted to only a small percentage of the total harvested acreage. Hence, its influence on the determination of total acreage is expected to be minimal. Data on contracted acreage and open market acreage are available for the selected 10 counties as well as the state total.[1]

Among these 10 selected counties, the data for 2 counties require further discussion. Merced is the only county with open market acreage greater than contract acreage. This unusual situation may result from its relatively significant acreage in the production of tomatoes for fresh uses. Thus, the likely interaction between fresh and processing markets in Merced County may make its demand and supply structure different from other counties. Therefore, Merced is excluded from the pooled analysis. Fresno is the other unusual county in tomato production. While it was ranked first by contract acreage for the first time in 1975, it was not even reported as a tomato production county in 1951. Fresno did not become a significant county until 1966 at which time the industry was pushing very hard toward the mechanization of harvesting. Because of these unusual characteristics, the pooled county model is estimated both with and without including Fresno County.

Grower Prices

Grower prices are average prices of tomatoes purchased from contracted acreage. Since processors may contract on different prices and they often contract with growers in different counties, the average grower price differs among counties. It was found, however, that these differences are very small.[2]

It should also be mentioned that the grower price as defined here refers to the prices received by growers at the farm. This price differs from the price paid at the door of

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[1]Appendix Table 1, *infra*, pp. 102–106.

[2]Appendix Table 3, *infra*, p. 109.

processing plants which has also been reported in recent years. The differences between these two price series are primarily the hauling costs from fields to processing plants.

Grower prices for the state as a whole are officially recorded for each season and are used when the analyses are conducted for the 10–county total.

Input Prices

As shown above, input prices are among the factors determining growers' acreage response function. Wage rates have been recorded for the preharvesting period in major tomato producing counties. Since June is the peak month for labor demand in the preharvesting operation, the wage rate in June is used for analysis. The average of wage rates in San Joaquin and Yolo Counties is taken as the average rate for the state because they have been the two most important tomato producing counties.

Fertilizer price is the only other input price for which good data are available. The reported price of ammonium nitrate in California is used. Complete data on rent and capital costs are, unfortunately, not available. Since rent can be viewed as an opportunity cost to growers, its impact on acreage response can be partially reflected by the introduction of the prices of competing crops. Furthermore, it is expected that capital costs might have moved with an upward trend similar to wage rates. Therefore, it is hoped that wage rates and fertilizer price account for most of the effects of other input prices on acreage determination as well. It is recognized, of course, that the coefficients of these terms may be biased upward.

Indicator of the Demand for Raw Tomatoes

The total quantity of processing tomatoes demanded cannot actually be observed at the time of contracting. An approximation is therefore required. To a limited extent, open market purchases can possibly be used by the processor to fill the gap between the desired quantity and the actual quantity produced from contracted acreage. Thus, the sum of the quantity from the contracted acreage and the quantity purchased from the open market is taken as the quantity indicator of the processors' demand at the time of contracting. These data are available for the selected 10 counties as well as the state total.[1]

Note that the total purchased quantities are not identical with production or harvested production, although they have been so labeled in various official compilations. It was found that an average of 2 to 3 percent of the total harvested tomatoes in the state were rejected by state inspection stations, and additional tonnages were further discarded in processors' inspections.[2]

Theoretically, one cannot separate the demand for California processing tomatoes from the demand for the same product in other states. Fortunately, it was found that

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[1]Appendix Table 2, *infra,* pp. 107 and 108.

[2]California Bureau of Fruit and Vegetable Standardization, *Annual Reports to Canners* (Sacramento, 1951, and subsequent years).

production in other states has been relatively stable without any significant trend over the period under consideration. The increasing trend of yield in other states has been offset by the declining trend in acreage (Figure 1). Thus, since relatively constant production has prevailed in other states, the treatment of the demand for raw tomatoes facing California growers is econometrically feasible.

Lagged Average Yield and Standard Deviation

Several formulations of yield expection were tried in preliminary analyses. The average yield of the preceding three years was found to be superior to using a one–year lag or the average of the preceding two years. Correspondingly, the standard deviation of the yields in the preceding three years is taken as the indicator measuring risk in yield expectation.

Prices of Competing Crops

The prices of competing crops are included for the purpose of investigating the effects on acreage response of possible multicrop operations of California tomato growers. Due to a large number of alternative crops found in each of the selected 10 counties, it is rather difficult to single out the one or two most important competing crops. Alfalfa hay, sugar beets, grain sorghum, fresh tomatoes, safflower, and cotton were used in preliminary testing. Sugar beets, grain sorghum, and alfalfa hay were found to have more consistent results and therefore were chosen for final empirical analysis.

Adoption of the Tomato Harvester

The static model as developed above has not considered the effect of technological change. The notable instance of this is the adoption of the tomato harvester in the late 1960s. Virtually all tomatoes were harvested by hand before 1963. In contrast, more than 95 percent of processing tomatoes have been harvested by mechanical harvesters since 1967. The period 1964–1966 was a transition period with mechanical harvesting gradually replacing hand harvesting.

The use of the tomato harvester has changed the cost structure of tomato production significantly. Also, the production function under hand harvesting would differ from that under mechanical harvesting. It is therefore important to know the extent to which the mechanization in harvesting has changed the structural parameters in both acreage response and raw tomato demand functions. The degree of mechanization is measured by the adoption rate of the tomato harvester.[1] Unfortunately, the data are not available by county. The estimate for the state is therefore used for the entire analysis.

Weighted Average of F.O.B. Product Prices

Due to the limited degrees of freedom from the relatively small sample size available for estimation, it is not feasible to include the prices of all processed tomato products

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[1]Appendix Table 8, *infra*, p. 114.

in the demand equation. But as mentioned previously, contracts are generally made in the period January through April before each season starts. Hence, assuming the processors utilize the most recent information about the prices of tomato products for their decision making, the weighted average f.o.b. price,

$$R = \sum_{j=1}^{5} \beta_j R_j,$$

is used where R_j is the average f.o.b. price of project j during January through March; β_j is the weight specified as the percentage of total shipments of project j during this period; and the five products are canned tomatoes, tomato juice, paste, puree, and catsup.[1]

Inventory and Consumer Incomes

The last two variables affecting the processors' demand for raw tomatoes are inventory and consumer income. To conserve degrees of freedom, the sum of the April 1 inventories of the five major products is used. Furthermore, the actual seasonally adjusted annual averages (in fiscal years) of disposable personal incomes are used as the projected figures at the time of contracting.

Definition of Variables

All variables used in the econometric models are specified in Table 11. Data sources as contained in the Appendix are also indicated.

Subscript i	*County*
1	San Joaquin
2	Yolo
3	Solano
4	Sutter
5	Sacramento
6	Stanislaus
7	Santa Clara
8	San Benito
9	Fresno
10	Merced

The definition of variables is made at three levels of aggregation, namely, (1) the county, (2) the 10–county total, and (3) the state as a whole. Econometric analyses are performed at both the county and aggregate 10–county levels. Some variables are not observable at the county or 10–county level; hence, observations for these variables at the state level are used.

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[1]Appendix Table 12, *infra*, pp. 118–121.

TABLE 11

Definition of Variables Used in the Econometric Models

Variables	Unit of measurement	County	Definition for 10-county total	California
(1) Contracted acreage	Thousand acres	A_i	A_c	*a*
(2) Purchased quantity (production)	Thousand tons	Q_i	Q_c	
(3) Grower price	Dollars per ton	P_i		P
(4) June wage rates	Dollars per hour	W_i	W	
(5) Adoption rate of tomato harvester	Percent			N
(6) Fertilizer price	Dollars per ton			F
(7) Average yield--three preceding years	Tons per acre	Y_i		Y
(8) Standard deviation of yield--three preceding years	Tons per acre	D_i		D
(9) Lagged alfalfa hay price	Dollars per ton			H_{t-1}
(10) Lagged sugar beet price	Dollars per ton			S_{t-1}
(11) Lagged grain sorghum price	Dollars per bushel			G_{t-1}
(12) January-March: weighted average of product prices	Dollars			R
(13) April 1 inventory	24/303 million cases			V
(14) U. S. disposable personal incomes	Billion dollars			I
(15) Dummy for the preharvester period	1 for 1951-1963 and 0 otherwise	M		

[a]Blanks indicate either no data available or unrelevance for the econometric analysis.

Sources:

Row 1:	Appendix Table 1.	Rows 7 and 8:	Appendix Table 5.
Row 2:	Appendix Table 2.	Rows 9, 10, and 11:	Appendix Table 7.
Row 3:	Appendix Table 3.	Row 12:	Appendix Table 12.
Row 4:	Appendix Table 6.	Row 13:	Appendix Table 11.
Rows 5 and 6:	Appendix Table 8.	Row 14:	Appendix Table 13.

5. ESTIMATION WITH AGGREGATE DATA

This section presents the results of estimation utilizing the aggregate data for the 10–major county total. As indicated above, the postulated system describing the decision processes of growers and processors consists of three basic equations—acreage response (10), demand for processing tomatoes (11), and quantity and acreage relation (12). All economic variables involved in the system can be either observed or approximately measured as discussed in the previous section.

Previous Estimates

Chern has estimated a similar model using data for 1951–1972.[1] Since the first attempt for the present effort is to update Chern's earlier model, it is instructive to review briefly the earlier findings. In Chern's earlier model, acreage response was expressed as a function of grower price (P), wage rates (W), adoption rate of the tomato harvester (N), price of ammonium nitrate (F), average yield of the preceding three years (Y), standard deviation of yields in the preceding three years (D), and the lagged prices of competing crops (S_{t-1}, G_{t-1}, and H_{t-1}).[2] As another alternative specification, N was replaced by N · P to investigate whether the introduction of tomato harvesters had any effect on the price elasticity of acreage response. The demand for processing tomatoes was expressed as a function of grower price (P), total April 1 inventory of tomato products (V), the weighted f.o.b. price of tomato products (R), and consumer disposable incomes (I). The final behavioral equation expressed acreage as a function of the quantity of tomatoes demanded and expected yield (Y).

Both linear arithmetic and linear logarithmic forms were investigated as alternative functional specifications. It was found that in most cases both formulations performed equally well.

The major conclusions of Chern's study are summarized as follows:

1. First, 2SLS and 3SLS estimates of structural coefficients were, in general, more plausible than OLS estimates. In particular, the OLS estimates of grower price coefficients were consistently lower in magnitude than the 2SLS and 3SLS estimates. However, differences between the 2SLS and 3SLS estimates were relatively small. Since all three estimates are consistent without simultaneity, whereas only 2SLS and 3SLS are consistent with simultaneity, this suggests rejection of a null hypothesis of no simultaneity.[3]

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[1]Chern, *op. cit.*

[2]The notations for several variables are not the same as those used by Chern; see *ibid.*; and *idem*, "Acreage Response and Demand for Processing Tomatoes in California," *American Journal of Agricultural Economics*, Vol. 58, No. 2 (May, 1976), pp. 209–216.

[3]It is also noted, however, that this may not necessarily imply rejection of leadership firm pricing since interaction or simultaneity of supply and demand are also important in that case; see Cohen and Cyert, *op. cit.*, p. 242.

2. The adoption of the tomato harvester was found to have a significant impact when acreage response was estimated by 3SLS.

3. The results also show that the adoption of the mechanical harvester had a positive impact on the price elasticity of acreage response even though the impact was numerically small on the average.

4. It was found that the prices of the three competing crops did not perform well in the model; their estimated coefficients had either the incorrect sign or a very low t ratio. Consequently, these variables were excluded from final equations. The standard deviation of yield (D) also had a very low t ratio in all cases.

The present study was conceived in an attempt to update and reestimate Chern's model by adding three more observations from 1973 to 1975. It was soon found, however, that the estimates of acreage response in the updated model were substantially different from those obtained previously by Chern. To illustrate these dramatic differences, one final set of equations estimated for the 10–county total for the two sample periods are presented in Tables 12 and 13.

The estimates of both the demand and quantity–acreage relation equations are fairly similar for the two sample periods. This similarity holds for all three estimation methods. However, several notable changes are observed in the estimates of acreage response in the updated model. First, the 2SLS and 3SLS estimates of the price elasticity became substantially higher in magnitude. Specifically, the 3SLS estimate of the price elasticity of acreage response is 2.70 for 1951–1975 as compared to 1.66 estimated by Chern for 1951–1972. Second, the estimated coefficients of the cross–product term (N · ln P) associated with the adoption rate of the tomato harvester all have a much smaller t ratio and are not statistically significant based on either the t test when OLS is used or the asymptotic t test when 2SLS and 3SLS are used.[1] (This coefficient was statistically significant in the Chern model when 3SLS was used.) Third, the 2SLS and 3SLS estimates of the fertilizer price coefficient (ln F) are much smaller in magnitude as estimated for 1951–1975. Fourth, several dramatic changes in the OLS equation are surprising. While the coefficients for wage rates (ln W), fertilizer price (ln F), and the lagged average yield (ln Y) were all statistically significant in the previously estimated equation for 1951–1972, most became insignificant in the updated equation. This substantial reduction in their magnitude is also disturbing. Finally, and perhaps most importantly, the estimated standard errors for most coefficients increased considerably when the sample size was expanded. This decrease in "precision" is particularly notable for ln P, ln W, and ln Y as their estimated standard errors increase by a factor of about 2.0.

The causes for the differences indicated above are not easy to identify. Nevertheless, the following facts are noted. First, there have been many drastic changes in several exogenous variables during 1972–1975. The most notable change occurred in fertilizer

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[1] It is well known that the t test and the Durbin–Watson statistic are strictly valid only with OLS when simultaneity does not exist. The standard errors for the 2SLS and 3SLS estimates refer to asymptotic distributions, and their validity in small samples is not generally known.

TABLE 12

Regression Results, 10-County Total, 1951-1972[a]

Normalized variable	Estimation method	ln P	N · ln P	ln W	ln F	ln Y	ln D	ln R	ln I	ln Q	Constant	R^2
$\ln A_c$	3SLS	1.658 (.31)	.0012 (.0006)	-2.568 (.61)	-4.062 (.78)	2.248 (.51)	-.029 (.05)				23.15 (4.4)	.80
	2SLS	1.405 (.33)	.0009 (.0007)	-2.037 (.66)	-3.765 (.82)	1.802 (.56)	-.032 (.06)				21.44 (4.7)	.84
	OLS	.883 (.18)	.0006 (.0005)	-1.358 (.46)	-3.353 (.63)	1.275 (.40)	-0.57 (.04)				19.62 (3.7)	.88
$\ln Q_c$	3SLS	- .701 (.46)						1.364 (.41)	.624 (.10)		4.13 (.95)	.84
	2SLS	- .661 (.46)						1.307 (.41)	.631 (.10)		4.04 (.95)	.85
	OLS	- .249 (.26)						1.012 (.30)	.603 (.09)		3.32 (.65)	.87
$\ln A_c$	3SLS					- .441 (.19)				.861 (.08)	- .64 (.42)	.91
	2SLS					- .428 (.19)				.855 (.09)	- .63 (.42)	.91
	OLS					- .354 (.18)				.813 (.08)	- .51 (.41)	.91

[a]Numbers in parentheses are estimated standard errors, and R is the correlation coefficient between the observed and estimated values of the normalized variable.

Sources: Wen S. Chern, "Supply Response and Price-Demand Relationships for California Processing Tomatoes" (unpublished Ph.D. dissertation, Department of Agricultural Economics, University of California, Berkeley), 1975, 159p.; also, *idem*, "Acreage Response and Demand for Processing Tomatoes in California," *American Journal of Agricultural Economics*, Vol. 58, No. 2 (May, 1976), pp. 209-216.

TABLE 13

Regression Results, 10-County Total, 1951-1975[a]

Normalized variable	Estimation method	ln P	N · ln P	ln W	ln F	ln Y	ln D	ln R	ln I	$\ln Q_c$	Constant	R^2
$\ln A_c$	3SLS	2.697 (.67)	.0015 (.001)	-2.644 (1.02)	-1.384 (.48)	2.669 (.92)	-.018 (.09)				6.83 (2.8)	.60
	2SLS	2.063 (.73)	.001 (.001)	-1.568 (1.15)	-1.072 (.52)	1.703 (1.02)	-.026 (.10)				5.23 (3.09)	.70
	OLS	.796 (.27)	.0005 (.0008)	- .066 (.58)	- .288 (.24)	.514 (.57)	-.082 (.07)				2.21 (1.8)	.81
$\ln Q_c$	3SLS	- .703 (.45)						1.247 (.42)	.629 (.10)		4.28 (.81)	.82
	2SLS	- .659 (.45)						1.195 (.42)	.633 (.10)		4.19 (.81)	.91
	OLS	- .284 (.23)						.875 (.25)	.608 (.09)		3.61 (.52)	.92
$\ln A_c$	3SLS					- .440 (.17)				.895 (.07)	- .89 (.30)	.94
	2SLS					- .396 (.18)				.874 (.08)	- .86 (.31)	.94
	OLS					- .310 (.17)				.832 (.07)	- .79 (.30)	.94

[a] Numbers in parentheses are estimated standard errors, and R is the correlation coefficient between the observed and estimated values of the normalized variable.

Sources: Wen S. Chern, "Supply Response and Price-Demand Relationships for California Processing Tomatoes" (unpublished Ph.D. dissertation, Department of Agricultural Economics, University of California, Berkeley), 1975, 159p.; also, *idem*, "Acreage Response and Demand for Processing Tomatoes in California," *American Journal of Agricultural Economics*, Vol. 58, No. 2 (May, 1976), pp. 209-216.

price (ln F) which reversed its historically declining trend in 1972 as a result of drastic increases in energy prices. The fertilizer price steadily declined from 1954 to 1972 and almost doubled between 1973 and 1974. Furthermore, the simple correlation coefficient between ln F and ln P changed from –0.47 for 1951–1972 to 0.35 for 1951–1975. The reversal in the sign of this simple correlation coefficient could cause some drastic changes in OLS regression results which are based on the inverse of the correlation matrix. Also, the impact of this reversal may not be limited to the coefficients of the two variables involved. However, multicollinearity did not seem strong either before or after updating the problem; hence, the above explanation does not seem to sufficiently explain the changes from Table 12 to Table 13.

Another possible explanation relates to the possible effect of a structural change surrounding adoption of the tomato harvester. Adding more observations in the postharvester period could possibly reflect the postharvester structure more as opposed to preharvester structure. Before updating, there were only 6 observations in the postharvester period as opposed to 13 in the preharvester period; thus, the earlier results of Chern are perhaps more reflective of the preharvester period. As observations are added from the postharvester period, however, any divergent structure between the two periods can cause shifts in estimates as well as a loss of precision.

The aggregate model findings indicate that the adoption of the tomato harvester has contributed to a higher price elasticity of acreage response (Tables 12 and 13). It is highly possible, however, that a much different price elasticity during the transition period may have been in effect because growers' sensitivity to price changes may have been greatly different when there was greater uncertainty about the impact of the tomato harvester. Indeed, the estimated coefficient for N • ln P became insignificant when the three more observations beyond 1972 were added (3SLS indicates significance in Table 12 but not in Table 13). For this reason, it appears desirable to reestimate the model––excluding the transition years, 1964–1966, during which the tomato harvester was adopted––and, in addition, to investigate the possibility that other structural changes took place with the introduction of the harvester.

Limited Flexibility With Aggregate Data

Consider eliminating the transition period (1964–1966) and investigating further structural change using aggregate data. To do this, the basic structure of the model can remain unchanged, but some additional features must be incorporated in the acreage response equation. First, since the transition period is excluded, the adoption rate of the tomato harvester (N) becomes irrelevant. In its place a new dummy variable (M) for the preharvester period is defined. Secondly, several cross–product terms between the dummy and various structural variables (such as ln P, ln W, and ln F) can be used to investigate the possibility of structural change.

The corresponding regression results are presented in Table 14. All variables except the dummy variable (M) are expressed in log form. Recall that the model consists of three structural equations with each estimated by OLS, 2SLS, and 3SLS. Equation sets (1.1), (2.1), and (3.1) in Table 17 are estimated for the 10–county total using the entire

TABLE 14

Estimated Acreage Response and Demand for Processing Tomatoes, Aggregate Model, 1951-1975, Excluding 1964-1966[a]

Equation set	Normalized variable	Estimation method	ln P	M • ln P	ln W	ln F	ln Y	ln D	$\ln G_{t-1}$	$\ln H_{t-1}$	$\ln S_{t-1}$	ln V	ln R	ln I	$\ln Q_c$	Constant	R^2
1.1	$\ln A_c$	3SLS	1.333 (.27)	.070 (.06)	- .228 (.47)	- .926 (.48)	1.125 (.50)	- .028 (.05)	.023 (.25)	- .233 (.27)	.407 (.27)	*b*				1.99 (2.20)	.901
		2SLS	1.431 (.33)	.088 (.07)	- .183 (.58)	-1.167 (.58)	.978 (.63)	- .074 (.059)	- .115 (.31)	- .221 (.33)	.610 (.32)					2.42 (2.69)	.911
		OLS	1.087 (.27)	.067 (.066)	.164 (.52)	- .692 (.51)	.544 (.56)	- .091 (.055)	- .271 (.28)	- .105 (.31)	.478 (.29)					1.04 (2.43)	.920
2.1	$\ln Q_c$	3SLS	- .186 (.38)									- .100 (.10)	.621 (.46)	.735 (.16)		3.23 (.77)	.928
		2SLS	- .333 (.39)									- .090 (.11)	.811 (.49)	.711 (.18)		3.53 (.81)	.930
		OLS	- .505 (.32)									- .087 (.11)	.990 (.43)	.708 (.17)		3.82 (.72)	.932
3.1	$\ln A_c$	3SLS					- .433 (.19)								.886 (.08)	- .848 (.31)	.949
		2SLS					- .420 (.19)								.881 (.08)	- .840 (.31)	.950
		OLS					- .332 (.18)								.839 (.07)	- .768 (.30)	.950
1.2	$\ln A_c$	3SLS	1.612 (.28)	.157 (.052)		- .974 (.27)	1.371 (.34)									- .406 (1.04)	.854
		2SLS	1.574 (.28)	.135 (.057)		- .986 (.29)	1.236 (.36)									.207 (1.12)	.860
		OLS	1.157 (.21)	.070 (.046)		- .638 (.23)	1.052 (.32)									.670 (1.0)	.879
2.2	$\ln Q_c$	3SLS	- .933 (.68)										1.559 (.71)	.607 (.10)		4.68 (1.23)	.922
		2SLS	-1.123 (.69)										1.788 (.72)	.588 (.10)		5.06 (1.24)	.915
		OLS	- .518 (.32)										1.178 (.36)	.586 (.09)		4.03 (.66)	.929
3.2[c]	$\ln A_c$	3SLS					- .397 (.19)								.872 (.08)	- .837 (.31)	.950
		2SLS					- .430 (.20)								.885 (.08)	- .849 (.31)	.949

[a]Numbers in parentheses are estimated standard errors, and R is the correlation coefficient between the observed and estimated values of the normalized variable.

[b]Blanks indicate variables not included.

[c]The OLS estimate is the same as (3.1).

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

set of variables identified earlier. Although several other composite variables like M · ln W and M · ln F were considered, in most cases the estimated coefficients of these variables had very large estimated standard errors. In some cases their presence disturbed the estimates of other coefficients. Consequently, only the variable M · ln P was kept in the equations.[1]

Bearing this in mind, the conclusions from this set of results are summarized as follows: First of all, the estimated coefficient of the grower price (ln P) has a very high t ratio in all three cases, but the 2SLS and 3SLS estimates of the price elasticity of acreage response are considerably greater than the OLS estimate. This phenomenon is, of course, also observed in Tables 12 and 13. But the differences among estimation methods are much more pronounced when other variables in the acreage response equation are compared. In the OLS equation all variables except ln P are statistically insignificant at the 10 percent level. The estimated coefficient of wage rates (ln W) even has the wrong sign. In the 2SLS and 3SLS equations, both the fertilizer price (ln F) and lagged average yield (ln Y) have lower t ratios than in Table 12. The estimated coefficients of wage rates, on the other hand, while having the correct sign, have very low t ratios. This finding is sharply different from that in Table 12 in which the wage rate was very significant using 3SLS. The drastic change in the wage rate coefficient as a result of adding three more observations in the postharvester period is presumably explained by the fact that the adoption of the tomato harvester has substantially reduced labor input and, thus, labor costs may have become less important. Unfortunately, the multicollinearity of M and M · ln W prevents further investigation of this hypothesis with aggregate data.

Like the previous results, the standard deviation of past yields (ln D), a variable included to measure the risk associated with yield expectation, did not exhibit a significant impact in all three cases. This is probably due to the fact that the risk factor in tomato production has been greatly reduced through contractual arrangements with processors. Also, again, the prices of competing crops did not show any significant impact on acreage response even though most coefficients have appeared with correct signs.

Eliminating ln W, ln D, ln G_{t-1}, ln H_{t-1}, ln S_{t-1}, and ln V (which appear unimportant above) from the system improves considerably the significance of coefficient estimates for all remaining variables. These results are shown in equation sets (1.2), (2.2), and (3.2) in Table 14. Estimated standard errors are substantially reduced, while estimated t ratios increase. It should be noted, however, that these results are strongly indicative of multicollinearity. These phenomena are especially notable in the 2SLS and 3SLS estimates of the coefficients for M · ln P in the acreage response equation and for ln P in the demand equation. A significant positive coefficient for M · ln P indicates that the price elasticity of acreage response is larger in the preharvester period than in the postharvester period. This is contrary to the results obtained in Tables 12 and 13 and shall be a further point of discussion later. Furthermore, the magnitude of both 2SLS and 3SLS estimates of the coefficient of ln P in both the acreage response and demand equations increases substantially as does the coefficient of ln R in the demand equation. The estimates of the acreage–quantity relation remain almost the same.

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[1]This, in itself, suggests that multicollinearity prevents the statistical identification of structural change which is needed. For a discussion of statistical identification, see Henri Theil, *Principles of Econometrics* (New York: John Wiley and Sons, Inc., 1971), pp. 446–448.

Conclusions With Respect to the Aggregate Model

In the course of updating the models previously estimated by Chern, it was found that the estimates of many structural parameters in the acreage response equations were greatly altered as a result of adding three more observations in the postharvester period. Among other things, the estimated price elasticity of acreage response was, perhaps, unreasonably high when 2SLS and 3SLS were used. The effect of the tomato harvester on supply response became insignificant. Also, the estimated coefficients of fertilizer price, wage rate, and lagged yield were not statistically significant under OLS, and standard errors of most coefficients increased. These results were in sharp contrast to the results obtained by Chern using data for 1951–1972. It was also noted that the coefficient of a cross–product term for harvester adoption and price became insignificant when the additional data were used.

A reasonable explanation for all of these results in that extensive structural change in supply response took place with the introduction of the tomato harvester and that, due to uncertainty or other factors, a very high price elasticity of supply was in effect during the transition years.

Further investigation with the aggregate model by deleting the transition years did not lead to any evidence contrary to this explanation. Indeed, the estimated price elasticity was considerably smaller when the transition period was excluded. Unfortunately, however, the attempt to determine the extent of structural change was thwarted by multicollinearity. As variables representing elasticity shifts for fertilizer and wage rates were added, the results became noisy (coefficient estimates changed signs, and standard errors became large); and, to a somewhat lesser extent, this was observed when the standard variables representing competing crop returns, wage rates, and risk were included. Furthermore, the price elasticity shift reversed directions, thus indicating an increase in elasticity associated with the harvester. This is particularly disturbing since normally, when one shifts the relative cost structure from variable to fixed, the supply (marginal cost) curve becomes more inelastic, *e.g.*, near the point of capacity utilization of capital equipment, whereas cost curves are usually relatively flat (elastic) when all inputs are variable. Nevertheless, the price elasticity shift variable is strongly correlated with the harvester indicator variable and other elasticity shift variables (cross–product terms involving the indicator) and is likely picking up the effect of other factors.

All of these results are suggestive of multicollinearity and imply that little credence can be placed in the aggregate model results. It is, therefore, concluded that the aggregate sample is not sufficient for conducting a more comprehensive investigation of potential structural change due to the adoption of the tomato harvester. To increase sample size and to utilize efficiently disaggregated county data, it is advantageous to estimate the structural model by pooling county and time series data. This is the subject of discussion in the next section.

6. DISAGGREGATION, EFFICIENCY, AND POOLED TIME SERIES CROSS–SECTION ESTIMATION

Two general purposes of this research suggest disaggregate estimation at the county level. The first is to investigate the effects of introducing the tomato harvester on the structure of the California tomato processing industry, and the second is to investigate the possibility of structural differences in supply response among counties.

One possible explanation for the failure to identify crops competing with processing tomatoes in the aggregate model is that perhaps there are too many alternative crops at the aggregate level; hence, no single crop can show a significant impact. One might expect that competing crops might be more identifiable if the model is estimated at the county level if crops competing for tomato acreage vary by locale. In addition, knowledge of structural differences may enable processors to determine strategies that can better attain the desired expansion of contract acreage. Disaggregate estimation with county detail can better reveal the extent to which these differences exist.

The reason that the effects of the tomato harvester can be examined in greater detail is that many more observations are thus available both before and after mechanization. Hence, hypotheses with much greater flexibility than a simple change in price elasticity can be examined. For example, it seems reasonable that wage rates would become much less important with mechanization. Although this hypothesis was examined with the aggregate model, the mere lack of observation could be the reason that no structural change was detected. Another great advantage in this context is that the period of possible disequilibrium immediately following the introduction of the tomato harvester can be eliminated from the data without critically affecting the remaining degrees of freedom in estimation. The extent to which this phenomenon has distorted results with the aggregate model will be discussed as results are presented.

As indicated above, as data in recent years were added in estimation, the estimated price elasticity increased, the wage elasticity began to decline, and other elasticities also changed. One possible explanation for this observation is that the whole structure of supply and demand was altered with the tomato harvester, and an effort to fit both periods simultaneously with the same relationships leads to major specification errors unless full flexibility is provided. Furthermore, as suggested above, it could be that estimated changes of elasticities are severely distorted because of inflexibility in modeling other elasticity changes. Complete flexibility could not be investigated in the aggregate model because a sufficient number of observations were not available in the postharvester period.

Pooled County and Time Series Estimation

Theoretically, more efficient estimates of the structural parameters can generally be obtained by estimation of all county systems simultaneously. This is so because the disturbance terms in both acreage response and demand equations are probably correlated among counties. Furthermore, while investigation with aggregate data has been possible in some respects, that analysis was based on a relatively small sample; and the existence of substantial small–sample biases in 2SLS and 3SLS estimates, in addition to specification biases, cannot be easily ruled out. By pooling county and time series data, on the other hand, the sample size can be increased. Thus, the disaggregated county data can be utilized more efficiently.

Another specific purpose for pooling county and time series data is to make available sufficient data to estimate the structural model in different time periods. As indicated previously, the adoption of the mechanical harvester represents a significant technological change midway in the period 1951–1975. The investigation of the impacts of mechanization can be best achieved by separating the sample period into subperiods with one before and one after the adoption of the tomato harvester; this approach avoids the type of specification bias discussed above. Then much more detailed and complex hypotheses can be investigated than in the aggregate model. For example, only a change in a few coefficients was investigated with the aggregate model, but a change in all the parameters can be investigated with a pooled model.[1] Since mechanical harvesters were not used prior to 1964, the period 1951–1963 is selected as the first subperiod. By 1967, hand–harvesting methods were virtually replaced by the mechanical systems in California; thus, the years 1967–1975 can serve as the second subperiod.

Theoretical Considerations in Pooling County Systems

In the case where grower price is exogenous to the system, sets of county equations can be appropriately treated as sets of seemingly unrelated regression equations in Zellner's terminology. Zellner[2] has proposed a corresponding Aitken generalized least–square estimator which is asymptotically more efficient than OLS. His approach is to estimate the variance–covariance matrix from OLS residuals and then apply Aitken's generalized least squares to estimate the unknown coefficients.[3] The use of such an approach in combining cross–section and time series data has been investigated extensively by Balestra

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[1]Degrees of freedom are insufficient with aggregate data in the latter case since only nine observations are available for the post–tomato harvester period.

[2]Arnold Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," *Journal of the American Statistical Association*, Vol. 57, No. 298 (June, 1962), pp. 348–368.

[3]For a more detailed discussion on the properties of these estimators, see:

Idem, "Estimators for Seemingly Unrelated Regression Equations: Some Exact Finite Sample Results," *Journal of the American Statistical Association*, Vol. 58, No. 304 (December, 1963), pp. 977–992.

Arnold Zellner and David S. Huang, "Further Properties of Efficient Estimators for Seemingly Unrelated Regression Equations," *International Economic Review*, Vol. 3, No. 3 (September, 1962), pp. 300–313.

As an alternative, Telser has developed an iterative estimation procedure; see Lester G. Telser, "Iterative Estimation of a Set of Linear Regression Equations," *Journal of the American Statistical Association*, Vol. 59, No. 307 (September, 1964), pp. 845–862.

The small sample properties of these alternative estimators were investigated by J. Kmenta and R. F. Gilbert, "Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regressions," *Journal of the American Statistical Association*, Vol. 63, No. 324 (December, 1968), pp. 1180–1200.

A further extension of the model was attempted by Parks to consider the case where the disturbances are also serially correlated; see Richard W. Parks, "Efficient Estimation of a System of Regression Equations When Disturbances Are Both Serially and Contemporaneously Correlated," *Journal of the American Statistical Association*, Vol. 62, No. 318 (June, 1970), pp. 500–509.

The small sample efficiency of several alternative estimators, including the one developed by Parks, was recently investigated by Kmenta and Gilbert, "Estimation of Seemingly Unrelated Regressions with Autoregressive Disturbances," *Journal of the American Statistical Association*, Vol. 65, No. 329 (March, 1970), pp. 186–197.

and Nerlove,[1] Nerlove,[2] and Maddala[3] for the case where each cross–sectional unit is described by a single equation rather than a simultaneous system.

On the other hand, the case where the disturbances are contemporaneously correlated among sets of seemingly unrelated simultaneous equation systems has not been considered explicitly. One might conjecture that an approach similar to Zellner's seemingly unrelated regression procedure would be appropriate. For example, one could obtain consistent estimates of the variance–covariance matrix from 2SLS residuals and then apply a generalized Aitken's procedure to estimate the structural parameters efficiently. Such an approach, however, turns out to be a mere application of 3SLS to the simultaneous system jointly composed of all the separate county equation systems.

For example, consider the set of simultaneous equation systems over all time periods (where i is a county index).[4]

$$\begin{bmatrix} y_{i1} \\ \vdots \\ y_{ip} \end{bmatrix} = \begin{bmatrix} Z_{i1} & & 0 \\ & \ddots & \\ 0 & & Z_{ip} \end{bmatrix} \begin{bmatrix} \delta_{i1} \\ \vdots \\ \delta_{ip} \end{bmatrix} + \begin{bmatrix} \epsilon_{i1} \\ \vdots \\ \epsilon_{ip} \end{bmatrix} \quad \text{or} \quad y_i = Z_i \delta_i + \epsilon_i, \quad i = 1, \ldots, n \qquad (16)$$

where

y_{ij} = T x 1 vector of observations on the *j*th endogenous variable in the *i*th county over all time periods

Z_{ij} = T x m_j matrix of similar observations on all endogenous and exogenous variables included in the *j*th equation

δ_{ij} = m_j x 1 vector of all parameters included in the *j*th equation

and

ϵ_{ij} = T x 1 serially independent vector of disturbances for the *j*th equation in the *i*th county.

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[1]Pietro Balestra and Marc Nerlove, "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," *Econometrica,* Vol. 34, No. 3 (July, 1966), pp. 585–612.

[2]Nerlove, "Further Evidence on the Estimation of Dynamic Economic Relations From a Time Series of Cross Sections," *Econometrica,* Vol. 39, No. 2 (March, 1971), pp. 359–382.

[3]G. S. Maddala, "The Use of Variance Components Models in Pooling Cross Section and Time Series Data," *Econometrica,* Vol. 39, No. 2 (March, 1971), pp. 341–358.

[4]Theil, *op. cit.,* Sec. 10.5.

These separate systems can be considered simultaneously in the model,

$$y = Z\delta + \epsilon, \tag{17}$$

where

$$y = \begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix} \quad Z = \begin{bmatrix} Z_1 & & 0 \\ & \ddots & \\ 0 & & Z_n \end{bmatrix} \quad \delta = \begin{bmatrix} \delta_1 \\ \vdots \\ \delta_n \end{bmatrix} \quad \epsilon = \begin{bmatrix} \epsilon_1 \\ \vdots \\ \epsilon_n \end{bmatrix}.$$

Recall that 3SLS estimation of δ_i essentially involves 2SLS estimation of ϵ_i by, say, $\hat{\epsilon}_i$; then estimating the associated contemporaneous covariance matrix, Σ_{ii}, by

$$\hat{\Sigma}_{ii} = \frac{1}{T} \sum_{t=1}^{T} \hat{\epsilon}'_{it} \hat{\epsilon}_{it}$$

where $\hat{\epsilon}_{it}$ is a p vector of estimated disturbances in county i at time t, and then computing 3SLS estimates by using the $\hat{\Sigma}_{ii}$ in a generalized Aitken's procedure,[1]

$$\hat{\delta}_i = \left\{ Z'_i \left[\hat{\Sigma}_{ii}^{-1} \otimes X_i (X'_i X_i)^{-1} X'_i \right] Z_i \right\}^{-1} Z'_i \left[\hat{\Sigma}_{ii}^{-1} \otimes X_i (X'_i X_i)^{-1} X'_i \right] y_i$$

where X_i is a submatrix of Z_i including all exogenous variables. But the 2SLS estimates are obtained equation by equation without regard to covariances between equations; furthermore, the reduced–form equations are identical for (16) and (17). Hence, the 2SLS estimates for (16) are identical to 2SLS estimates of (17). Applying the Zellner "seemingly unrelated regression" concept to the set of systems in (16) would involve estimating cov $(\epsilon_{it}, \epsilon_{jt})$ by

$$\hat{\Sigma}_{ij} = \frac{1}{T} \sum_{t=1}^{T} \hat{\epsilon}'_{it} \hat{\epsilon}_{jt},$$

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[1] *Ibid.*

then using those estimates to form an overall estimate of $\Sigma = \text{cov}\ (\epsilon_t)$ [where $\epsilon_t = (\epsilon'_{1t} \ldots \epsilon'_{nt})'$],

$$\hat{\Sigma} = (\hat{\Sigma}_{ij}),$$

and, finally applying a generalized Aitken procedure to obtain the estimator,

$$\hat{\delta} = \left\{ Z' \left[\hat{\Sigma}^{-1} \otimes X\ (X'\ X)^{-1}\ X' \right] Z \right\}^{-1} Z' \left[\hat{\Sigma}^{-1} \otimes X\ (X'\ X)^{-1}\ X' \right] y. \quad (18)$$

This procedure is obviously equivalent to 3SLS on (17) where the covariance matrix Σ is estimated directly from 2SLS estimates of ϵ, say $\hat{\epsilon}$, *i.e.*,

$$\hat{\Sigma} = \frac{1}{T} \sum_{t=1}^{T} \hat{\epsilon}'_t\ \hat{\epsilon}_t = \left(\frac{1}{T} \sum_{t=1}^{T} \hat{\epsilon}'_{it}\ \hat{\epsilon}_{jt} \right) = (\hat{\Sigma}_{ij})$$

and then applying a generalized Aitken's procedure. Estimation of (16) by 3SLS essentially amounts to ignoring the covariance between ϵ_{it} and ϵ_{jt} $(i \neq j)$ as compared with 3SLS applied to (17).

It thus appears that asymptotically efficient estimators can (only) be obtained by considering the 8 three–equation county systems as a single 24–equation simultaneous system except in the special case where $\Sigma_{ij} = 0$ for all $i \neq j$. Unfortunately, however, difficulties can be encountered with the overall 3SLS estimator when the number of time series observations is small for the individual cross–sectional units. That is, there are only T observations on each covariance in Σ which can be used to calculate $\hat{\Sigma}$. Or, more basically, there are only T observations (estimates) for each disturbance. Hence, it is necessarily the case that rank $(\hat{\epsilon}) \leqslant T$. This fact necessarily implies that rank $(\hat{\Sigma})$ = rank $[(1/T)\ \hat{\epsilon}'\ \hat{\epsilon}] \leqslant T$, but order $(\hat{\Sigma}) = np$ where p is the number of equations in each individual (county) system in (16). For the problem at hand, considering only eight counties, $T = 25$ and $np = 24$ if all of the data from 1951–1975 are considered; hence, nonsingularity is just barely possible using the overall period.[1] On the other hand, if only data before (after) the adoption of the tomato harvester are considered, then rank $(\hat{\Sigma}) <$ order $(\hat{\Sigma})$ and $\hat{\Sigma}$ is necessarily singular. But if $\hat{\Sigma}^{-1}$ does not exist, then the usual 3SLS estimator is not defined.[2]

For the purposes of this study, it is thus concluded that some modifications of the usual 3SLS procedure are required in order to improve efficiency over 2SLS. But since the rank problems encountered here disappear asymptotically, it is clear that any set of modifications or constraints which do not affect $\hat{\Sigma}$ asymptotically will lead to the same asymptotic properties as 3SLS. Hence, there is a broad class of arbitrary modifications which could achieve the desired result. For example, consider the alternative estimator Σ^* defined by

$$\Sigma^* = \left(\hat{\Sigma}^+ + \frac{k}{T} I\right)^{-1} \tag{19}$$

where superscript + denotes the Moore–Penrose generalized inverse;[3] and Σ^* is thus nonsingular but is still a consistent estimator of Σ so the associated 3SLS estimator with Σ^* substituted in place of $\hat{\Sigma}$ in (18) exists (as long as other conditions for 3SLS estimation in individual counties are satisfied) and is asymptotically equivalent to ordinary 3SLS on (17). But the effect of arbitrary changes, such as (19) on small–sample properties, depends critically on the arbitrary specification. For example, if k is large, then the modified

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[1]Even in the 1951–1975 case with eight counties, the $\hat{\Sigma}$ matrix may be nearly singular if the sum of residuals $\hat{\epsilon}_t$ over time periods is near zero (as it usually is in practical problems with constant terms). If residuals sum to zero, then rank $(\hat{\epsilon}) \leqslant T - 1$ and, hence,

$$\text{rank } (\hat{\Sigma}) = \text{rank} \left(\frac{1}{T} \hat{\epsilon}' \hat{\epsilon}\right) \leqslant T - 1$$

where $\hat{\epsilon} = (\hat{\epsilon}_1, \ldots, \hat{\epsilon}_T)'$.

[2]Theil, *op. cit.*

[3]For computational simplicity, note that, if $\hat{\Sigma}^+$ is computed from the spectral decomposition $\hat{\Sigma} = P \Lambda P'$ where Λ is diagonal with some zeros on the diagonal, then Σ^* is approximately given by

$$\Sigma^* \approx P \left(\Lambda^+ + \frac{k}{T} I\right)^{-1} P'.$$

This approximation makes the computation of what shall be called a ridge 3SLS estimator possible with only one spectral decomposition. Normally, another would be required to find a transformation matrix F such that $(\Sigma^*)^+ = FF'$. For a further discussion of generalized inverses, see C. Radhakrishna Rao and Sujit Kumar Mitra, *Generalized Inverse of Matrices and Its Applications* (New York: John Wiley and Sons, Inc., 1971), 240p.

estimator will approximate 2SLS while, if k is sufficiently small, the near singularity condition will cause computational problems (for practical purposes) just as if the ordinary 3SLS method is attempted. This suggests the possibility of a ridgelike 3SLS estimator where one would attempt to choose k small enough to avoid a large bias but large enough to reduce the (estimated) covariance matrix for the coefficient estimators and, in particular, large enough to maintain computational nonsingularity of Σ^*.[1] If this approach is used, however, the true covariance matrix for the δ estimator should be estimated somewhat differently than usual as will be made clear below.

Another possible arbitrary modification is to calculate the 3SLS estimator by computing a generalized inverse of $\hat{\Sigma}$. In this case the 3SLS estimator can exist for $T < np$, but it will be equivalent to ordinary 3SLS (with probability one) for all sample sizes $T > np$ (assuming $\Sigma > 0$). This approach has been discussed in the context of generalized least squares by Theil.[2] Where F is defined such that

$$\hat{\Sigma}^+ = FF', \tag{20}$$

it necessarily follows that rank (F) = rank $(\Sigma^+) \leqslant T$ and that F' can be chosen as zero in the last $np - T$ rows (if $np > T$ and F is square) or simply as a T by np matrix. Theil thus shows that transforming the data matrix by F' (as in the usual generalized least–squares approach) has the effect of reducing the number of observations (in this case, for a single time period) to the rank of $\hat{\Sigma}$. In other words, the number of observations in a single time period, np, would necessarily be reduced to T if $T < np$. In the overall problem with covariance matrix $\hat{\Sigma} \otimes I$ (considering T observations on p equations in n different cross–sectional units), the Tnp observations would thus be reduced to T^2 obsetvations. It is clear that, if T is small and n is large, the remaining observations may not be sufficient to identify all parameters. That is, if $T^2 < k$ where k is the total number of parameters or dimension of δ in (17), "degrees of freedom" would be negative. Hence, when the cross–sectional aspects of a study are important (or hold relatively greater potential for efficiency), it may well be that results of the generalized inverse approach for $\hat{\Sigma}$ will not even identify all parameters. Furthermore, problems may be serious even when $T^2 > k$ because, as Theil shows, the first T observations (those not zero for the above reasons) may be zero (or singular) even though the original data matrix is of full rank.[3] The equations estimated in this study led to this outcome in both cases which were attempted. Where k was 32 and 36 and T was 9 and 13, respectively, the transformed

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[1]Although the term "ridge 3SLS" will be used throughout this study for simplicity, it should be noted that only the mathematical approach to obtaining a true inverse (rather than any heuristic justification) bears any resemblance to ridge regression.

[2]Theil, *op. cit.*, pp. 275-279.

[3]*Ibid.*, p. 277.

matrix was not only singular (for computational purposes); that is, from 7 to 12 transformed variables had to be dropped to identify the remaining parameters with standard tolerance levels on pivot elements.[1]

An alternative approach which can attain the desired small–sample nonsingularity in $\hat{\Sigma}$ is to attach sufficient constraints of one kind or another to the Σ estimate. For example, various particular covariances can be constrained (possibly to zero). If such constraints hold in reality, then the resulting modified 3SLS estimator will have the same asymptotic properties as ordinary 3SLS; otherwise, the modified estimator may be asymptotically less efficient than ordinary 3SLS. On the other hand, properties may be improved over the 2SLS estimator in lieu of the true 3SLS estimator which does not exist for observed sample sizes. It seems particularly reasonable, if some *a priori* information can justify the desired constraints, that the resulting nonsingularity in $\hat{\Sigma}$ may lead to a more efficient combination of the information from different equations than simple 2SLS. But this could also be true even if the constraints do not hold exactly but are approximations.

Consider an alternative estimator $\bar{\Sigma}$ for Σ where $\hat{\bar{\Sigma}}$ differs from $\hat{\Sigma}$ only by imposing a few constraints on individual elements of $\hat{\Sigma}$ to attain nonsingularity. If the constraints imposed in $\hat{\bar{\Sigma}}$ apply in reality, then the resulting 3SLS estimator [with $\hat{\Sigma}$ replaced by $\hat{\bar{\Sigma}}$ in (18)] is asymptotically equivalent to ordinary 3SLS, and the asymptotic distribution of $\sqrt{T}\,(\hat{\delta} - \delta)$ is normal with mean zero and covariance matrix,

$$\mathrm{T}\ \mathrm{cov}\ (\hat{\delta}) = \mathrm{T} \left\{ Z' \left[\Sigma^{-1} \otimes X\,(X'\,X)^{-1}\ X' \right] Z \right\}^{-1} \tag{21}$$

On the other hand, if the constraints do not hold for Σ, then the asymptotic distribution is modified. The true asymptotic covariance matrix can be deduced as follows. First, note that 3SLS is nothing more than a generalized least–squares estimate for the system,[2]

$$(I \otimes X)'\ y = (I \otimes X)'\ Z\delta + (I \otimes X)'\ \epsilon, \qquad E\ (\epsilon\epsilon') = \Sigma \otimes I,$$

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[1]James N. Boles and Elaine Borkon, *The 1130 Multiple Linear Regression System*, University of California, Giannini Foundation of Agricultural Economics (Berkeley, 1970), 92p.

[2]Theil, *op. cit.*

or

$$\tilde{y} = \tilde{Z}\delta + \tilde{\epsilon}, \qquad E(\tilde{\epsilon}\tilde{\epsilon}') = \Omega$$

where

$$\tilde{y} = (I \otimes X)' \, y$$

$$\tilde{Z} = (I \otimes X)' \, Z$$

$$\tilde{\epsilon} = (I \otimes X)' \, \epsilon$$

and

$$\Omega = \Sigma \otimes X' X.$$

If one uses the covariance matrix $\bar{\Omega} = \bar{\Sigma} \otimes X' X$ to compute the generalized least–squares estimator instead of Ω (*i.e.*, if one substitutes $\bar{\Sigma}$ for Σ), then it can easily be determined that the estimator, say $\bar{\delta}$, has the covariance matrix:

$$\begin{aligned} \text{Cov}(\bar{\delta}) &= \text{Cov}\left[(\tilde{Z}' \bar{\Omega}^{-1} \tilde{Z})^{-1} \tilde{Z}' \bar{\Omega}^{-1} \tilde{y}\right] \\ &= (\tilde{Z}' \bar{\Omega}^{-1} \tilde{Z})^{-1} \tilde{Z}' \bar{\Omega}^{-1} \Omega \bar{\Omega}^{-1} \tilde{Z} (\tilde{Z}' \bar{\Omega}^{-1} \tilde{Z})^{-1} \\ &= \left\{Z' \left[\bar{\Sigma}^{-1} \otimes X (X' X)^{-1} X'\right] Z\right\}^{-1} Z' \left[\bar{\Sigma}^{-1} \Sigma \bar{\Sigma}^{-1} \otimes X (X' X)^{-1} X'\right] Z \\ &\quad \times \left\{Z' \left[\bar{\Sigma}^{-1} \otimes X (X' X)^{-1} X'\right] Z\right\}^{-1} \end{aligned} \tag{22}$$

and mean $E(\bar{\delta}) = \delta$. Similarly, if one substitutes an estimator $\hat{\bar{\Sigma}}$ for $\bar{\Sigma}$, one finds that the asymptotic distribution of the corresponding estimator $\hat{\bar{\delta}}$,

$$\hat{\bar{\delta}} = \left\{Z' \left[\hat{\bar{\Sigma}}^{-1} \otimes X (X' X)^{-1} X'\right] Z\right\}^{-1} Z' \left[\hat{\bar{\Sigma}}^{-1} \otimes X (X' X)^{-1} X'\right] y, \tag{23}$$

is such that the estimator in (22) continues to apply for $\hat{\bar{\delta}}$ where $\hat{\bar{\Sigma}}$ replaces $\bar{\Sigma}$ and will exist if the usual rank–and–order conditions are satisfied for individual county systems even when the ordinary 3SLS estimator in (18) does not. Furthermore, asymptotic unbiasedness is retained.

One cannot say conclusively that the estimator $\hat{\bar{\delta}}$ is asymptotically better or worse than 2SLS without further information. But it is clear that, depending on choice of constraints, $\hat{\bar{\delta}}$ can be at least as efficient (asymptotically) as 2SLS; this is because (23) reduces to 2SLS if all off–diagonal elements of $\hat{\bar{\Sigma}}$ are made equal to zero. The problem thus tends to suggest choosing the elements of $\hat{\hat{\Sigma}}$ to make the covariance matrix in (22) as small as possible. It thus appears that a useful alternative to 2SLS may be simply investigating several sets of (possibly *ad hoc*) covariance constraints and selecting the most suitable $\hat{\hat{\delta}}$ on the basis of associated estimates of cov $(\hat{\hat{\delta}})$.

These recommendations may appear objectionable at first thought because of the *ad hoc* approach involved. But one must note that the procedure is only computationally *ad hoc* as opposed to being theoretically *ad hoc*. Theoretically, one is merely attempting to minimize (22) in some sense with respect to $\bar{\Sigma}$ subject to a constraint of computational nonsingularity for $\bar{\Sigma}$. This is equivalent to the theoretical approach used in deriving the ordinary 3SLS estimator in the case where Σ is nonsingular. Computational differences arise only because analytic minimization is possible in the ordinary case, whereas numerical or computational methods of minimization must be used in the case considered here. And because of computational complexity, it may only be feasible to investigate several alternatives in an attempt to improve upon 2SLS. Such is the case with the empirical problem analyzed below.

Econometric Results Using County Time Series Data

It was decided that only three or four alternatives would be feasible as a search for an efficient estimator. Of course, with this limited number of alternatives, it could be that 2SLS estimates could indicate more efficiency than the modified 3SLS alternatives; if so, then 2SLS estimates would be selected in lieu of the modified 3SLS estimates.

The five alternatives for which estimates are reported are as follows:

I. OLS.

II. 2SLS.

III. All covariances between counties (not between equations) are set to zero in $\hat{\Sigma}$ to form, say, $\hat{\hat{\Sigma}}_1$.

IV. All covariances between equations (not between counties) are set to zero in $\hat{\Sigma}$ thus forming $\hat{\hat{\Sigma}}_2$.

V. A ridge is added to $\hat{\Sigma}$ according to (19) thus forming $\hat{\hat{\Sigma}}_3 \equiv \Sigma^*$.

The last three alternatives correspond to the modified 3SLS techniques discussed above. The respective modified 3SLS estimators $\hat{\hat{\delta}}_i$ are formed by replacing $\hat{\hat{\Sigma}}_i$ in (23). The rationale for case III is that, if covariances between counties are relatively unimportant as compared to covariances between equations, then $\hat{\delta}_1$ will have nearly the same asymptotic distribution as the true 3SLS estimator;[1] this would be true for $\hat{\delta}_2$ if covariances between equations are relatively unimportant as compared with covariances between counties. The last or ridge 3SLS case is somewhat similar to reducing all covariances by a small amount to attain nonsingularity of $\hat{\hat{\Sigma}}_3$. A fourth alternative was also attempted where zeros were inserted in $\hat{\Sigma}$ according to other reasoning, but a nonsingular $\hat{\hat{\Sigma}}$ could not be attained with a reasonable number of such assumptions.[1]

To develop the pooled estimates, it was decided to concentrate on the eight counties which have behaved in roughly the same way since 1951. That is, Merced County was excluded because it was the only county where noncontract acreage has been dominant. As found previously by Chern, estimates in the aggregate model were not sensitive to whether or not noncontract acreage was included; hence, the pooled estimates will presumably be useful whether or not Merced County is included. Also, because Fresno County was only an important tomato producer after the harvester was introduced, it was excluded from the estimates which compared with the preharvester period below; but results were derived both with and without Fresno County for the postharvester period.

Structural Differences Among Counties

Before proceeding to the presentation of the pooled model results, consider first the extent to which parameters vary among counties. If the structure among counties is the same, then much greater efficiency can generally be gained by pooling because fewer parameters must be estimated in the pooled model. This possibility can be considered statistically through hypothesis testing. In this case, however, since structural change may have occurred with the introduction of the tomato harvester, it is desirable to allow freedom for parameters in each county to change with harvester adoption in performing this test. But, unfortunately, there are insufficient data in the postharvester period to identify parameters just as in the aggregate model case. The only feasible alternative is to test for county structural differences only in the preharvester period.

For the purposes of performing this test, the econometric system in each county i was specified as

$$A_i = A_i^s \ (P_i, \ Y_i, \ D_i, \ F, \ G_{t-1}, \ W_i) \tag{24}$$

$$Q_i = Q_i^d \ (P_i, \ V, \ R, \ I) \tag{25}$$

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[1]Also, note that $\hat{\delta}_1$ is identical to separate 3SLS estimation with each county (if no other constraints are imposed across counties).

[2]For example, disturbances in the third equation of each county were assumed uncorrelated with all other disturbances, supply disturbances were assumed uncorrelated between counties which were not geographically connected, and the supply disturbance in each county was assumed uncorrelated with the demand disturbance in each other county.

$$A_i = A_i^d (Y_i, Q_i) \tag{26}$$

with all variables entering the relationships log linearly.

Since distributional results hold only asymptotically for simultaneous equations estimators, it was decided to perform this test using reduced–form equations. Unrestricted reduced–form estimators have the usual properties as long as disturbances in the structural equations are jointly, uniformly, and normally distributed in time without serial correlation. Furthermore, any structural change should also imply a change in the reduced form.

Using this approach, the following pair of hypotheses was entertained with respect to the three reduced–form equations associated with equations (24), (25), and (26).

H_0: All parameters except constant terms are the same across counties.

H_1: H_0 does not hold.

The test was performed using 1951–1963 data for the eight counties which are concentrated upon in the pooled results: San Joaquin, Yolo, Solano, Sutter, Sacramento, Stanislaus, Santa Clara, and San Benito. The resulting F statistics are .404 for the price reduced–form equation, 1.669 for the quantity reduced–form equation, and 2.315 for the acreage equation. In this case there are 56 and 32 degrees of freedom, so the critical F value is approximately 1.73 at the 5 percent level and 2.4 at the 0.5 percent level.

Unfortunately, it is not easy to test the hypothesis with respect to these three equations jointly without further knowledge of the contemporaneous covariance matrix.[1] However, as one can see, the simple tests suggest nonrejection of H_0 with both the price and quantity equations at the 5 percent level and with all three equations at the 0.5 percent level.

It is therefore concluded that elasticities were similar across the eight counties in the preharvester period. Thus, imposing such constraints in pooled estimation should not impose serious problems while leading to much greater efficiency in estimation. Since data are insufficient for testing a similar hypothesis (or using the more general formulation) in the postharvester period, a similar specification is followed in the 1967–1975 period.

The Pooled Estimation Results

To estimate the pooled model, the system structure is assumed to follow (24), (25), and (26) except that intercept shift terms are considered for each county. The dummy coefficients are associated with counties as follows:

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[1]The necessary procedure is given by Morrison in the context of multivariate regression; see Donald F. Morrison, *Multivariate Statistical Methods* (New York: McGraw–Hill Book Company, Inc., 1967), Chap. 5, pp. 159–204.

D1	San Joaquin
D2	Yolo
D3	Solano
D4	Sutter
D5	Sacramento
D6	Stanislaus
D7	Santa Clara
D8	San Benito.

The results for the preharvester period (1951–1963) and the postharvester period (1967–1975), including the eight counties listed above, are presented in Tables 15 and 16, respectively. For comparison, the postharvester results are also derived including Fresno County, along with the other eight counties, in Table 17.[1] The results are derived using OLS, 2SLS, and the various modified 3SLS procedures described above.

In each case the k relevant to the ridge 3SLS estimator (estimator V) was varied over a wide range to attain best results. It was found, however, that both coefficient and standard–error estimates were very insensitive to k variation in some cases. In most cases the k which achieves best results will be somewhere in the positive interval (*i.e.*, somewhere between 2SLS and 3SLS in terms of the effective covariance matrix); and, the closer k is to zero, the closer the estimator is to true 3SLS. It stands to reason that, as the number of observations gets large, the best–performing k will move close to zero because the covariance matrix approaches nonsingularity, the case where the true 3SLS estimator exists (and does not, in effect, discard observations). This indeed seemed to be true in deriving the results in Tables 15 to 17 since lower true standard–error estimates were obtained with k = .0001 with 13 annual observations (1951–1963 in Table 15) as opposed to k = 0.1 with 9 annual observations (1967–1975 in Tables 16 and 17). It is also interesting to note, however, that the choice of k was a less sensitive matter with the greater number of observations; varying k by a factor of 100 (up to 0.1) did not change most coefficient and standard–error estimates even in the second decimal place.

It should also be noted that the method IV–modified 3SLS estimates are not reported in Table 17 (for the 1967–1975 case including Fresno County) because they do not exist. This phenomenon results for the following reason. When covariances between equations are zero but covariances between counties are nonzero, the covariance matrix for the overall pooled model is block diagonal (or can be so arranged) with three blocks corresponding to the three equations. Each (square) block is dimensioned by the number of counties included in the study—–eight in Tables 15 and 16 and nine in Table 17. In order for the modified 3SLS estimator to exist (without discarding data as when generalized inverses are used), the overall matrix must be of full rank and, hence, each block must be of full rank. One must note, however, that each block is computed from covariance estimators based on 2SLS residuals. Just as in the decomposition in (20), the rank of the resulting matrix cannot be larger than the number of observations which are used; in fact, the rank will generally be one less than the number of observations (for computational

[1]Fresno County was not considered in the 1951–1963 period since it was not an important producing county in the preharvester period and, in fact, separate data were not even reported during the early years. However, it is interesting to note that Fresno County was the most important producing county in the state in 1975.

purposes) since disturbance estimates sum to near zero. Since there are only nine observations in the postharvester period (1967–1975), the rank of each block is thus equal to eight. The order (size) of each block is eight when Fresno County is excluded, so the associated estimators exist in Table 16; however, the order of each block is nine when Fresno County is included, so each block and thus the overall matrix become singular, and the estimator (type IV) does not exist for Table 17. Thus, one has a peculiar situation where the estimator may not exist when the number of cross–sectional observations increased.[1]

Goodness of Fit

As one can see, the goodness of fit of the pooled model is quite good. The R^2 coefficients for the 1967–1975 results are of approximately the same magnitude as obtained in the aggregate model, while those obtained for 1951–1963 are higher except for the demand equation (which is only slightly lower).

Comparison of Elasticities

One of the objectives of this study is to obtain estimates of important elasticities for acreage response and demand for processing tomatoes. The knowledge of these elasticities is necessary and useful for further policy analyses. Since the results presented earlier appear to be sensitive to both sample period and estimation methods, it is of some importance to point out the extent to which the resulting elasticities differ in the context of a model which possesses sufficient generality for investigating those differences.

Table 18 presents selected estimated elasticities of acreage response for all those determinants which were of statistical importance in both estimation periods. The contrast of these results with the results of the aggregate model is remarkable. While the preharvester price elasticities are somewhat similar to those indicated in Table 18, the postharvester price elasticities are considerably smaller; and whereas before there was little difference in pre– and postharvester price elasticities, the pooled estimates indicate a sizable change. It may also be noted that simultaneous methods did not tend to give uniformly higher estimates of price elasticity as in Chern.[2]

It is further interesting that the pooled estimates indicate a considerable drop in yield and fertilizer elasticities from pre– to postharvester periods. By comparison, the aggregate estimates of Table 18, for the most part, fall in between the elasticities of the pooled pre– and postharvester estimates. Recalling that multicollinearity seemed to prevent detailed investigation of structural change with aggregate data, the pooled results, indeed, support the earlier arguments. In light of the results in Table 18, it would seem that the variables M and M $\cdot$ ln P were picking up the effects of changes in elasticities for yield and fertilizer as well (not to mention wage, risk, and competing crop price).

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[1]Of course, in this case one could define the estimator more generally using generalized inverses. But along the same lines discussed above, this would effectively result in throwing away the information from the added counties (or cross–sectional units).

[2]Chern, "Supply Response and Price–Demand Relationships . . ."; and *idem*, "Acreage Response and Demand. . . ."

TABLE 15

Estimated Acreage Response and Demand for Processing Tomatoes, Pooled Model, 1951-1963[a]

Equation	Constant	ln P_i	ln Y_i	ln D_i	ln F	ln G_{t-1}	ln W_i	ln Q_i	ln Y	ln I	ln R	D1	D2	D3	D4	D5	D6	D7	R^2
Estimation method I (OLS)																			
1	5.7632 (4.0074)	1.3744 (.2824)	1.3673 (.2504)	- .0274 (.0440)	-2.9685 (.7652)	- .5055 (.2398)	-1.6605 (.5126)	b				3.2554 (.1026)	2.6239 (.0952)	1.3998 (.0926)	1.2916 (.0955)	1.8621 (.0941)	1.2804 (.0984)	.8364 (.0959)	.954
2	- 5.4430 (1.0901)	- .8156 (.4083)							- .1379 (.1188)	1.6418 (.2661)	1.7985 (.5621)	2.8611 (.1108)	2.4277 (.1108)	1.1904 (.1108)	1.1069 (.1109)	1.5988 (.1108)	.8863 (.1109)	.5506 (.1108)	.924
3	- 2.0809 (.2089)		- .2464 (.0808)					.9253 (.0289)				.4048 (.0959)	.3405 (.0822)	.2549 (.0539)	.2499 (.0527)	.3013 (.0634)	.2481 (.0522)	.1616 (.0444)	.990
Estimation method II (2SLS)																			
1	- 1.3204 (4.8405)	2.1011 (.3876)	1.6988 (.2844)	- .0290 (.0456)	2.1365 (.8448)	- .4314 (.2498)	-1.9484 (.5405)					3.2978 (.1073)	2.6328 (.0986)	1.4095 (.0959)	1.2959 (.0989)	1.8804 (.0977)	1.3223 (.1030)	.8716 (.1001)	.951
2	- 4.3387 (1.2441)	-1.9059 (.6635)							- .1871 (.1254)	1.8621 (.2948)	2.6452 (.7054)	2.8648 (.1151)	2.4337 (.1151)	1.1948 (.1151)	1.1187 (.1153)	1.6025 (.1151)	.8983 (.1153)	.5443 (.1151)	.918
3	- 2.0803 (.2106)		- .2917 (.0861)					.9611 (.0366)				.2972 (.1174)	.2517 (.0994)	.2105 (.0609)	.2079 (.0591)	.2408 (.0741)	.2904 (.0578)	.1387 (.0470)	.990
Estimation method III (modified 3SLS)																			
1	- 4.5256 (3.1548) (5.2755)	1.7172 (.2686) (.4178)	.9148 (.2034) (.2859)	- .0246 (.0303) (.0369)	- .6586 (.5469) (.9263)	- .6012 (.1730) (.2583)	-2.1255 (.3716) (.4982)					3.2144 (.0981) (.0982)	2.6002 (.0874) (.0715)	1.3777 (.1102) (.0994)	1.2528 (.0887) (.0804)	1.8232 (.0940) (.1069)	1.1980 (.1017) (.0933)	.8245 (.0955) (.0744)	.940
2	- 3.1400 (.8342) (1.3758)	-1.6534 (.4481) (.6789)							- .1644 (.0785) (.1403)	1.6420 (.1986) (.3260)	2.0973 (.4385) (.7598)	2.8639 (.1289) (.1608)	2.4323 (.1218) (.1236)	1.1938 (.1231) (.0981)	1.1160 (.1273) (.1479)	1.6016 (.1437) (.1872)	.8955 (.1510) (.1673)	.5458 (.1390) (.0975)	.918
3	- 1.4208 (.1825) (.3181)		- .4177 (.0705) (.1345)					.8791 (.0279) (.0563)				.5169 (.0946) (.1758)	.4446 (.0817) (.1465)	.3023 (.0594) (.0831)	.2906 (.0550) (.0768)	.3623 (.0640) (.1003)	.2609 (.0603) (.0801)	.1759 (.0493) (.0509)	.989
Estimation method IV (modified 3SLS)																			
1	- 1.1148 (5.0864) (5.0863)	2.1779 (.3935) (.3934)	1.5145 (.2366) (.2366)	- .0691 (.0250) (.0248)	-2.1200 (.9018) (.9012)	- .4468 (.2212) (.2212)	-2.2893 (.3068) (.3067)					3.2571 (.0935) (.0935)	2.5961 (.0691) (.0691)	1.3826 (.0985) (.0985)	1.2504 (.0781) (.0781)	1.8441 (.1057) (.1057)	1.2800 (.0900) (.0900)	.8577 (.0711) (.0711)	.948
2	- 5.2803 (.9157) (.9157)	- .7481 (.3224) (.3224)							- .1603 (.0995) (.0995)	1.6668 (.2210) (.2210)	1.4878 (.4949) (.4949)	2.8609 (.1609) (.1609)	2.4273 (.1235) (.1235)	1.1901 (.0981) (.0981)	1.1061 (.1478) (.1478)	1.5986 (.1872) (.1872)	.8856 (.1672) (.1672)	.5509 (.0974) (.0974)	.923
3	- 3.4155 (.1875) (.1875)		.4187 (.0865) (.0865)					.7662 (.0340) (.0340)				.9376 (.1129) (.1129)	.7572 (.0953) (.0953)	.4731 (.0617) (.0617)	.4639 (.0560) (.0560)	.6049 (.0657) (.0657)	.4955 (.0627) (.0627)	.2942 (.0419) (.0419)	.983
Estimation method V (ridge 3SLS; k = .0001)																			
1	2.7074 (14.3927) (3.3959)	1.5708 (.4128) (.4129)	1.2809 (.2696) (.2696)	- .1205 (.0264) (.0264)	-2.3780 (.8957) (.8963)	- .3938 (.2444) (.2444)	-1.7651 (.3785) (.3786)					3.2128 (19.9308) (3.8396)	2.5332 (25.6140) (6.9391)	1.3606 (22.8611) (4.4572)	1.4433 (27.2418) (2.9981)	1.7659 (21.9032) (4.5290)	1.1997 (17.1253) (2.4793)	.9111 (23.4153) (4.5707)	.942
2	- 3.5509 (15.8070) (1.9846)	-1.6011 (.5335) (.5335)							- .0732 (.1167) (.1167)	1.5666 (.2769) (.2769)	2.4938 (.6161) (.6161)	2.7669 (27.2695) (2.7772)	2.0359 (29.1786) (3.4633)	1.0065 (32.9793) (4.0503)	.9804 (22.5810) (2.1625)	1.5273 (14.6332) (1.7316)	.8014 (21.8072) (1.9982)	.1341 (31.3617) (3.9115)	.898
3	- 2.3060 (25.1259) (7.7599)		- .3744 (.1368) (.1368)					.9757 (.0608) (.0608)				.6775 (32.9339) (8.2876)	.6546 (37.9072) (11.6042)	.7323 (36.9378) (9.2670)	.6640 (38.2779) (9.8142)	.7534 (40.2519) (8.7476)	.5346 (33.0141) (6.9940)	.6789 (39.6136) (9.2815)	.971

[a]For OLS and 2SLS, the numbers in parentheses are the estimated standard errors. For the various 3SLS modifications, the upper numbers in parentheses are the estimated standard errors computed according to equation (21) assuming the associated covariance matrix constraints hold; the lower numbers in parentheses are the standard error estimates computed according to equation (22) under the assumption that imposed constraints do not hold in reality.

[b]Blanks indicate variables not included.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

TABLE 16

Estimated Acreage Response and Demand for Processing Tomatoes, Pooled Model, 1967-1975, Excluding Fresno County[a]

Equation	Constant	ln P_i	ln Y_i	ln F	ln Q_i	ln V	ln I	ln R	D1	D2	D3	D4	D5	D6	D7	R^2
Estimation method I (OLS)																
1	- .2902 (.9444)	.7675 (.2364)	.2171 (.3310)	- .2560 (.2189)	*b*				1.5133 (.1178)	1.7813 (.1141)	.7278 (.1126)	.6821 (.1096)	.1317 (.1187)	.0696 (.1151)	.0115 (.1080)	.916
2	3.6027 (1.5248)	- .3747 (.2972)				- .1291 (.1428)	.2943 (.2254)	.7701 (.3981)	1.3823 (.1078)	1.6426 (.1079)	.5744 (.1078)	.5692 (.1078)	- .0321 (.1078)	- .0471 (.1078)	- .0445 (.1078)	.909
3	- 1.7748 (.5079)		- .2388 (.1712)		.8715 (.0561)				.2221 (.1090)	.2686 (.1191)	.1538 (.0728)	.1281 (.0705)	.0699 (.0630)	.0464 (.0610)	.0091 (.0577)	.975
Estimation method II (2SLS)																
1	- .2726 (.9455)	.8314 (.2643)	.2164 (.3312)	- .3093 (.2402)					1.5137 (.1179)	1.7821 (.1142)	.7284 (.1126)	.6825 (.1096)	.1321 (.1188)	.0693 (.1151)	.0114 (.1081)	.916
2	4.4425 (1.6830)	- .6055 (.3547)				- .1506 (.1446)	.2319 (.2324)	1.0269 (.4531)	1.3804 (.1084)	1.6395 (.1084)	.5717 (.1084)	.5674 (.1084)	- .0342 (.1084)	- .0461 (.1084)	- .0442 (.1084)	.908
3	- 1.8458 (.5213)		- .3265 (.2039)		.9398 (.1013)				.1126 (.1740)	.1433 (.1955)	.1026 (.0969)	.0795 (.0930)	.0564 (.0658)	.0364 (.0630)	.0040 (.0587)	.975
Estimation method III (modified 3SLS)																
1	- 1.3881 (.5455) (.6358)	.5166 (.1460) (.1660)	.6331 (.1818) (.2204)	- .1145 (.1316) (.1519)					1.5819 (.0914) (.1192)	1.8383 (.0788) (.0432)	.7804 (.0867) (.0556)	.7253 (.0984) (.0731)	.2024 (.0969) (.1201)	.1339 (.0805) (.0859)	.0508 (.0680) (.0785)	.912
2	1.1044 (.7706) (1.2103)	- .1851 (.1373) (.2554)				- .2421 (.0671) (.1052)	.7565 (.1031) (.1763)	.2966 (.1591) (.3329)	1.3839 (.0813) (.0675)	1.6452 (.0661) (.0698)	.5766 (.0759) (.0823)	.5707 (.0957) (.1074)	- .0304 (.0899) (.0789)	- .0480 (.0617) (.0608)	- .0447 (.0697) (.0628)	.902
3	- 1.0369 (.3808) (.7106)		- .4543 (.1468) (.2227)		.8639 (.0660) (.1131)				.1961 (.1166) (.1822)	.2499 (.1309) (.2065)	.1295 (.0672) (.0903)	.1091 (.0751) (.0958)	.0318 (.0479) (.0565)	.0132 (.0623) (.0672)	- .0114 (.0397) (.0434)	.974
Estimation method IV (modified 3SLS)																
1	- .7776 (.2778) (.2788)	.9201 (.0263) (.0264)	.3634 (.0875) (.0878)	- .3723 (.0235) (.0236)					1.5396 (.1141) (.1143)	1.8046 (.0317) (.0317)	.7490 (.0486) (.0486)	.6991 (.0698) (.0698)	.1589 (.1147) (.1149)	.9013 (.0802) (.0803)	.0251 (.0761) (.0762)	.915
2	2.8731 (.7693) (.7693)	- .1810 (.1237) (.1237)				- .0120 (.0670) (.0670)	.2670 (.1164) (.1164)	.6729 (.1807) (.1807)	1.3839 (.0675) (.0675)	1.6453 (.0698) (.0698)	.5766 (.0822) (.0823)	.5707 (.1074) (.1074)	- .0304 (.0788) (.0788)	- .0480 (.0608) (.0608)	- .0448 (.0628) (.0628)	.907
3	20.6337 (.1557) (.1558)		-6.6412 (.0507) (.0507)		.5503 (.0105) (.0105)				- .4198 (.0502) (.0502)	- .1310 (.0465) (.0465)	- .5145 (.0379) (.0379)	- .3822 (.0562) (.0562)	- 1.0618 (.0429) (.0429)	- .9410 (.0596) (.0596)	- .6040 (.0392) (.0392)	.475
Estimation method V (ridge 3SLS; k = .1)																
1	- 1.8735 (1.3783) (.9930)	1.1331 (.2522) (.2523)	.7911 (.3291) (.3290)	- .6023 (.2315) (.2315)					1.6136 (1.2115) (.1262)	1.8694 (1.2313) (.0537)	.8083 (1.3859) (.0642)	.7470 (1.2563) (.0776)	.2353 (1.1852) (.1274)	.1549 (1.1753) (.0933)	.0645 (1.2206) (.0815)	.908
2	1.6112 (1.6160) (1.3057)	-5.5289 (.2756) (.2759)				.3932 (.1140) (.1141)	.8477 (.1868) (.1870)	.6382 (.3643) (.3647)	1.3811 (1.3315) (.0672)	1.6405 (1.3664) (.0695)	.5726 (1.2162) (.0821)	.5680 (1.1663) (.1072)	- .0335 (1.2864) (.0786)	- .0464 (1.2776) (.0603)	- .0443 (1.2224) (.0626)	.891
3	- 2.6789 (1.6785) (1.4816)		- .4147 (.6227) (.6220)		1.1551 (.2275) (.2271)				- .2005 (1.2285) (.3973)	- .2241 (1.3043) (.4430)	- .0337 (1.2745) (.2011)	- .0532 (1.2729) (.1911)	.0473 (1.1526) (.1128)	.0336 (1.3364) (.1054)	.0055 (1.2991) (.0647)	.966

[a]For OLS and 2SLS, the numbers in parentheses are the estimated standard errors. For the various 3SLS modifications, the upper numbers in parentheses are the estimated standard errors computed according to equation (21) assuming the associated covariance matrix constraints hold; the lower numbers in parentheses are the standard error estimates computed according to equation (22) under the assumption that imposed constraints do not hold in reality.

[b]Blanks indicate variables not included.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

TABLE 17

Estimated Acreage Response and Demand for Processing Tomatoes, Pooled Model, 1967-1975, Including Fresno County[a]

Equation	Constant	ln P_i	ln Y_i	ln F	ln Q_i	ln V	ln I	ln R
	Estimation method I (OLS)							
1	- .4029 (.8044)	.8226 (.2475)	.6739 (.3036)	- .2953 (.2308)	[b]			
2	3.7920 (1.6663)	- .4423 (.3256)				- .0999 (.1571)	.4037 (.2484)	.9437 (.4379)
3	- 1.5500 (.4102)		- .2146 (.1575)		.8579 (.0488)			
	Estimation method II (2SLS)							
1	- .3928 (.8051)	.8921 (.2792)	.6770 (.3038)	- .3539 (.2553)				
2	4.8357 (1.8559)	- .7299 (.3943)				- .1255 (.1593)	.3256 (.2569)	1.2651 (.5042)
3	- 1.6963 (.4392)		- .4071 (.2152)		.9728 (.0977)			
	Estimation method III (modified 3SLS)							
1	- .8490 (.4840) (.5757)	.4855 (.1486) (.1581)	.8479 (.1675) (.2051)	- .0483 (.1343) (.1440)				
2	.8393 (.8476) (1.4160)	- .1645 (.1550) (.3056)				- .2711 (.0718) (.1198)	.9741 (.1133) (.2029)	.2649 (.1842) (.3974)
3	- .4364 (.3222) (.6540)		- .6046 (.1516) (.2628)		.8666 (.0611) (.1158)			
	Estimation method V (ridge 3SLS; k = .1)							
1	- 1.3298 (1.4260) (1.2143)	-1.1280 (.3596) (.3602)	.8874 (.4526) (.4536)	- .4711 (.3251) (.3256)				
2	.0440 (1.8632) (1.7444)	- .3924 (.3588) (.3595)				- .3336 (.1485) (.1489)	1.1450 (.2418) (.2425)	.6386 (.4680) (.4690)
3	- 4.7851 (1.5238) (1.3300)		-1.0999 (.6855) (.6850)		1.7941 (.3203) (.3199)			

Equation	D1	D2	D3	D4	D5	D6	D7	D8	R^2
	(OLS)								
1	.2074 (.1168)	.4644 (.1184)	- .5945 (.1194)	.6519 (.1217)	- 1.1717 (.1165)	- 1.2452 (.1179)	- 1.3297 (.1233)	- 1.3839 (.1363)	.899
2	.2874 (.1252)	.5473 (.1253)	- .5208 (.1252)	- .5257 (.1252)	- 1.1271 (.1252)	- 1.1412 (.1252)	- 1.1388 (.1252)	- 1.0944 (.1252)	.882
3	.0130 (.0593)	.0624 (.0624)	- .0673 (.0687)	- .0936 (.0707)	- .1585 (.0840)	- .1828 (.0865)	- .2214 (.0913)	- .2322 (.0988)	.974
	(2SLS)								
1	.2078 (.1168)	.4651 (.1185)	- .5941 (.1194)	- .6517 (.1217)	- 1.1713 (.1165)	- 1.2458 (.1180)	- 1.3303 (.1233)	- 1.3847 (.1364)	.899
2	.2842 (.1259)	.5426 (.1260)	- .5249 (.1260)	- .5288 (.1259)	- 1.1305 (.1260)	- 1.1407 (.1259)	- 1.1392 (.1259)	- 1.0952 (.1259)	.881
3	- .0069 (.0633)	.0172 (.0726)	.0127 (.0920)	- .0081 (.0962)	- .0167 (.1350)	- .0343 (.1404)	- .0621 (.1496)	- .0600 (.1618)	.972
	(modified 3SLS)								
1	.1920 (.1401) (.1702)	.4429 (.1236) (.1005)	- .6174 (.1307) (.0877)	- .6778 (.1356) (.0588)	- 1.1864 (.1448) (.1691)	- 1.2595 (.1335) (.1404)	- 1.3552 (.1250) (.1116)	- 1.4262 (.1270) (.1105)	.896
2	.2844 (.1625) (.2042)	.5459 (.1468) (.1262)	- .5229 (.1512) (.1092)	- .5288 (.1583) (.0704)	- 1.1299 (.1673) (.2045)	- 1.1477 (.1476) (.1446)	- 1.1444 (.1533) (.1557)	- 1.0996 (.1405) (.1666)	.872
3	.0388 (.0631) (.0496)	.0956 (.0695) (.0595)	- .0201 (.0769) (.0908)	- .0367 (.0881) (.0921)	- .1224 (.0975) (.1494)	- .1374 (.1100) (.1559)	- .1533 (.1050) (.1660)	- .1280 (.1134) (.1842)	.971
	(ridge 3SLS; k = .1)								
1	.1943 (1.2310) (.1728)	.4477 (1.2648) (.1082)	- .6145 (1.2701) (.0984)	- .6782 (1.2940) (.0801)	- 1.1834 (1.0956) (.1713)	- 1.2660 (1.1221) (.1450)	- 1.3621 (1.2682) (.1268)	- 1.4359 (1.2428) (.1478)	.894
2	.2805 (1.0995) (.2042)	.5407 (1.0590) (.1263)	- .5275 (1.1490) (.1093)	- .5327 (1.2033) (.0704)	- 1.1340 (1.0397) (.2045)	- 1.1488 (1.0776) (.1446)	- 1.1461 (1.1269) (.1557)	- 1.1017 (1.1251) (.1666)	.855
3	- .1982 (1.2324) (.0756)	- .3724 (1.3714) (.1351)	.5092 (1.2182) (.2313)	.5111 (1.3741) (.2469)	.9496 (1.2108) (.3984)	.9648 (1.3048) (.4182)	.9743 (1.3686) (.4507)	1.0042 (1.3279) (.4944)	.887

[a]For OLS and 2SLS, the numbers in parentheses are the estimated standard errors. For the various 3SLS modifications, the upper numbers in parentheses are the estimated standard errors computed according to equation (21) assuming the associated covariance matrix constraints hold; the lower numbers in parentheses are the standard error estimates computed according to equation (22) under the assumption that imposed constraints do not hold in reality.

[b]Blanks indicate variables not included.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

TABLE 18

Comparison of Selected Estimated Elasticities of Acreage Response
1951-1963 and 1967-1975

Elasticity	Estimation method	Preharvester (1951-1963)	Postharvester (1967-1975) Without Fresno County	Postharvester (1967-1975) Including Fresno County
Price	I (OLS)	1.37	.77	.82
	II (2SLS)	2.10	.83	.89
	III (3SLS)	1.72	.52	.49
	IV (3SLS)	2.18	.92	*a*
	V (3SLS)	1.57	1.13	1.13
Yield	I (OLS)	1.37	.22	.67
	II (2SLS)	1.70	.22	.68
	III (3SLS)	.91	.63	.85
	IV (3SLS)	1.51	.36	
	V (3SLS)	1.28	.79	.89
Fertilizer price	I (OLS)	-2.97	- .26	- .30
	II (2SLS)	-2.14	- .31	- .35
	III (3SLS)	- .66	- .11	- .05
	IV (3SLS)	-2.12	- .37	
	V (3SLS)	-2.38	- .60	- .47

[a]Blanks indicate no estimates available.

Sources: Tables 15, 16, and 17, *supra*, pp. 72-77.

Table 19 presents estimated elasticities of demand for both periods of estimation; again, the contrast with aggregate results is striking. In point of fact, the aggregate model with its limited data availability did not allow investigation of structural change with adoption of the tomato harvester; but the results in Table 19 suggest that such structural change did take place.[1] With a single exception (grower price elasticity estimates with 3SLS–V), all estimates in Table 19 suggest a substantial fall in price and income elasticities of demand. Again, the aggregate estimates are by comparison somewhere in between the pooled pre– and postharvester estimates. And, as in the supply equation, it is again found that simultaneous methods do not tend to produce uniformly higher estimates of elasticity as noted in the aggregate study by Chern.[2]

In Table 19, it is of interest to note that in all cases the elasticity with respect to the product price is greater in absolute value than that with respect to the grower price. Thus, the California tomato processors' supply of processed tomato products is more price elastic than their demand for raw tomatoes. This is as suggested by most textbook discussions of agricultural processing industries.

Reduced–Form Equations

To facilitate a more detailed investigation of the effects of the tomato harvester on acreage and price (after removing the effects of other factors), the reduced–form equations corresponding to Tables 15 and 16 are derived in Table 20 (for 1951–1963) and Table 21 (for 1967–1975). Table 17 is not used for this purpose since any difference from Tables 15 and 16 also could be due to the inclusion of an additional county, Fresno, in Table 17.

When the reduced–form equations are derived from the estimated structural equations, they are termed restricted reduced forms. If the reduced forms are estimated directly from the sample data without constraints, they are unrestricted. Klein has argued that the restricted reduced forms are more efficient for prediction than the unrestricted equations.[3] But Dhrymes has recently shown that 2SLS–induced, restricted reduced–form estimators are not necessarily (asymptotically) efficient relative to unrestricted reduced–form estimators.[4] He further showed that the 3SLS–induced, restricted reduced–form estimator is asymptotically efficient relative to the 2SLS–induced estimator and to the unrestricted estimator. For this reason, 2SLS–induced estimates are not presented. But it is interesting to compare the estimated structure of the restricted versus unrestricted reduced forms, particularly since asymptotic conditions do not hold exactly.

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[1]This result will be discussed in detail, *infra,* pp. 85–96.

[2]Chern, "Supply Response and Price–Demand Relationships . . ."; and *idem,* "Acreage Response and Demand. . . ."

[3]L. R. Klein, "The Efficiency of Estimation in Econometric Models," *Essays in Economics and Econometrics: A Volume in Honor of Harvey Hotelling* (ed.) Ralph William Pfouts (Chapel Hill: University of North Carolina Press, 1960).

[4]Dhrymes, *op. cit.*

TABLE 19

Comparison of Selected Estimated Elasticities of Demand
1951-1963 and 1967-1975

Elasticity	Estimation method	Preharvester (1951-1963)	Postharvester (1967-1975) Without Fresno County	Postharvester (1967-1975) Including Fresno County
Grower price	I (OLS)	- .82	- .37	- .44
	II (2SLS)	-1.91	- .61	- .73
	III (3SLS)	-1.65	- .19	- .16
	IV (3SLS)	- .75	- .18	*a*
	V (3SLS)	-1.60	-5.53	- .39
Inventory	I (OLS)	- .14	- .13	- .10
	II (2SLS)	- .19	- .15	- .13
	III (3SLS)	- .16	- .24	- .27
	IV (3SLS)	- .16	- .01	
	V (3SLS)	- .07	.39	- .33
Consumer income	I (OLS)	1.64	.29	.40
	II (2SLS)	1.86	.23	.33
	III (3SLS)	1.64	.76	.97
	IV (3SLS)	1.67	.27	
	V (3SLS)	1.57	.85	1.15
Produce price	I (OLS)	1.80	.77	.94
	II (2SLS)	2.65	1.03	1.27
	III (3SLS)	2.10	.30	.26
	IV (3SLS)	1.49	.67	
	V (3SLS)	2.49	.64	.64

[a] Blanks indicate no estimates available.

Sources: Tables 15, 16, and 17, *supra*, pp. 72-77.

TABLE 20

Restricted and Unrestricted Reduced-Form Estimates, Pooled Model, 1951-1963[a]

Variable	Constant	ln Y	ln D	ln F	$\ln G_{t-1}$	ln V	ln I	ln R
	Unrestricted reduced form							
$\ln A_i$	.4312	1.3006	.0421	-2.7613	.3414	- .2853	1.4193	.9119
	(5.1387)	(.2758)	(.0442)	(.7840)	(.3711)	(.1262)	(.5730)	(.4153)
$\ln P_i$	1.9739	- .1616	.0329	- .3265	.2632	- .0993	.4521	.5271
	(1.3220)	(.0709)	(.0114)	(.2017)	(.0955)	(.0325)	(.1474)	(.1068)
	Restricted reduced form corresponding to method III							
$\ln A_i$	- 4.3390	.1932	- .0113	- .3019	- .2756	- .0783	.7817	.9985
$\ln P_i$	.1086	- .4203	.0078	.2077	.1896	- .0456	.4552	.5815
	Restricted reduced form corresponding to method IV							
$\ln A_i$	- 6.1388	.6470	- .0144	- .4417	- .0931	- .0972	1.0110	.9024
$\ln P_i$	- 2.3068	- .3983	.0251	.7706	.1624	- .0446	.4642	.4143
	Restricted reduced form corresponding to method V (k = .0001)							
$\ln A_i$	- 1.5432	.4510	- .0601	-1.1857	- .1963	- .0358	.7663	1.2199
$\ln P_i$	- 2.7061	- .5283	.0385	.7590	.1257	- .0228	.4879	.7766

(Continued below.)

Variable	ln W	D1	D2	D3	D4	D5	D6	D7
	Unrestricted reduced form							
$\ln A_i$	- 1.7000	3.0059	2.6731	1.4317	1.3474	1.8931	1.2968	.8485
	(.6657)	(.1008)	(.0931)	(.0901)	(.0950)	(.0929)	(.0999)	(.0927)
$\ln P_i$	.2758	.0001	.0207	.0121	.0290	.0095	- .0058	- .0146
	(.1713)	(.0259)	(.0240)	(.0232)	(.0244)	(.0239)	(.0257)	(.0239)
	Restricted reduced form corresponding to method III							
$\ln A_i$	- .9743	3.1169	2.5907	1.3637	1.2630	1.7946	1.1169	.7331
$\ln P_i$	.6704	- .0568	- .0055	- .0082	.0059	- .0167	- .0473	- .0532
	Restricted reduced form corresponding to method IV							
$\ln A_i$	- .4770	3.1561	2.6126	1.3844	1.2986	1.8327	1.1961	.7458
$\ln P_i$	.8322	- .0464	.0076	.0008	.0222	- .0053	- .0385	- .0514
	Restricted reduced form corresponding to method V (k = .0001)							
$\ln A_i$	- .8801	3.2952	2.5872	1.5379	1.5322	2.0054	1.2582	.8603
$\ln P_i$	.5634	.0524	.0344	.1129	.0566	.1525	.0373	- .0324

[a]Numbers in parentheses are OLS standard error estimates.

Source: Derived from Appendix Tables, *infra,* pp. 102ff.

TABLE 21

Restricted and Unrestricted Reduced-Form Estimates, Pooled Model, 1967-1975[a]

Variable	Constant	ln Y	ln F	ln V	ln I	ln R	D1	D2	D3	D4	D5	D6	D7
	Unrestricted reduced form												
ln A_i	2.5624	- .2501	- .2317	- .0967	.0061	.8589	1.4276	1.7030	.6566	.6255	.0428	.0021	- .0315
	(1.2154)	(.4961)	(.2104)	(.1557)	(.2857)	(.3431)	(.1311)	(.1236)	(.1203)	(.1139)	(.1329)	(.1255)	(.1106)
ln P_i	2.7198	.0895	.6395	- .2372	- .3168	.3028	.0069	- .0007	.0005	.0020	.0067	.0181	.0097
	(.3081)	(.1257)	(.0533)	(.0395)	(.0724)	(.0870)	(.0332)	(.0313)	(.0305)	(.0289)	(.0337)	(.0318)	(.0280)
	Restricted reduced form corresponding to method III												
ln A_i	- .3914	- .1973	- .0271	- .1597	.4990	.1956	1.4366	1.7107	.6637	.6312	.0521	.0101	- .0262
ln P_i	1.9296	-1.6075	.1692	- .3091	.9660	.3787	- .2813	- .2470	- .2260	- .1821	- .2909	- .2397	- .1491
	Restricted reduced form corresponding to method IV												
ln A_i	19.9690	-5.9571	- .0364	- .0059	.1326	.3341	.4588	.8750	- .1048	.0070	- .9577	- .8640	- .5648
ln P_i	22.5492	-6.8697	.3651	- .0065	.1441	.3632	-1.1748	-1.0104	- .9280	- .7525	-1.2136	-1.0383	- .6411
	Restricted reduced form corresponding to method V (k = .1)												
ln A_i	-1.1876	.0077	- .2110	- .2951	.6361	.4790	1.4714	1.7404	.6910	.6534	.0880	.0412	- .0071
ln P_i	.6053	- .6914	.3453	- .2604	.5614	.4227	- .1255	- .1138	- .1035	- .0826	- .1300	- .1003	- .0632

[a]Numbers in parentheses are OLS standard error estimates.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

As is often the case, several implausible signs in Tables 20 and 21 are obtained in several cases by unrestricted least squares. For example, in Table 20, OLS estimates imply that yield variability and competing crop price have positive impacts on acreage and that fertilizer price has a negative impact on grower price. This is not the case with all three of the modified 3SLS–induced estimates. In Table 21 some questionable signs are obtained with all methods except the ridge estimator (V), but the unrestricted reduced forms again appear more questionable than the others. The yield impacts by OLS are exactly of the opposite sign as one would expect.

Also, as expected, with the larger capital investment associated with tomato harvester technology, acreage is less responsive to all factors of supply as well as demand in the postharvester period except, possibly, to inventory (methods III and IV) and yield (method IV). Similar qualitative results are obtained for production responsiveness (not reported) except in the case of consumer income and final product price by method IV. The impacts of the harvester on responsiveness of price are much less clear since different results are obtained by different methods. However, all four methods imply that final product price has played a smaller role in grower price determination in the postharvester period. One obvious possible explanation for this result is increased processing costs.

To determine the impact of the tomato harvester on acreage and price after compensating for the effects of other coincidentally varying factors of supply and demand, Table 22 has been developed by applying Tables 20 and 21 to the average data point for the 1951–1975 period.[1] These results are developed only for the 3SLS estimation methods since, as indicated above, unrestricted least–squares estimates of reduced–form equations in Tables 20 and 21 are implausible. The results indicate a reduction in total acreage among the eight counties although several counties increase by a minor amount. The most noticeable change is the rather large acreage reduction in San Joaquin County. It can also be noted that the estimated magnitudes of change are very similar with all estimation methods.

An interesting result in Table 22 that will be discussed below is that the estimated impact of the harvester on price is negative.[2] It is also somewhat surprising that quantities did not move consistently in either direction. If the tomato harvester has really reduced marginal costs, then the impacts on firms remaining in business should be to increase acreage, *ceteris paribus,* if competition prevails. If small producing firms cease tomato production because of high fixed costs, however, the overall or aggregate effect of the harvester may be to reduce acreage as indicated by Table 22.

That is, suppose the long–run average total cost curve shifts from, say AC to AC′ in Figure 5 while prices also fall from, say, p to p′. Then small growers who could

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[1]The results corresponding to method IV are not reported because they were somewhat implausible in magnitude. A more careful investigation of the problem revealed that this was due mostly to the implausible coefficients of production and yield in the third structural equation under method IV. This problem is discussed in more detail in "Evaluation of the Estimation Methodology," *infra*, p. 96.

[2]The estimates from these techniques are regarded as more reliable than OLS on the basis of arguments by Klein and Dhrymes; see Klein, *op. cit.,* and Dhrymes, *op. cit.* It should also be noted that a similar negative price impact estimate was obtained with 2SLS.

TABLE 22

Impacts of the Tomato Harvester Holding Other Factors Constant, Pooled Model

Variable	County	Impact of mechanization	
		Estimation method III (3SLS)	Estimation method V (3SLS)
A	San Joaquin	-22.1 (-46)	-32.4 (-58)
	Yolo	+ 5.8 (+20)	+ 3.0 (+11)
	Solano	+ 3.7 (+44)	+ 1.0 (+11)
	Sutter	+ 4.1 (+54)	+ .7 (+7)
	Sacramento	- 6.3 (-49)	- 9.5 (-62)
	Stanislaus	- .3 (-4)	- 1.7 (-23)
	Santa Clara	+ 1.6 (+36)	+ .4 (+9)
	San Benito	+ 4.0 (+190)	+ 3.3 (+159)
	8-county total	- 9.5 (-8)	-35.2 (-27)
P	San Joaquin	-11.4 (-29)	-11.7 (-29)
	Yolo	-12.5 (-31)	-10.7 (-27)
	Solano	-11.8 (-29)	-13.7 (-32)
	Sutter	-11.0 (-27)	-10.7 (-26)
	Sacramento	-14.6 (-35)	-16.2 (-35)
	Stanislaus	-14.5 (-34)	-10.4 (-26)
	Santa Clara	-12.0 (-28)	- 6.6 (-18)
	San Benito	- 4.7 (-11)	- 5.8 (-15)

Sources: Derived from Tables 20 and 21, *supra*, pp. 81 and 82, and from Appendix Tables, *infra*, pp. 102ff.

previously produce profitably at, say, q could no longer produce profitably, while larger growers producing at q′ could continue to produce profitably by adopting the tomato harvester. This explanation is, in fact, plausible given the negative price impact estimates of Table 22 (recall that yields are exogenous so the effect of prices on production is in the same direction as on acreage).

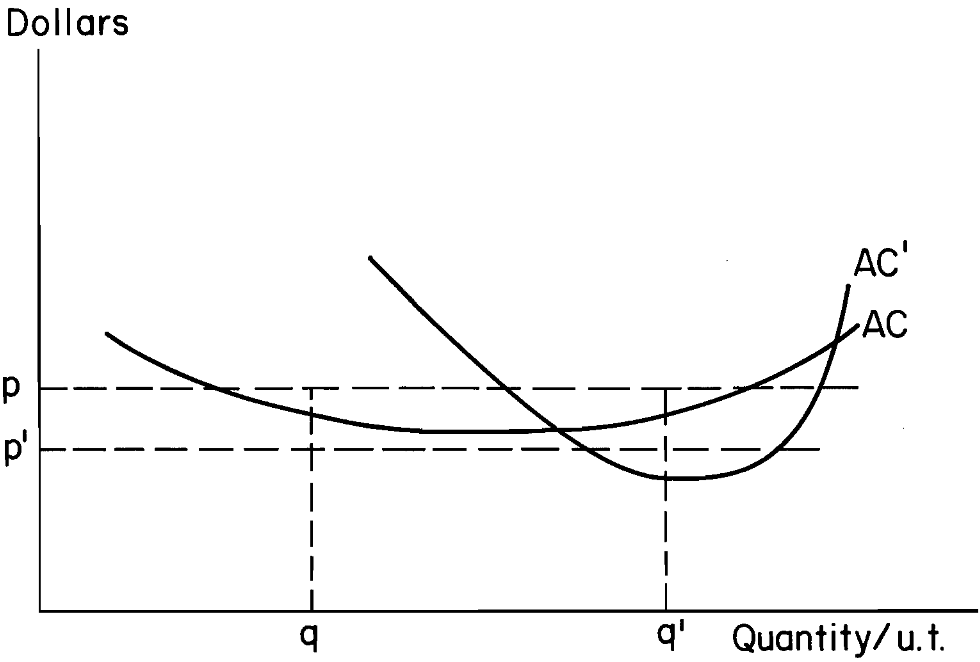

FIGURE 5. Price Effects on Growers With Different Cost Structures

But this brings up another interesting point. That is, if the harvester has caused significant structural change only in supply, a reduction in quantity should be coupled with an increase in price. The negative price impact estimates in Table 22 thus suggest that yet a further phenomenon which could lead to lower producer prices is an increase in market power among processors over producers. With market power, processors could extract much of the cost savings brought about by the harvester from producers so that grower prices could actually fall.

The Impact of the Tomato Harvester

For the purposes of investigating the effects of the tomato harvester, the differences in Tables 15 and 16, as compared in Tables 18, 19, and 22, must be analyzed statistically. Since the estimates in Tables 15 and 16 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 in Tables 15 and 16. Asymptotically, the marginal distribution of each coefficient estimator in, say, Table i, i = 15, 16, and 17, is normal with mean, μ_i, and standard deviation, σ_i, where σ_i is estimated by the reported standard deviation. With independence, one thus finds

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

under the hypothesis of equality where $\hat{\mu}_k$ is the associated estimator in Table k, k = 15, 16, and 17 (for corresponding variables).

Using pooled estimation methods and the above hypothesis–testing approach, it is possible to consider structural changes due to the tomato harvester in a much more comprehensive framework than with the aggregate model. Table 23 is developed for this purpose to determine the significance of structural change on each coefficient individually.

The results in Table 23 add substance to the substantial structural change (with the introduction of the tomato harvester) suggested by Tables 18 and 19. The supply equation results suggest the possibility of a significant structural change in every elasticity. At least three of the five estimators indicate a significant change at the 5 percent level for the elasticities of price, yield, competing crop price, and wages. At least two estimators indicate significant change at the 5 percent level in every case.

The supply of processing tomatoes has apparently become less price elastic with the adoption of the tomato harvester. As noted earlier, this is what one would expect when changing the production technology to one with higher fixed costs and lower variable costs. 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.

Consider, for example, the unit cost curves in Figure 6. Average cost is initially represented by AC. Now suppose a variable cost such as for harvesting labor is subtracted. Since labor costs are relatively flat with respect to output (*i.e.*, a set rate per unit of output), the resulting cost curve AC′ would be lower but of similar curvature (approximately vertically parallel). Now suppose fixed cost is increased by an amount represented by the fixed cost curve FC. Adding AC′ and FC obtains AC″ which represents average cost after variable labor costs have been replaced by fixed harvester costs. Obviously, the new average cost curve is more sharply U–shaped even though significant cost savings may or may not be generated. It may further be noted in Figure 6 as suggested earlier that, at constant price P*, the competitive supply curve becomes less price elastic since the slope of the marginal cost curve increases as quantity increases. (This must be so since the U–shaped marginal cost curve falls in a vertically parallel manner.)

This same explanation would also imply less sensitive supply response to all other factors affecting supply. Interestingly, this is exactly the implication of Table 23. For

TABLE 23

Significance of the Structural Impact of the Tomato Harvester, Pooled Model
1951-1963 Versus 1967-1975[a]

Equation	Coefficient	Estimation method				
		I	II	III	IV	V
		Asymptotic standard normal statistics				
Supply	$\ln P_i$	-1.66	-2.71	-2.67	-3.19	- .90
	$\ln Y_i$	-2.77	-3.40	- .78	-4.56	-1.15
	$\ln D_i$	.62	.64	.67	2.78	4.56
	$\ln F$	3.41	2.08	.46	1.94	1.92
	$\ln G$	2.11	1.72	2.33	2.02	1.61
	$\ln W_i$	3.24	3.60	4.27	7.46	4.66
		Asymptotic standard normal statistics				
Demand	$\ln P_i$	.87	1.73	2.02	1.64	1.79
	$\ln V$	.05	.19	- .44	1.24	-1.96
	$\ln I$	-3.86	-4.34	-2.76	-5.60	-2.15
	$\ln R$	-1.49	-1.93	-2.17	-1.55	-2.59

[a]For those variables which appear only in Table 15 (not in Table 16), the simple t ratio from Table 15 is given. These variables are $\ln D_i$, $\ln G$, and $\ln W_i$. The corresponding statistics for the acreage-yield relationship are not given because there is little reason to expect structural change in that equation; indeed, four out of five estimation techniques yielded statistics of less than .85 (in absolute value) in the case of each coefficient.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

every supply response factor with a positive (negative) elasticity estimate in Table 15, the results in Table 23 suggest a significant negative (positive) change in elasticity.[1] That is, each supply elasticity is significantly closer to zero in the postharvester period by at least one estimation method. Factors such as risk ($\ln D_i$), competing crop prices, and wage rates have apparently become very unimportant, while yield and fertilizer price are of reduced importance. The most significant changes occur in wage elasticities; this is sensible since wage labor was the factor replaced by the tomato harvester.[2]

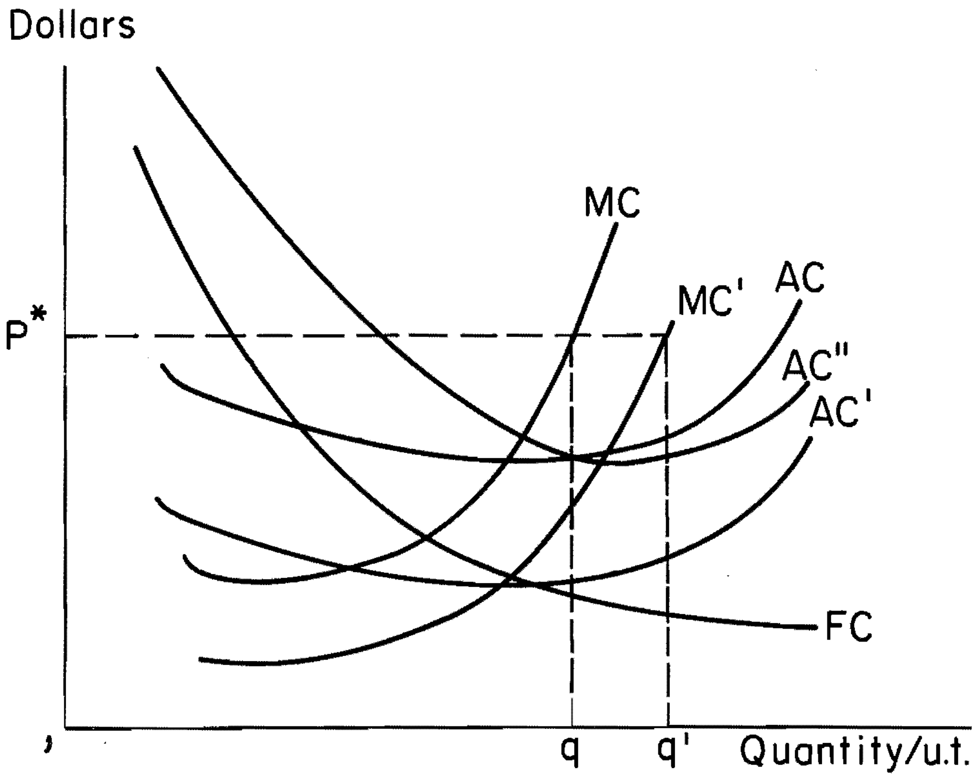

FIGURE 6. Shift in Cost Structure as Variable Costs Are Replaced by Fixed Costs

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[1]For the variables $\ln D_i$, $\ln G$, and $\ln W_i$ which do not appear in Table 15, there are admittedly some weaknesses in the statistics reported in Table 23. These variables were not retained in Table 16 because nonsensical coefficient estimates were obtained (implying misspecification with their inclusion).

[2]Although a drop in wage rates could again make hand harvesting profitable, the short–run response likely would be small due to sunken costs in capital until mechanical harvesters already in operation become "worn out."

A Change in Perceived Demand Structure: Implied Oligopsonistic Market Structure

Although structural change was not expected in demand, Table 23 also suggests a fairly consistent structural change (across estimation techniques) for the income elasticity and possibly the grower and product price elasticities of demand. As in the case of supply, all three elasticities have tended to zero with tomato harvester adoption. In the context of competition, such a shift 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.[1]

Suppose, on the other hand, that 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 7.[2] Suppose further that processing costs per unit can be represented by the vertical differences in $\bar{D}$ and D so that D would be the demand curve facing growers in the case 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. With monopoly–monopsony, however, the middleman–processor 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 grower 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 farmers. In the monopsonistic case, this is the demand curve which would be estimated econometrically by using grower prices and quantities.[3]

Now consider the situation where supply becomes inelastic in response to tomato harvester adoption. Suppose preharvester supply is represented by S_0 in Figure 8 and postharvester supply is represented by S_1. Note that the relative positions of S_0 and S_1 are consistent with the explanation of Figure 6, *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 $\bar{D}$ always converge at the price axis in Figure 7, it is clear that PD_0 would be the perceived demand in Figure 8 in the preharvester case; and PD_1 would be the

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[1]This statement, of course, ignores the supposedly minute general equilibrium impact that increased grower or machinery industry employee incomes might have on tomato demand.

[2]Although the econometric model is specified with constant elasticities, the graphical interpretation of this section is presented with linearity to facilitate intuition, comprehension, and simple construction.

[3]One can easily note that a similar observation also 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 imply observation of PD rather than the true demand curve.

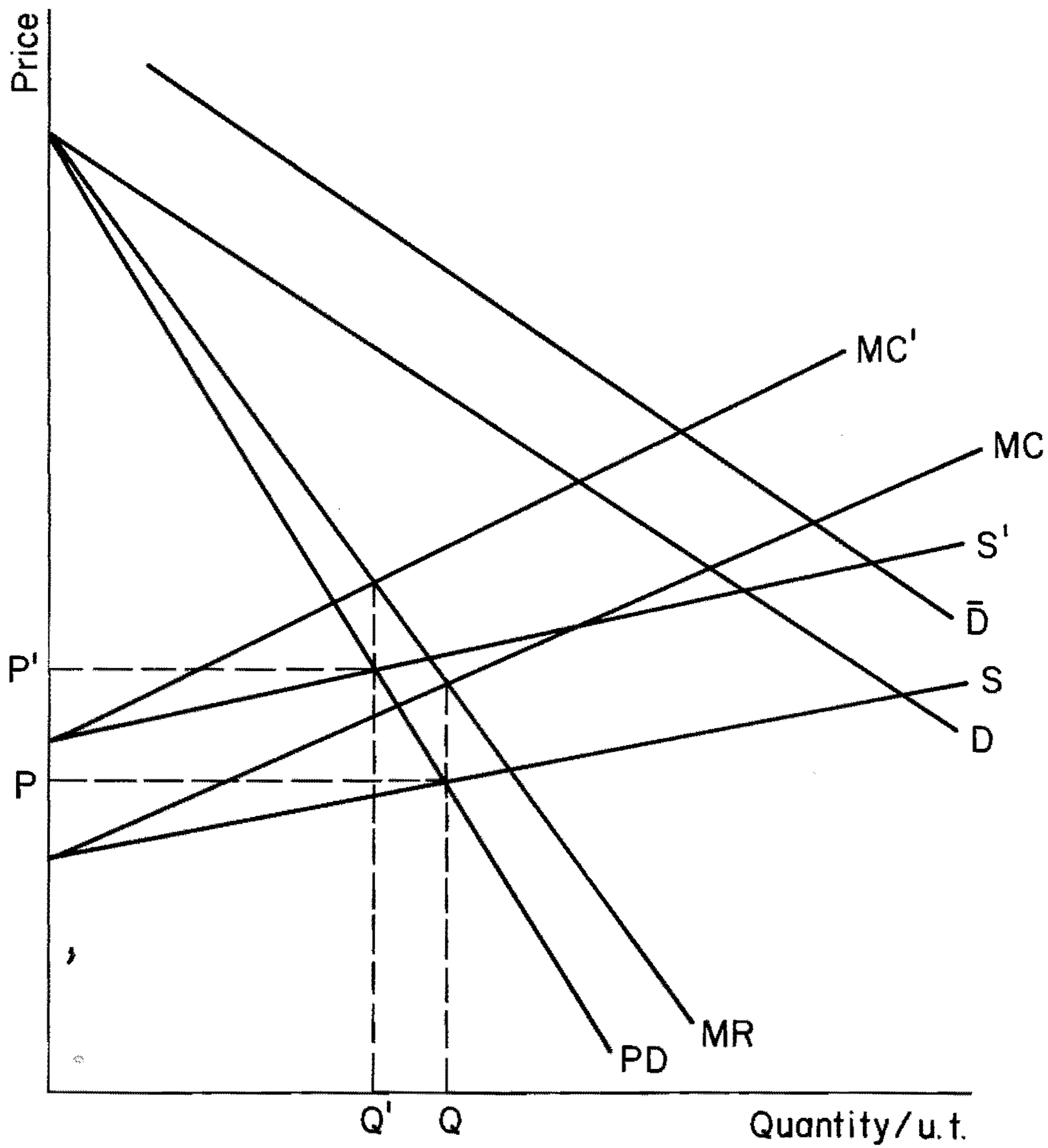

FIGURE 7. Perceived Demand Under Monopsony

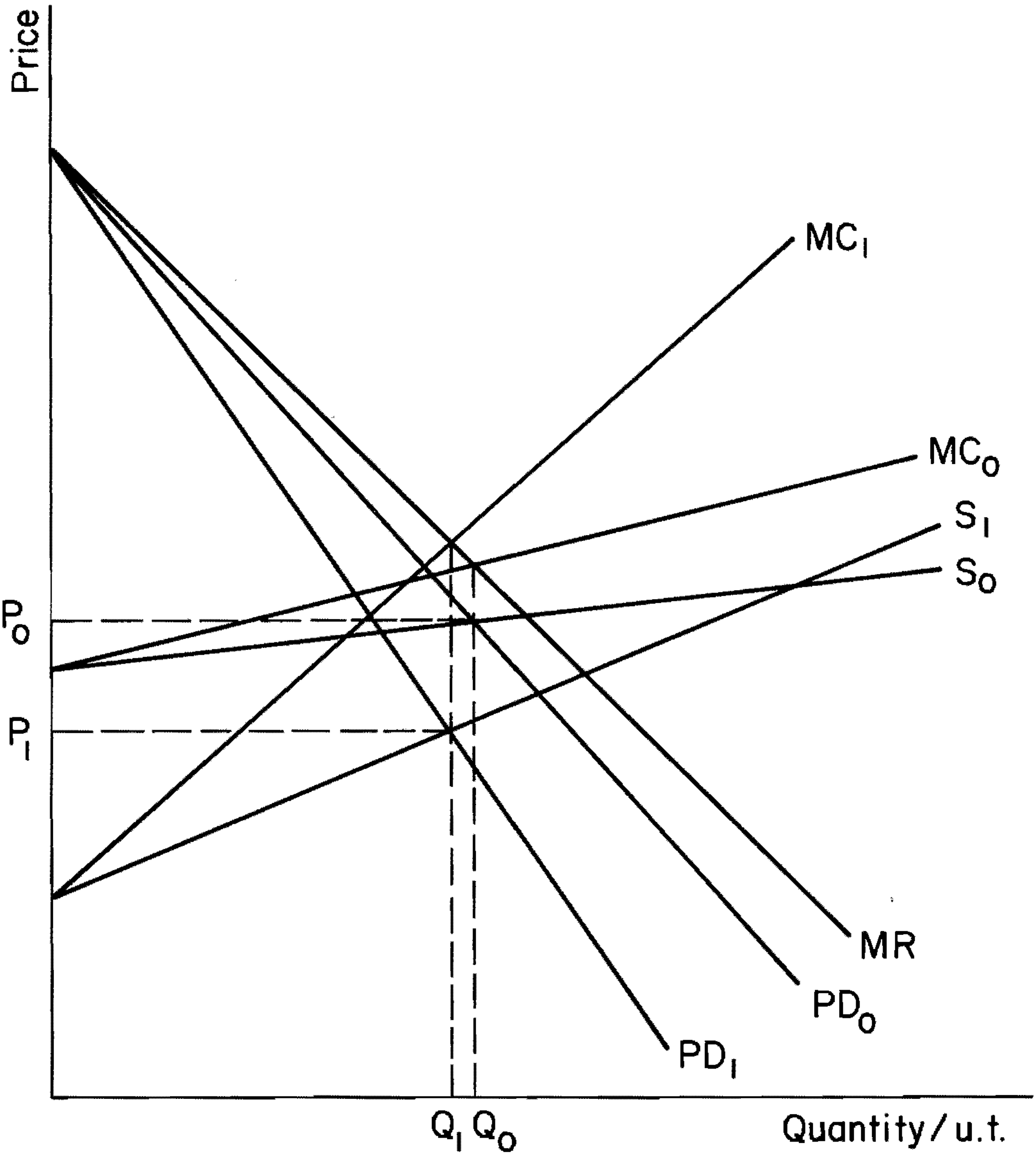

FIGURE 8. Effect of Technological Change Under Monopsony

perceived demand in the postharvester case. It is thus clear from Figure 8 that a more inelastic perceived demand will always be associated with a more inelastic supply in the case of monopsonistic buying regardless of whether or not monopoly prevails in selling the processed goods.

This is exactly the impact associated with the tomato harvester according to the estimates in Table 23. As supply becomes less elastic with tomato harvester adoption (as implied by negative impacts in the first supply row of Table 23), the perceived grower demand has become more inelastic (as implied by positive impacts in the first demand row of Table 23). Thus, it appears that one explanation for the observed impact of the tomato harvester on perceived grower demand is that the tomato processing industry has colluded to act jointly as a monopsonist in buying processing tomatoes from farmers or that the price leader firm has set prices in the monopsonistic interest of the industry. The former case seems to be somewhat questionable on the basis of evidence of industry operation cited earlier (which supports price leadership). The latter possibility also seems unlikely since a single firm is likely to operate in its own best interest rather than in the collective interest of a larger group of firms.

Suppose, on the other hand, that the tomato processing industry is oligopsonistic with dominant firm price leadership. Indeed, some experts (who prefer not to be quoted) maintain that the one firm continually responsible for the largest market share during the past several decades has, indeed, been a price leader at least during part of the sample period. Oligopsonistic price leadership by a dominant firm may be described by Figure 9.[1] 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 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 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 10 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 10 with Figure 7, it is clear that PD* (rather than PD^o) is comparable to the perceived demand curve PD in Figure 7 under monopsony. Hence, all the qualitative conclusions surrounding perceived demand in Figure 8 noted above apply to PD* in Figure 10. Finally, it can be noted that, by

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[1]A similar case for oligopolistic price leadership is presented by Cohen and Cyert, *op. cit.*, pp. 241 and 242.

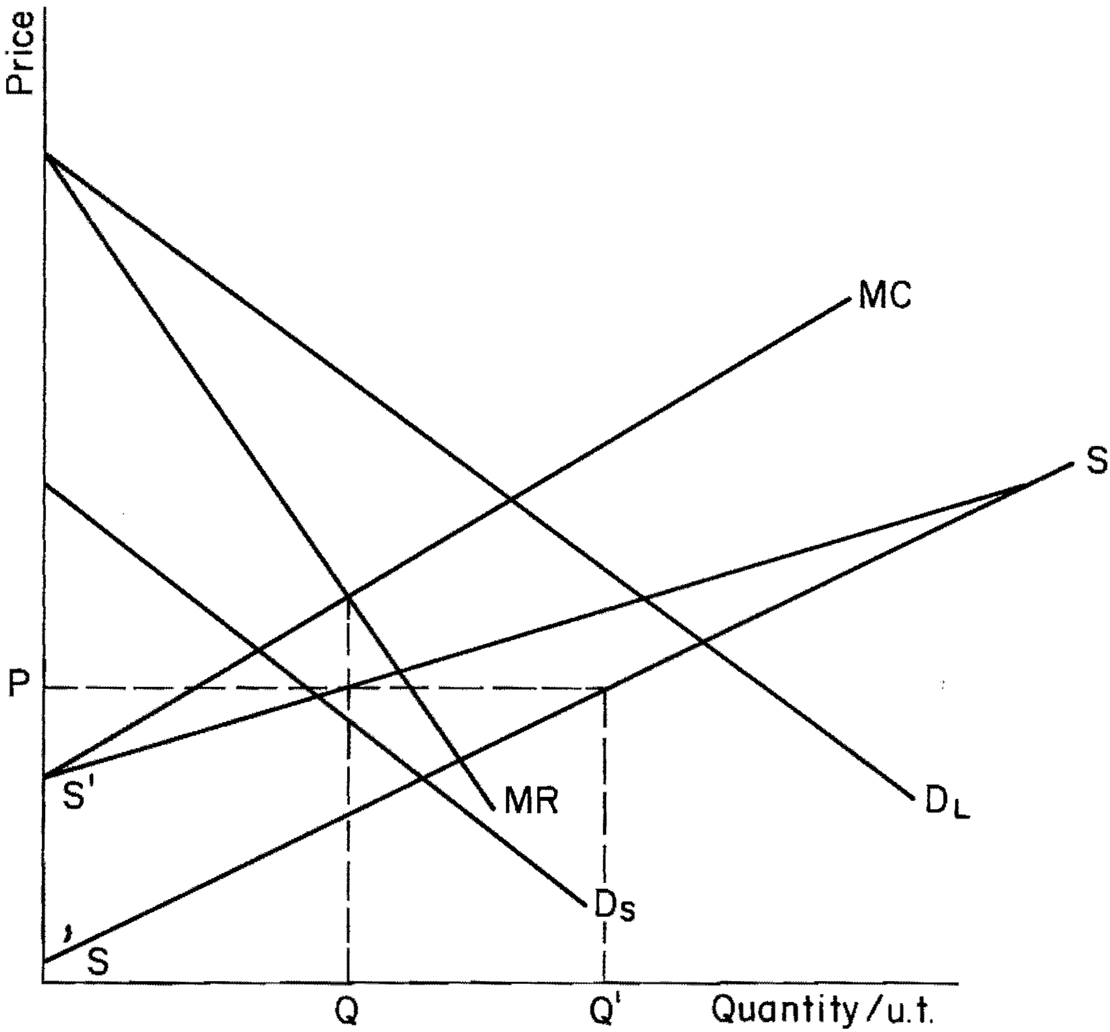

FIGURE 9. Price Determination Under Oligopsony

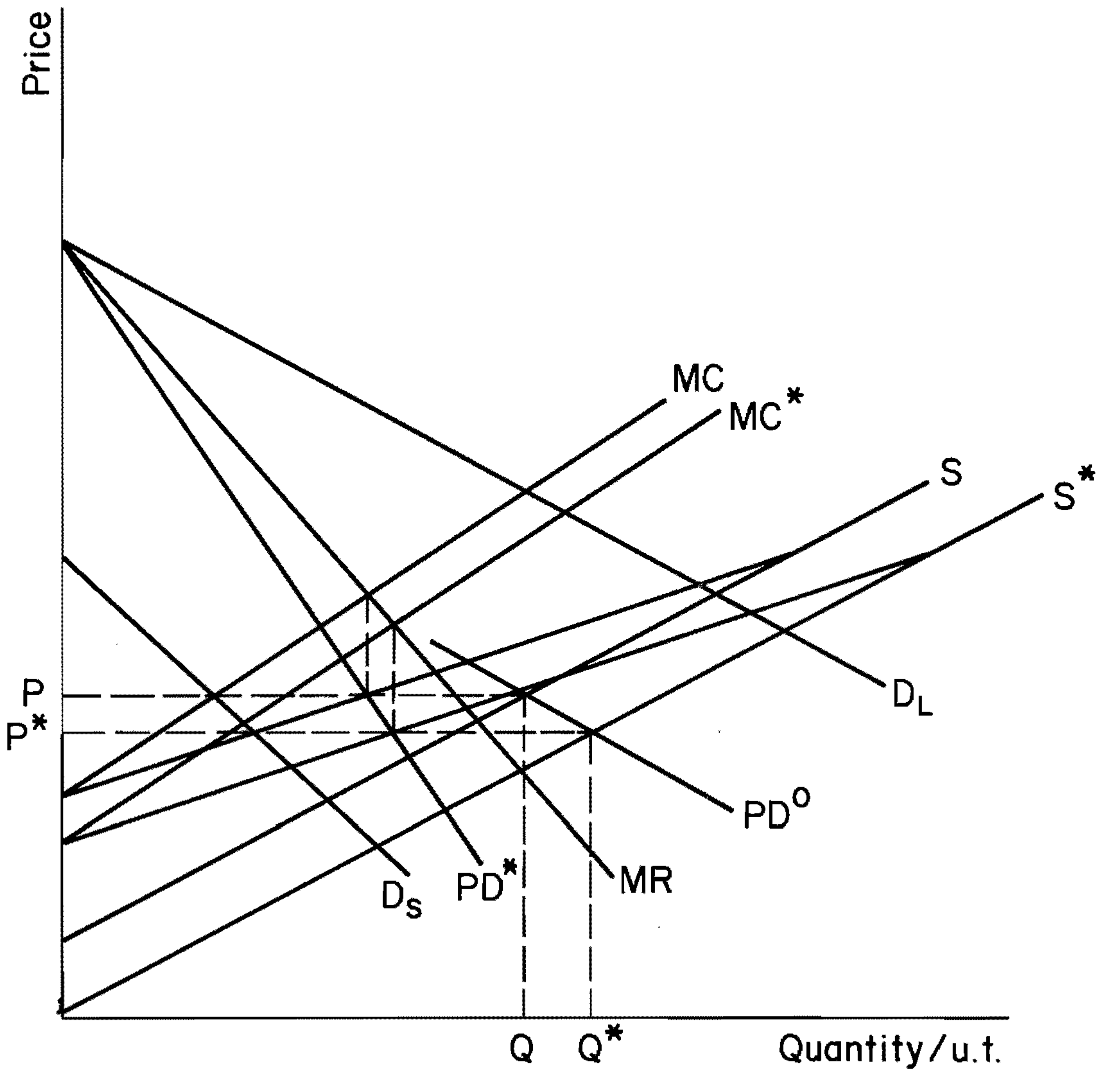

FIGURE 10. Perceived Demand Under Oligopsony

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 do not change as supply changes. The same qualitative conclusions associated with perceived demand in Figure 8 thus apply to perceived demand under oligopsonistic dominant firm–price leadership. Thus, the introduction of harvesting equipment which replaces variable costs with fixed 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 toward inelasticity. This shift, in conjunction with the supply shift, would cause an 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 8).

It is indeed interesting to note that virtually all of the results of estimation are consistent with the above explanation. In every case the results of Table 18 suggest that supply became more inelastic. Most methods show this effect to be statistically significant (Table 23). Table 19 shows, likewise, that (perceived) demand became more inelastic; with the exception of a single case, every method shows a decrease in elasticity whether or not Fresno County is included. Although the significance of this shift is somewhat less than for supply, Table 23 indicates statistical significance with at least one estimation method. Finally, Table 22 implies that prices and quantities have behaved exactly as the theory above suggests. Prices have fallen in every case (after removing the effect of exogenous forces), while qualitative impacts on quantities have been in either direction. The phenomena observed in the processing tomato market are, thus, remarkably consistent with the theory of oligopsonistic dominant firm–price leadership.

But other explanations 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, on the contrary, this change would, *ceteris paribus*, lead to increased demand for raw processing tomatoes, whereas the estimates indicate reduced perceived demand. Apparently, this reduction in perceived demand could have been even greater in the absence of varietal changes.

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 a leftward shift in demand. This explanation is, thus, more consistent with the observed results even though no causal corroboration is offered by the model. Since data were not available on processing costs, this possibility could not be further investigated empirically.

Evaluation of the Estimation Methodology

Inasmuch as the estimation techniques employed for pooled estimation in this study have not been studied previously, it is fitting that particular attention be given to their merits. It can indeed be noted that the results obtained with the pooled model reveal much more information about the effect of the tomato harvester and about the competitive aspects of the tomato pricing mechanism than the aggregate results. It should also be noted that discovery of some of the problems in the earlier estimates by Chern was motivated originally by investigation of the pooled model. This is demonstrated by comparing Tables 15 and 16 with Table 24. When both the pre– and postharvester periods were lumped together with the transition periods, unreasonably high price elasticities of supply were obtained, particularly with method V which in this case (because of the additional observations) corresponds to ordinary 3SLS (note k = 0). However, when the pre– and postharvester periods were investigated separately (Tables 15, 16, and 17), much lower and reasonable elasticities were obtained. It was on this basis and for this reason that the earlier aggregate results were reevaluated and the model reformulated in the present study.

Given that estimation of a pooled model is necessary and that data are insufficient to compute the ordinary 3SLS (or final) estimate, one must compare the OLS and 2SLS methods with the various 3SLS modifications suggested in this study for estimating seemingly unrelated simultaneous equations systems. In this respect it appears that the efficiency gains from the various 3SLS modifications may be substantial in terms of estimated standard errors, *etc.*[1] The most significance of structural change was indicated by one of the modified 3SLS methods rather than the OLS or 2SLS estimators (which exist in the ordinary sense) in 9 out of 10 cases in Table 23. It is also apparent from Tables 15, 16, and 17 that lower structural standard errors than either OLS or 2SLS estimates were obtained by at least one of the modified 3SLS methods in most cases. Again, in many cases the gains are substantial.

It does not appear, however, that this approach is without problems. In particular, it is disturbing that the method IV estimator ceases to exist as county observations are *added* (compare Tables 16 and 17). Furthermore, potential problems are pointed out by some of the odd results obtained from the Table 16 method IV estimator (where the addition of one county would have rendered the estimator nonexistent). For example, the coefficient for yield in the third equation is quite unreasonable and leads to very high yield elasticities in the associated reduced–form equations (Table 21). In turn, the associated results corresponding to Table 22 were also unreasonable. The most disturbing part of this problem is that the apparent loss of precision is not reflected by structural standard error estimates. In fact, the method IV yield coefficient standard errors in the third equation indicate greater precision than with other methods. This, of course, raises an important problem about the relationship of estimated versus actual precision which needs to be dealt with in future research.

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[1] Admittedly, however, a Monte Carlo study would be necessary to investigate whether this estimated efficiency gain actually holds in finite sample cases.

7. CONCLUDING REMARKS

Several interesting and useful results are apparent with respect to both the tomato industry and econometric practice, and the major ones are capsulated here for the reader's convenience.

Econometric Methodology Results

1. The use of aggregate models can often force one into specification errors because limited data are available between major structural changes. One approach which would and should be examined to avoid such problems is pooling time series and cross–section data. When the individual cross–sectional units (counties) are described by simultaneous equations systems, this can amount to a problem of seemingly unrelated simultaneous equations systems.

2. An asymptotically efficient method of estimating seemingly unrelated simultaneous equations systems is to apply 3SLS to the overall simultaneous system composed of all the individual simultaneous systems.

3. Whether or not coefficients are constrained across the cross–sectional units (counties), the ordinary 3SLS estimator of the overall system will not exist if the number of cross–sectional units is large relative to the number of time periods—even if the ordinary 3SLS estimates exist for each cross–sectional unit individually.

4. One approach in this case is to consider computational minimization of the covariance matrix (of the estimator) subject to a constraint of computational existence of the estimator.

5. The estimated efficiency gains associated with this approach can be substantial; however, Monte Carlo work is needed to investigate whether the actual gains in the finite sample case are worthwhile.

Tomato Industry Results

1. The transition period during which the tomato harvester was being adopted in California apparently created a great deal of instability and uncertainty in the supply of processing tomatoes. When the transition period is considered in estimation (Table 21), some of the supply elasticities increase four– or fivefold. In particular, the price and wage elasticities (the two factors which would presumably affect a decision to switch to a tomato harvester most) increase from the neighborhood of about 2 to about 5 or 6 (using the ordinary 3SLS estimates in Table 21). This, of course, implies that a change in price or wage rates would generate a much larger change in production during the transition period.

2. Grower supply has, after complete adoption of the tomato harvester, become much less price responsive. In fact, supply has become less responsive in all other respects as well. As divisible, variable labor costs have been replaced by lumpy, fixed harvester costs (now exceeding $140,000 per machine), the need to cover fixed costs has greatly reduced the impact of changing input prices and competing output (crop) prices. Wage

TABLE 24

Estimated Acreage Response and Demand for Processing Tomatoes, Pooled Model, 1951-1975, Excluding Fresno[a]

Equation	Constant	$\ln P_i$	$\ln Y_i$	$\ln D_i$	$\ln F$	$\ln G_{t-1}$	$\ln W_i$	$\ln Q_i$	$\ln Y$
									Estimation method I (OLS)
1	- 3.5748 (1.1461)	1.0615 (.2041)	1.1164 (.2802)	.0064 (.0434)	- .4688 (.3012)	- .1020 (.1962)	- .3068 (.2279)	*b*	
2	- .6082 (.5327)	- .1411 (.2202)							- .1174 (.0994)
3	- 1.4059 (.1380)		- .4902 (.0599)					.9414 (.0212)	
									Estimation method II (2SLS)
1	- 4.3881 (1.2425)	2.0618 (.3723)	1.5924 (.3307)	.0353 (.0470)	-1.3353 (.4137)	.1620 (.2233)	-1.0984 (.3406)		
2	1.3720 (.8308)	-1.5141 (.4751)							- .1896 (.1113)
3	- 1.4896 (.1495)		- .3913 (.0867)					.8909 (.0382)	
									Estimation method III (modified 3SLS)
1	- 1.3884 (.9280) (1.7912)	1.5678 (.2876) (.5156)	.5190 (.2519) (.3744)	.0979 (.0363) (.0419)	- .9502 (.3235) (.5693)	.1367 (.1725) (.3136)	- .2864 (.2637) (.4268)		
2	- .5628 (.6076) (1.1590)	- .8433 (.3498) (.6611)							- .2194 (.0766) (.1629)
3	- 1.0720 (.1286) (.2323)		- .4463 (.0718) (.1318)					.8327 (.0310) (.0592)	
									Estimation method IV (modified 3SLS)
1	- 3.9740 (1.0703) (1.0703)	2.4673 (.4221) (.4221)	1.7866 (.1919) (.1919)	- .0087 (.0198) (.0198)	-1.8504 (.4337) (.4337)	.4513 (.1879) (.1879)	-1.6809 (.3093) (.3093)		
2	.0080 (.6221) (.6221)	- .6118 (.2962) (.2962)							- .0944 (.1077) (.1077)
3	- 1.9010 (.1684) (.1684)		- .0306 (.0875) (.0875)					.7314 (.0410) (.0410)	
									Estimation method V (ridge 3SLS; k = 0)[c]
1	-22.3294 (.4053)	6.3024 (.1891)	5.8170 (.0385)	- .0257 (.0028)	-3.2244 (.1834)	1.0412 (.0637)	-5.3688 (.1194)		
2	4.8114 (.1725)	-1.9511 (.0558)							- .3013 (.0240)
3	.4347 (.0645)		- .1443 (.0217)					.2685 (.0094)	

Equation	$\ln I$	$\ln R$	D1	D2	D3	D4	D5	D6	D7	R^2
(OLS)										
1			2.6035 (.1153)	2.3441 (.1065)	1.1871 (.1047)	1.0943 (.1042)	1.2338 (.1099)	.8390 (.1100)	.5674 (.1066)	.854
2	.8579 (.1611)	.3061 (.2952)	2.2410 (.1030)	2.0669 (.1030)	.9115 (.1030)	.8436 (.1030)	.8989 (.1030)	.4829 (.1030)	.3277 (.1030)	.851
3			.2402 (.0631)	.2292 (.0581)	.1707 (.0402)	.1606 (.0391)	.1746 (.0410)	.1283 (.0373)	.0939 (.0345)	.985
(2SLS)										
1			2.7121 (.1269)	2.4055 (.1147)	1.2384 (.1123)	1.1369 (.1114)	1.3069 (.1189)	.9090 (.1188)	.6408 (.1154)	.837
2	1.0503 (.1860	1.3380 (.4468)	2.2332 (.1131)	2.0571 (.1132)	.9028 (.1131)	.8421 (.1131)	.8916 (.1131)	.4857 (.1131)	.3174 (.1132)	.822
3			.3681 (.1025)	.3433 (.0925)	.2260 (.0535)	.2117 (.0510)	.2326 (.0552)	.1686 (.0455)	.1196 (.0385)	.984
(modified 3SLS)										
1			2.5572 (.1406) (.1720)	2.3133 (.1234) (.0880)	1.1414 (.1308) (.0824)	1.0527 (.1249) (.0779)	1.1947 (.1405) (.1694)	.7276 (.1268) (.1317)	.5332 (.1195) (.1022)	.832
2	1.1936 (.1304) (.2699)	.6595 (.3179) (.6439)	2.2371 (.1428) (.1635)	2.0619 (.1207) (.1057)	.9071 (.1258) (.0858)	.8428 (.1253) (.1035)	.8952 (.1519) (.1844)	.4843 (.1327) (.1260)	.3224 (.1405) (.0791)	.840
3			.4904 (.0872) (.1555)	.4583 (.0837) (.1377)	.2740 (.0507) (.0713)	.2561 (.0488) (.0685)	.2779 (.0510) (.0772)	.1878 (.0465) (.0621)	.1337 (.0393) (.0439)	.981
(modified 3SLS)										
1			2.7445 (.1622) (.1622)	2.4151 (.0813) (.0813)	1.2542 (.0766) (.0766)	1.1478 (.0731) (.0731)	1.3142 (.1640) (.1640)	.9459 (.1209) (.1209)	.6653 (.0953) (.0953)	.810
2	.8538 (.1757) (.1757)	.8719 (.3579) (.3579)	2.2383 (.1634) (.1634)	2.0635 (.1056) (.1056)	.9085 (.0858) (.0858)	.8431 (.1035) (.1035)	.8964 (.1843) (.1843)	.4839 (.1260) (.1260)	.3242 (.0790) (.0790)	.847
3			.7802 (.1107) (.1107)	.7090 (.0977) (.0977)	.4055 (.0533) (.0533)	.3774 (.0527) (.0527)	.4224 (.0589) (.0589)	.3040 (.0509) (.0509)	.2054 (.0377) (.0377)	.977
(ridge 3SLS; k = 0)[c]										
1			3.4486 (.1580)	2.8362 (.0785)	1.6480 (.0743)	1.4885 (.0713)	1.8301 (.1621)	1.5932 (.1173)	1.1416 (.0922)	.542
2	.6646 (.0396)	1.7920 (.0726)	2.2355 (.1635)	2.0568 (.1057)	.9022 (.0858)	.8438 (.1036)	.8947 (.1844)	.4896 (.1260)	.3162 (.0790)	.744
3			1.8018 (.0472)	1.6556 (.0391)	.8177 (.0313)	.7589 (.0345)	.8252 (.0377)	.5099 (.0400)	.3477 (.0320)	.864

[a] For OLS and 2SLS, the numbers in parentheses are the estimated standard errors. For the various 3SLS modifications, the upper numbers in parentheses are the estimated standard errors computed according to equation (21) assuming the associated covariance matrix constraints hold; the lower numbers in parentheses are the standard error estimates computed according to equation (22) under the assumption that imposed constraints do not hold in reality.

[b] Blanks indicate variables not included.

[c] Note that method V in this case (k = 0) corresponds to the ordinary 3SLS method.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

TABLE 24

Estimated Acreage Response and Demand for Processing Tomatoes, Pooled Model, 1951-1975, Excluding Fresno[a]

Estimation method	Equation	Constant	$\ln P_i$	$\ln Y_i$	$\ln D_i$	$\ln F$	$\ln G_{t-1}$	$\ln W_i$	$\ln Q_i$	$\ln Y$
Estimation method I (OLS)	1	- 3.5748 (1.1461)	1.0615 (.2041)	1.1164 (.2802)	.0064 (.0434)	- .4688 (.3012)	- .1020 (.1962)	- .3068 (.2279)	b	
	2	- .6082 (.5327)	- .1411 (.2202)							- .1174 (.0994)
	3	- 1.4059 (.1380)		- .4902 (.0599)					.9414 (.0212)	
Estimation method II (2SLS)	1	- 4.3881 (1.2425)	2.0618 (.3723)	1.5924 (.3307)	.0353 (.0470)	-1.3353 (.4137)	.1620 (.2233)	-1.0984 (.3406)		
	2	1.3720 (.8308)	-1.5141 (.4751)							- .1896 (.1113)
	3	- 1.4896 (.1495)		- .3913 (.0867)					.8909 (.0382)	
Estimation method III (modified 3SLS)	1	- 1.3884 (.9280) (1.7912)	1.5678 (.2876) (.5156)	.5190 (.2519) (.3744)	.0979 (.0363) (.0419)	- .9502 (.3235) (.5693)	.1367 (.1725) (.3136)	- .2864 (.2637) (.4268)		
	2	- .5628 (.6076) (1.1590)	- .8433 (.3498) (.6611)							- .2194 (.0766) (.1629)
	3	- 1.0720 (.1286) (.2323)		- .4463 (.0718) (.1318)					.8327 (.0310) (.0592)	
Estimation method IV (modified 3SLS)	1	- 3.9740 (1.0703) (1.0703)	2.4673 (.4221) (.4221)	1.7866 (.1919) (.1919)	- .0087 (.0198) (.0198)	-1.8504 (.4337) (.4337)	.4513 (.1879) (.1879)	-1.6809 (.3093) (.3093)		
	2	.0080 (.6221) (.6221)	- .6118 (.2962) (.2962)							- .0944 (.1077) (.1077)
	3	- 1.9010 (.1684) (.1684)		- .0306 (.0875) (.0875)					.7314 (.0410) (.0410)	
Estimation method V (ridge 3SLS; k = 0)[c]	1	-22.3294 (.4053)	6.3024 (.1891)	5.8170 (.0385)	- .0257 (.0028)	-3.2244 (.1834)	1.0412 (.0637)	-5.3688 (.1194)		
	2	4.8114 (.1725)	-1.9511 (.0558)							- .3013 (.0240)
	3	.4347 (.0645)		- .1443 (.0217)					.2685 (.0094)	

Estimation method	Equation	$\ln I$	$\ln R$	D1	D2	D3	D4	D5	D6	D7	R^2
(OLS)	1			2.6035 (.1153)	2.3441 (.1065)	1.1871 (.1047)	1.0943 (.1042)	1.2338 (.1099)	.8390 (.1100)	.5674 (.1066)	.854
	2	.8579 (.1611)	.3061 (.2952)	2.2410 (.1030)	2.0669 (.1030)	.9115 (.1030)	.8436 (.1030)	.8989 (.1030)	.4829 (.1030)	.3277 (.1030)	.851
	3			.2402 (.0631)	.2292 (.0581)	.1707 (.0402)	.1606 (.0391)	.1746 (.0410)	.1283 (.0373)	.0939 (.0345)	.985
(2SLS)	1			2.7121 (.1269)	2.4055 (.1147)	1.2384 (.1123)	1.1369 (.1114)	1.3069 (.1189)	.9090 (.1188)	.6408 (.1154)	.837
	2	1.0503 (.1860	1.3380 (.4468)	2.2332 (.1131)	2.0571 (.1132)	.9028 (.1131)	.8421 (.1131)	.8916 (.1131)	.4857 (.1131)	.3174 (.1132)	.822
	3			.3681 (.1025)	.3433 (.0925)	.2260 (.0535)	.2117 (.0510)	.2326 (.0552)	.1686 (.0455)	.1196 (.0385)	.984
(modified 3SLS)	1			2.5572 (.1406) (.1720)	2.3133 (.1234) (.0880)	1.1414 (.1308) (.0824)	1.0527 (.1249) (.0779)	1.1947 (.1405) (.1694)	.7276 (.1268) (.1317)	.5332 (.1195) (.1022)	.832
	2	1.1936 (.1304) (.2699)	.6595 (.3179) (.6439)	2.2371 (.1428) (.1635)	2.0619 (.1207) (.1057)	.9071 (.1258) (.0858)	.8428 (.1253) (.1035)	.8952 (.1519) (.1844)	.4843 (.1327) (.1260)	.3224 (.1405) (.0791)	.840
	3			.4904 (.0872) (.1555)	.4583 (.0837) (.1377)	.2740 (.0507) (.0713)	.2561 (.0488) (.0685)	.2779 (.0510) (.0772)	.1878 (.0465) (.0621)	.1337 (.0393) (.0439)	.981
(modified 3SLS)	1			2.7445 (.1622) (.1622)	2.4151 (.0813) (.0813)	1.2542 (.0766) (.0766)	1.1478 (.0731) (.0731)	1.3142 (.1640) (.1640)	.9459 (.1209) (.1209)	.6653 (.0953) (.0953)	.810
	2	.8538 (.1757) (.1757)	.8719 (.3579) (.3579)	2.2383 (.1634) (.1634)	2.0635 (.1056) (.1056)	.9085 (.0858) (.0858)	.8431 (.1035) (.1035)	.8964 (.1843) (.1843)	.4839 (.1260) (.1260)	.3242 (.0790) (.0790)	.847
	3			.7802 (.1107) (.1107)	.7090 (.0977) (.0977)	.4055 (.0533) (.0533)	.3774 (.0527) (.0527)	.4224 (.0589) (.0589)	.3040 (.0509) (.0509)	.2054 (.0377) (.0377)	.977
(ridge 3SLS; k = 0)[c]	1			3.4486 (.1580)	2.8362 (.0785)	1.6480 (.0743)	1.4885 (.0713)	1.8301 (.1621)	1.5932 (.1173)	1.1416 (.0922)	.542
	2	.6646 (.0396)	1.7920 (.0726)	2.2355 (.1635)	2.0568 (.1057)	.9022 (.0858)	.8438 (.1036)	.8947 (.1844)	.4896 (.1260)	.3162 (.0790)	.744
	3			1.8018 (.0472)	1.6556 (.0391)	.8177 (.0313)	.7589 (.0345)	.8252 (.0377)	.5099 (.0400)	.3477 (.0320)	.864

[a]For OLS and 2SLS, the numbers in parentheses are the estimated standard errors. For the various 3SLS modifications, the upper numbers in parentheses are the estimated standard errors computed according to equation (21) assuming the associated covariance matrix constraints hold; the lower numbers in parentheses are the standard error estimates computed according to equation (22) under the assumption that imposed constraints do not hold in reality.

[b]Blanks indicate variables not included.

[c]Note that method V in this case (k = 0) corresponds to the ordinary 3SLS method.

Source: Derived from Appendix Tables, *infra*, pp. 102ff.

rates, in particular, have become almost completely unimportant in determining supply response, whereas they were very significant prior to the introduction of the tomato harvester.

3. Finally, this study shows that effective demand for processing tomatoes at the grower level has become less price elastic with tomato harvester adoption and has, in fact, declined after the effects of other factors are removed. Consequently, the *ceteris paribus* effects of the supply and demand shifts taken together imply a fall in price, while production may be affected in either direction. All of these changes are suggestive of either monopsonistic behavior or oligopsonistic, dominant–firm price leadership on the part of the tomato processing industry. This explanation suggests that the lower tomato prices received for crops of smaller overall size occurred because higher fixed costs in tomato production (once harvesters were purchased) made growers more vulnerable to processors' market power.

With respect to the latter conclusion, it is interesting to note that a strong grower marketing cooperative has developed in the last several years. After growing rapidly in the mid–1970s, the Canning Tomato Growers Association now handles the marketing of most of the processing tomato crop. Such a strong unification of growers serves to considerably increase their bargaining position. Indeed, it seems that this development could be a direct result of growers seeking to regain the bargaining position they held before adoption of the tomato harvester.

APPENDIX

APPENDIX TABLE 1

Harvested Acreage of Processing Tomatoes, Contracted and Open Market
Selected Counties, California, Other States, and the United States, 1948-1975

Year	San Joaquin County			Yolo County			Fresno County		
	Contracted, A_1	Open market	Total acreage	Contracted, A_2	Open market	Total acreage	Contracted, A_3	Open market	Total acreage
	acres								
1948	27,654	1,627	29,281	14,394	1,042	15,436	*a*		
1949	27,119	1,252	28,371	11,274	217	11,491			
1950	24,847	852	25,699	11,222	4	11,226			
1951	44,173	2,026	46,199	22,292	382	22,674			
1952	37,120	805	37,925	18,577	55	18,632			
1953	29,722	743	30,465	14,185		14,185			
1954	26,578	854	27,432	14,481	43	14,524	20		20
1955	37,656	1,251	38,907	20,474	123	20,597	316	121	437
1956	45,878	2,464	48,342	26,464	329	26,793	1,636		1,636
1957	44,025	995	45,020	26,713	157	26,870	330	190	520
1958	43,532	3,792	47,324	32,613	56	32,669	420	5	425
1959	37,281	3,370	40,651	25,424	1,160	26,584	427		427
1960	34,549	1,146	35,695	32,311	154	32,465	1	62	63
1961	40,964	378	41,342	25,603	87	25,690	100	8	108
1962	47,667	460	48,127	32,757	83	32,840	565		565
1963	35,502	563	36,065	25,492	223	25,715	1,239	150	1,389
1964	39,464	276	39,740	29,862	105	29,967	1,335		1,335
1965	34,286	555	34,841	23,637	55	23,692	3,054		3,054
1966	41,523	665	42,188	25,674	128	25,802	15,504		15,504
1967	47,282	1,349	48,631	31,367		31,367	15,828		15,828
1968	45,405	1,304	46,709	35,745	1,122	36,867	27,033	68	27,101
1969	32,100	80	32,180	30,500	230	30,730	13,800	71	13,871
1970	24,980	830	25,810	34,890	240	35,130	11,510	30	11,540
1971	27,420	70	27,490	37,970	40	38,010	22,840	170	23,010
1972	26,590	340	26,930	40,840	320	41,160	26,310	210	26,520
1973	26,280	350	26,630	57,460	70	57,530	36,380	320	36,700
1974	28,580	620	29,200	59,150	320	59,470	36,180	930	37,110
1975	32,820	72	32,892	55,500	0	55,500	61,130	366	61,496

(Continued on next page.)

APPENDIX TABLE 1--continued.

Year	Solano County			Sutter County			Sacramento County		
	Contracted, A_4	Open market	Total acreage	Contracted, A_5	Open market	Total acreage	Contracted, A_6	Open market	Total acreage
	acres								
1948	3,428	90	3,518	3,306		3,306	7,486	424	7,910
1949	2,473	230	2,703	2,926	3	2,929	9,293	161	9,454
1950	2,421	6	2,427	3,659		3,659	8,782	100	8,882
1951	4,983	49	5,032	8,563	21	8,584	14,953	500	15,453
1952	4,653	20	4,673	5,854		5,854	12,919	52	12,971
1953	3,716	4	3,720	4,599	55	4,654	8,326	8	8,334
1954	4,022	50	4,072	3,598		3,598	9,121	14	9,135
1955	5,798	146	5,944	5,607	52	5,659	10,859	20	10,879
1956	7,557	176	7,733	7,155	95	7,250	11,945	223	12,168
1957	6,211	45	6,256	5,513	45	5,558	8,925	376	9,301
1958	9,293	48	9,341	7,280		7,280	11,725	212	11,937
1959	8,682	549	9,231	8,397	17	8,414	7,234	325	7,559
1960	9,348	27	9,375	6,950		6,950	9,465	102	9,567
1961	10,444	47	10,491	7,095		7,095	12,886	112	12,998
1962	13,429		13,429	8,323		8,323	13,925	152	14,077
1963	8,080	38	8,118	5,890		5,890	9,102	20	9,122
1964	7,890	1	7,891	7,118	20	7,138	10,492	59	10,551
1965	8,956	29	8,985	6,808		6,808	7,293	10	7,303
1966	9,619	30	9,649	8,184	4	8,188	9,096	106	9,202
1967	9,223		9,223	10,233		10,233	9,095	15	9,110
1968	14,808		14,808	15,840		15,840	12,223	75	12,298
1969	11,400	157	11,557	8,740	80	8,820	10,100		10,100
1970	10,780	300	11,080	8,550		8,550	6,470	30	6,500
1971	13,170	190	13,360	10,610	20	10,630	6,190	10	6,200
1972	15,240		15,240	15,280	240	15,520	6,680	30	6,710
1973	17,880	0	17,880	18,830	480	19,310	6,380	0	6,380
1974	22,450	260	22,710	20,950	20	20,970	7,580	0	7,580
1975	20,410	0	20,410	25,510	0	25,510	8,250	0	8,250

(Continued on next page.)

APPENDIX TABLE 1--continued.

Year	Stanislaus County			Merced County			Santa Clara County		
	Contracted, A_7	Open market	Total acreage	Contracted, A_8	Open market	Total acreage	Contracted, A_9	Open market	Total acreage
	acres								
1948	4,143	179	4,322	1,440	2,335	3,775	2,793	37	2,830
1949	3,596		3,596	593	439	1,032	1,134	97	1,231
1950	6,435	24	6,459	556	232	788	1,056	74	1,130
1951	9,023	150	9,173	944	1,212	2,156	3,994	337	4,331
1952	5,193	32	5,225	741	1,007	1,748	2,649	74	2,723
1953	3,268	122	3,390	384	1,171	1,555	1,899	111	2,010
1954	2,384	181	2,561	255	1,614	1,869	1,171	144	1,315
1955	5,891	483	6,374	535	2,920	3,455	3,140	31	3,171
1956	8,810	1,458	10,268	1,175	2,100	3,275	3,970	100	4,070
1957	5,867	918	6,785	751	2,783	3,534	2,578	28	2,606
1958	4,762	899	5,661	995	4,294	5,289	3,733	183	3,916
1959	4,821	601	5,422	640	4,475	5,115	4,200	193	4,393
1960	3,926	361	4,287	527	2,813	3,340	4,106	23	4,129
1961	6,241	46	6,287	2,731	3,678	6,409	5,884	15	5,899
1962	5,970	49	6,019	3,775	5,660	9,435	7,342	40	7,382
1963	6,962	166	7,128	2,979	2,350	5,329	6,130		6,130
1964	6,054	206	6,260	3,849	2,143	5,992	7,363	44	7,407
1965	5,611	78	5,689	5,227	2,128	7,355	6,510	34	6,544
1966	6,931		6,931	8,509	1,602	10,111	7,381		7,381
1967	7,447	2	7,449	10,483	2,807	13,290	7,954		7,954
1968	9,897	310	10,207	7,790	4,140	11,930	10,235		10,235
1969	5,870	80	5,950	6,030	1,882	7,912	5,274	18	5,292
1970	6,070	30	6,100	6,630	1,230	7,860	4,610	10	4,620
1971	8,150	10	8,160	4,550	600	5,150	5,650		5,650
1972	8,150	60	8,210	5,170	580	5,750	7,050		7,050
1973	6,810	20	6,830	6,500	520	7,020	7,310	0	7,310
1974	7,010	90	7,100	6,380	900	7,280	9,750	10	9,760
1975	9,570	6	9,576	11,140	850	11,990	9,150	11	9,161

(Continued on next page.)

APPENDIX TABLE 1--continued.

Year	San Benito County			Total 10 counties			California total			Other states	United States
	Contracted, A_{10}	Open market	Total acreage	Contracted, A_c	Open market	Total acreage	Contracted, $\tilde{A}_c$	Open market[b]	Total acreage, A_h		
	acres										
1948	1,470		1,470	66,114	5,734	71,848	79,828	7,872	87,700	303,500	391,200
1949	273	41	314	58,681	2,440	61,121	71,642	3,758	75,400	249,100	324,500
1950	315		315	59,293	1,292	60,585	72,546	2,954	75,500	260,650	336,150
1951	1,165	59	1,224	110,090	4,736	114,826	141,563	6,737	148,300	271,030	419,330
1952	660		660	88,366	2,045	90,411	109,485	3,415	112,900	260,300	373,200
1953	708	57	765	66,808	2,271	69,079	79,875	3,125	83,000	221,500	304,500
1954	921	25	946	62,551	2,925	65,476	75,621	3,879	79,500	183,450	262,950
1955	1,477	5	1,482	91,753	5,152	96,905	110,286	6,014	116,300	214,200	330,500
1956	2,730		2,730	117,320	6,945	124,265	142,720	8,780	151,500	202,980	354,480
1957	1,953	38	1,991	102,866	5,575	118,441	122,360	6,340	128,700	175,620	304,320
1958	2,555	191	2,746	116,908	9,680	126,588	142,193	10,707	152,900	190,750	343,650
1959	2,614	308	2,922	99,720	10,998	110,718	118,160	11,540	129,700	167,230	296,930
1960	1,551	274	1,825	102,734	4,962	107,696	123,830	6,170	130,000	149,950	279,950
1961	2,933	355	3,288	114,881	4,726	119,607	140,640	6,160	146,800	157,750	304,550
1962	4,502	434	4,936	138,255	6,878	145,133	170,100	7,100	177,200	150,700	327,900
1963	2,951	237	3,188	104,327	3,747	108,074	124,400	4,600	129,000	121,460	250,460
1964	2,910	457	3,367	116,337	3,311	119,648	139,800	3,200	143,000	130,350	273,350
1965	2,593	233	2,826	103,975	3,122	107,097	119,400	3,400	122,800	134,720	257,520
1966	4,728	110	4,838	137,149	2,645	139,794	159,500	3,000	162,500	137,330	299,830
1967	6,381	173	6,554	155,293	4,346	159,639	180,300	6,400	186,700	140,360	327,060
1968	6,501		6,501	185,477	7,019	192,496	223,900	7,400	231,300	139,250	270,550
1969	5,610	26	5,636	129,424	2,624	132,048	151,200	2,800	154,000	112,590	266,590
1970	6,600	10	6,610	121,090	2,710	123,800	138,300	3,000	141,300	103,790	245,090
1971	6,580	10	6,590	143,130	1,120	144,250	162,400	1,300	163,700	94,430	258,130
1972	6,800	210	7,010	158,110	1,990	160,100	176,800	2,100	178,900	86,120	265,020
1973	8,100	10	8,110	191,930	1,770	193,700	216,000	2,000	218,000	77,100	295,100
1974	9,700	0	9,700	207,730	3,150	210,880	246,200	3,700	249,900	87,800	337,700
1975	10,290	0	10,290	243,770	1,306	245,075	297,800	1,400	299,200		

(Continued on next page.)

APPENDIX TABLE 1--continued.

[a]Blanks indicate no data available.

[b]This series does not include the open-market acreage of pear tomatoes.

Sources:

For counties, California Crop and Livestock Reporting Service (Sacramento, 1948-1975), unpublished data. These figures might differ slightly from the published data because no distinction between contracted acreage and open-market acreage for pear tomatoes is made in official reports.

For California, *idem*, *Tomatoes for Processing: Acres Harvested and Tons Produced by Counties*, Final Reports (Sacramento, 1948, and subsequent annual issues).

For other states and the United States, Federal-State Market News Service, *Marketing California Tomatoes* (Sacramento, 1948, and subsequent annual issues); and U. S. Department of Agriculture, Statistical Reporting Service, *Agricultural Statistics, 1948* (1948 and subsequent annual issues).

APPENDIX TABLE 2

Total Purchases of Processing Tomatoes, Selected Counties, California, and Other States, 1948–1975[a]

Year	County										Total counties, Q_c	California, Q_s	Other states
	San Joaquin	Yolo	Fresno	Solano	Sutter	Sacramento	Stanislaus	Merced	Santa Clara	San Benito			
	tons												
1948	365,206	155,333	*b*	41,064	38,408	90,610	61,628	24,169	21,454	14,773	812,645	955,900	1,927,050
1949	395,708	156,986		40,814	39,204	139,315	46,849	11,295	14,852	1,827	846,850	1,002,800	1,466,300
1950	327,078	156,638		32,734	51,062	114,446	78,407	3,964	13,060	4,058	781,447	958,800	1,669,260
1951	732,573	358,837	2,480	79,820	128,976	244,179	138,348	27,892	60,120	16,625	1,789,850	2,210,000	2,047,950
1952	587,961	331,809		86,247	98,868	220,222	85,885	20,928	44,852	12,916	1,489,688	1,817,700	1,728,550
1953	508,269	261,458		71,709	75,051	152,145	49,826	23,780	35,883	15,030	1,193,151	1,411,000	1,857,400
1954	463,544	255,439	340	76,421	64,988	161,176	34,133	28,373	23,725	17,598	1,125,737	1,343,600	1,356,090
1955	686,482	363,958	3,569	116,801	101,995	181,378	106,211	48,983	52,702	29,023	1,691,102	1,988,700	1,289,620
1956	888,110	560,198	9,668	158,145	142,820	220,979	190,458	56,955	73,158	53,850	2,354,342	2,772,400	1,865,610
1957	660,438	454,187	6,818	102,220	92,894	144,758	102,206	60,354	52,900	43,280	1,720,053	2,020,600	1,293,530
1958	791,221	581,198	6,713	166,169	121,338	215,448	92,157	79,641	83,064	63,252	2,200,201	2,629,900	1,651,290
1959	587,062	453,710	4,464	135,617	142,879	108,116	67,359	78,417	73,179	47,658	1,698,461	1,997,400	1,541,630
1960	577,852	571,914	1,075	164,158	136,328	182,472	64,818	40,984	79,806	45,622	1,865,029	2,249,000	1,804,770
1961	632,661	401,121	637	149,262	116,744	211,965	97,175	75,834	113,740	67,770	1,866,909	2,319,000	1,938,900
1962	879,940	633,598	16,634	247,525	168,743	255,769	127,537	120,946	127,278	96,140	2,674,110	3,218,000	2,175,900
1963	679,264	515,959	1,239	156,708	121,838	177,799	132,296	45,606	122,725	83,107	2,036,541	2,463,900	1,635,790
1964	804,553	666,586	19,958	193,442	168,483	217,220	135,949	116,563	160,288	86,792	2,569,744	3,003,000	1,580,310
1965	716,969	468,075	53,215	181,166	140,551	152,004	120,918	114,088	126,219	74,484	2,147,689	3,468,300	2,032,840

(Continued on next page.)

APPENDIX TABLE 2--continued.

Year	San Joaquin	Yolo	Fresno	Solano	Sutter	Sacra-mento	Stanis-laus	Merced	Santa Clara	San Benito	Total counties, Q_c	California, Q_s	Other states
	County												
	tons												
1966	835,248	537,689	210,967	197,278	176,170	176,339	142,832	127,521	158,811	122,078	2,684,933	3,136,200	1,524,370
1967	857,791	529,430	223,388	162,465	157,075	164,969	116,256	181,790	165,079	166,059	2,724,302	3,192,600	1,994,850
1968	1,042,205	787,419	519,822	332,145	329,472	268,073	220,084	231,406	224,500	181,200	4,136,326	4,903,600	2,062,260
1969	660,043	718,503	334,505	258,294	208,500	199,500	113,334	120,688	130,544	138,930	2,882,841	3,372,600	1,525,100
1970	616,965	877,290	247,058	249,937	212,900	155,914	155,753	176,866	108,970	173,900	2,975,553	3,362,950	1,696,000
1971	608,455	915,975	531,810	326,048	277,602	148,066	183,172	133,582	150,500	157,250	3,432,460	3,879,700	1,634,200
1972	640,700	1,034,800	694,200	363,700	414,300	159,300	221,200	125,100	178,100	190,500	4,021,900	4,526,150	1,278,450
1973	597,150	1,281,700	733,750	421,500	451,500	149,300	160,350	129,950	181,800	188,900	4,795,900	4,861,400	1,073,150
1974	729,850	1,320,400	900,900	459,850	485,400	160,850	200,100	161,650	265,300	219,550	4,903,800	5,847,650	1,172,200
1975	861,838	1,354,200	1,621,886	472,650	617,250	205,400	228,698	253,546	203,014	228,450	6,046,932	7,270,550	

[a]The "purchases" shown here are referred to as "production" in various official publications.

[b]Blanks indicate no data available.

Sources:

For counties, California Crop and Livestock Reporting Service (Sacramento, 1948-1975), unpublished data.

For California, *idem, Tomatoes for Processing: Acres Harvested and Tons Produced by Counties,* Final Reports (Sacramento, 1948, and subsequent annual issues); and *idem, California Vegetable Crops* (Sacramento, 1948-1975).

For other states, Federal-State Market News Service, *Marketing California Tomatoes* (Sacramento, 1948, and subsequent selected issues); and U. S. Department of Agriculture, *Agricultural Statistics, 1948* (1948 and subsequent annual issues).

APPENDIX TABLE 3

Grower Prices for Processing Tomatoes, Selected Counties and California, 1951-1975

Year	San Joaquin, $P_{c,1}$	Yolo, $P_{c,2}$	Fresno, $P_{c,3}$	Solano, $P_{c,4}$	Sutter, $P_{c,5}$	Sacramento, $P_{c,6}$	Stanislaus, $P_{c,7}$	Merced, $P_{c,8}$	Santa Clara, $P_{c,9}$	San Benito, $P_{c,10}$	California, P_c
	County										
	dollars per ton										
1951	30.54	30.42	[a]	30.14	30.46	30.29	30.53	30.18	29.99	29.89	30.20
1952	25.45	25.33		24.74	25.67	25.24	25.77	24.87	24.97	25.05	25.50
1953	22.88	22.94		22.67	23.09	22.66	22.98	22.63	22.42	22.30	22.90
1954	20.37	20.32	20.00	20.53	20.42	20.11	19.79	20.47	20.05	20.18	20.40
1955	22.33	22.76	22.50	22.76	23.12	22.25	22.39	22.43	22.61	22.57	22.80
1956	22.57	22.66	22.50	22.73	22.88	22.73	22.90	22.69	22.40	22.48	22.70
1957	21.66	22.04	22.50	22.09	22.04	21.98	21.98	22.58	21.79	22.37	21.90
1958	22.60	22.87	22.50	22.69	22.78	22.82	22.61	22.55	22.46	22.54	22.70
1959	21.70	21.65	21.50	21.93	21.78	21.61	22.33	21.62	21.44	21.57	21.80
1960	23.61	23.17	22.50	23.60	23.35	23.57	24.10	23.54	23.09	23.53	23.40
1961	30.09	30.24	30.00	30.09	30.30	30.31	30.47	30.08	30.06	30.25	30.10
1962	27.55	27.51	28.52	27.45	27.66	27.70	27.82	27.39	27.43	27.68	27.60
1963	25.34	25.39	25.00	25.24	25.40	25.44	25.54	25.64	25.11	25.14	25.40
1964	25.19	25.08	25.67	25.20	25.50	25.16	25.30	25.19	25.04	25.04	25.30
1965	35.55	35.34	35.63	35.51	35.68	35.90	35.86	35.92	35.39	38.01	35.50
1966	30.04	29.99	29.69	30.22	30.04	30.35	29.14	29.08	29.98	31.66	30.00
1967	38.46	38.10	38.59	38.18	37.74	38.59	37.49	39.01	39.13	39.23	38.70
1968	35.34	35.36	35.29	35.19	35.46	35.25	35.61	35.52	35.11	35.09	35.20
1969	27.35	27.45	27.85	27.31	27.83	27.51	27.91	27.89	27.78	27.51	27.50
1970	24.95	25.23	25.33	25.13	25.15	24.88	25.21	25.22	24.87	25.37	25.20
1971	28.02	27.79	28.01	27.96	28.01	28.00	28.01	28.00	28.01	28.01	28.00
1972	28.08	27.90	28.07	27.98	27.97	28.05	28.10	28.07	28.05	28.03	28.00
1973	34.55	34.50	35.08	34.74	34.68	35.09	35.95	35.36	35.39	35.20	35.00
1974	56.69	55.48	57.31	56.20	56.50	56.55	57.95	58.26	57.66	56.88	56.80
1975	55.13	54.21	55.81	54.34	55.06	53.96	57.38	58.28	56.46	56.21	55.60

[a]Blanks indicate no data available.

Sources:

For counties, California Crop and Livestock Reporting Service (Sacramento, 1951-1975), unpublished data.

For California, *idem, Tomatoes for Processing: Acres Harvested and Tons Produced by Counties*, Final Reports (Sacramento, 1951, and subsequent annual issues); and *idem, California Vegetable Crops* (Sacramento, 1951-1975).

APPENDIX TABLE 4

Processing Tomato Yields, Selected Counties and California, 1951-1975

Year	County										California
	San Joaquin	Yolo	Fresno	Solano	Sutter	Sacramento	Stanislaus	Merced	Santa Clara	San Benito	
	tons per acre										
1951	15.86	15.83	*a*	15.87	15.02	15.80	15.07	12.94	13.86	13.50	14.90
1952	15.50	17.81		18.46	16.89	16.98	16.44	11.97	16.47	19.57	16.10
1953	16.69	18.43		19.29	16.13	18.26	14.70	15.29	17.80	19.64	17.00
1954	16.90	17.59		18.76	18.06	17.64	13.31	15.18	18.04	18.60	16.90
1955	17.64	17.67		19.65	18.05	16.67	16.68	14.18	16.62	19.58	17.10
1956	18.36	20.91		20.45	19.69	18.16	18.54	17.39	17.97	19.71	18.30
1957	14.66	16.90		16.33	16.71	16.21	14.94	17.08	20.30	21.73	15.70
1958	16.70	17.79		17.78	16.66	18.08	16.24	15.06	21.21	23.02	17.20
1959	14.45	17.08		14.67	16.97	14.30	12.41	15.33	16.65	16.30	15.40
1960	16.13	17.62		17.51	19.61	19.07	15.21	12.27	19.32	25.04	17.30
1961	15.30	15.61		14.22	16.45	16.30	15.45	11.83	19.28	20.61	15.80
1962	18.29	19.30		18.43	20.27	18.17	21.18	12.82	17.24	19.48	18.20
1963	18.83	20.06		19.30	20.69	19.50	18.57	17.56	20.02	26.09	19.10
1964	20.25	22.24		24.52	23.60	20.58	21.72	19.45	21.64	25.75	21.00
1965	20.57	19.75	19.00	20.16	21.64	20.81	21.24	15.55	19.27	26.24	20.10
1966	19.77	20.84	13.61	20.45	21.52	19.20	20.61	12.61	21.52	25.23	19.30
1967	17.64	16.88	14.11	17.62	15.35	18.11	15.61	13.68	20.75	25.34	17.10
1968	22.31	21.36	19.18	22.43	20.80	21.30	21.56	19.40	21.92	27.86	21.20
1969	20.60	23.40	24.10	22.40	23.90	19.80	19.30	15.25	24.60	24.70	21.90
1970	23.90	25.00	21.40	22.60	24.90	24.00	25.50	22.50	23.60	26.30	23.80
1971	22.10	24.10	23.10	24.40	26.10	23.90	22.50	25.94	26.60	23.90	23.70
1972	23.79	25.14	26.18	27.66	29.09	23.74	26.94	21.76	25.26	27.18	25.30
1973	22.70	22.30	20.20	23.60	24.00	23.40	23.50	20.00	24.90	23.30	22.30
1974	25.50	22.30	24.90	20.50	23.20	21.20	28.50	25.30	27.20	22.60	23.40
1975	26.20	24.40	26.40	23.20	24.20	24.90	23.90	20.90	22.20	22.20	24.30

[a] Blanks indicate no data available.

Sources:

For counties, California Crop and Livestock Reporting Service (Sacramento, 1951-1975), unpublished data.

For California, *idem*, *Tomatoes for Processing: Acres Harvested and Tons Produced by Counties*, Final Reports (Sacramento, 1951, and subsequent annual issues); and *idem*, *California Vegetable Crops* (Sacramento, 1951-1975).

APPENDIX TABLE 5

Lagged Three-Year Standard Deviation of Yields, Selected Counties and California, 1951-1975

Year	County										California, D
	San Joaquin, D_1	Yolo, D_2	Fresno, D_3	Solano, D_4	Sutter, D_5	Sacramento, D_6	Stanislaus, D_7	Merced, D_8	Santa Clara, D_9	San Benito, D_{10}	
1951	0.653	1.763	[a]	1.401	1.001	1.339	0.869	3.004	2.001	2.901	1.020
1952	1.315	0.965		0.992	0.675	1.206	1.226	3.358	0.994	3.483	0.929
1953	1.431	1.576		2.030	1.211	1.723	1.794	3.523	2.014	3.018	1.408
1954	0.498	1.109		1.457	0.768	1.005	0.748	1.394	1.637	2.878	0.860
1955	0.616	0.356		0.343	0.794	0.523	1.280	1.540	0.691	0.475	0.403
1956	0.407	0.379		0.366	0.907	0.654	1.383	0.500	0.621	0.477	0.082
1957	0.596	1.547		0.690	0.771	0.617	2.165	1.342	0.654	0.495	0.618
1958	1.602	1.738		1.784	1.219	0.832	1.470	1.446	1.520	0.984	1.062
1959	1.513	1.719		1.706	1.417	0.901	1.488	1.033	1.364	1.362	1.066
1960	1.015	0.384		1.271	0.136	1.543	1.590	0.896	1.970	2.912	0.787
1961	0.955	0.303		1.407	1.324	2.055	1.618	1.384	1.871	3.736	0.873
1962	0.686	0.849		1.456	1.383	1.956	1.380	1.557	1.249	3.568	0.818
1963	1.260	1.508		1.807	1.667	1.154	2.759	0.403	0.971	2.399	0.990
1964	1.553	1.944		2.218	1.907	1.313	2.342	2.500	1.176	2.887	1.393
1965	0.827	1.246	1.167	2.689	1.481	0.986	1.375	2.789	1.817	3.532	1.167
1966	0.756	1.108	0.896	2.285	1.212	0.571	1.386	1.593	0.989	0.689	0.776
1967	0.329	1.019	2.546	1.990	0.953	0.711	0.455	2.802	1.090	0.614	0.698
1968	1.237	1.670	2.436	1.271	2.937	1.109	2.519	1.215	0.934	0.469	1.236
1969	1.909	2.001	2.530	1.974	2.755	1.324	2.610	2.980	0.486	1.033	1.675
1970	1.929	2.723	4.083	2.260	3.534	1.303	2.452	2.413	1.612	1.364	2.117
1971	1.348	1.490	2.004	0.088	1.745	1.738	2.562	2.970	1.106	1.290	1.098
1972	1.350	0.660	1.120	0.900	0.900	1.960	2.530	4.460	1.250	1.000	0.870
1973	0.820	0.460	1.980	2.090	1.760	0.110	1.850	1.822	1.230	1.390	0.730
1974	0.700	1.170	2.440	1.760	2.090	0.250	1.900	2.491	0.730	1.710	1.230
1975	1.152	1.339	2.571	2.932	2.609	1.108	2.090	2.204	1.010	2.014	1.239

[a]Blanks indicate no data available.

Source: Computed from Appendix Table 4, *supra*, p. 110.

APPENDIX TABLE 6

Wage Rates in Preharvesting Period (June), Selected Counties, California, 1951-1975

Year	Average San Joaquin-Yolo, W	County									
		San Joaquin, W_1	Yolo, W_2	Fresno, W_3	Solano, W_4	Sutter, W_5	Sacramento, W_6	Stanislaus, W_7	Merced, W_8	Santa Clara, W_9	San Benito, W_{10}
	dollars per hour										
1951	.88	.85	.90	.80	.88[a]	.85[a]	.80	.80	.92	.92	.90
1952	.86	.85	.88	.85	.88	.85[a]	.82	.85	.85	.85	.82
1953	.85	.85	.85[a]	.88	.88[a]	.85[a]	.90	.85	.85	.92	.88
1954	.91	.95	.88[a]	.85	.88[a]	.85[a]	.82	.85	.90	.92	.88
1955	.90	.92	.88[a]	.88[b]	.88[a]	.85	.82	.85	.85[b]	.92	.88
1956	.90	.92	.88	.85	.85[a]	.85	.88	.88	.92[b]	.92	.88
1957	.94	1.00	.88	.95	.85[a]	.85	.92	.88	.95[b]	.92	.85
1958	.89	.90	.88	1.00	.85[a]	.85[a]	.90	.90	.95	.92	.88
1959	.92	.95	.90	1.00	.90[a]	.90[a]	.90	.90	.95[b]	1.00	.95
1960	.95	1.00	.90	.95	1.00[a]	.90[a]	1.00	1.00	.95[b]	1.00	.95
1961	1.00	1.00	1.00	1.05	1.00[a]	1.00[a]	1.00	1.00	1.00[b]	1.00	.95
1962	1.00	1.00	1.00	1.05	1.00	1.00[a]	1.00	1.00	1.12[b]	1.00	1.00
1963	1.00	1.00	1.00	1.18	1.00	1.05[a]	1.02	1.00	1.12[b]	1.00	1.05
1964	1.08	1.00	1.15	1.10	1.15	1.25[a]	1.15	1.12	1.12[a]	1.00	1.10
1965	1.40	1.40	1.40	1.25	1.32	1.25[a]	1.40	1.40	1.25[a]	1.32	1.32
1966	1.40	1.40	1.40	1.35	1.45	1.40[a]	1.40	1.45	1.35[a]	1.32	1.40
1967	1.40	1.40	1.40	1.40	1.40	1.50	1.45	1.50	1.40[b]	1.45	1.40
1968	1.56	1.58	1.55	1.38	1.50	1.58	1.50	1.58	1.55	1.58	1.50
1969	1.69	1.72	1.65	1.65	1.65	1.70	1.65	1.70	1.65	1.65	1.65
1970	1.72	1.75	1.70	1.65	1.70	1.70[a]	1.70	1.65	1.65	1.75	1.70
1971	1.75	1.75	1.75	1.70	1.75	1.70[a]	1.70	1.65	1.70	2.00	1.75
1972	1.94	2.00	1.88	1.88	1.88	1.88[a]	1.88	1.65	1.85	2.00	1.88
1973	2.10	2.13	2.07	2.18	2.07	2.10	2.07	2.13	1.93	2.00	1.92
1974	2.15	2.15	2.15[a]	2.25	2.15	2.25	2.15	2.38	2.23	2.17	2.36
1975	2.25	2.25	2.25[a]	2.40	2.25[a]	2.35[a]	2.25[a]	2.40	2.30	2.35	2.42

[a] Estimated.

[b] May wage rate; June rate not reported.

Source: California Department of Human Resources Development, *Agricultural Labor Report by Counties and Crops* (Sacramento, 1951, and subsequent weekly issues).

APPENDIX TABLE 7

Price of Selected Crops, California, 1951-1974

Year	Alfalfa hay, H	Sugar beets, S	Grain sorghum, G
	dollars per ton		dollars per bushel
1951	30.40	11.70	1.85
1952	31.30	12.20	1.88
1953	21.60	11.70	1.55
1954	21.10	10.90	1.49
1955	26.40	10.90	1.31
1956	23.50	11.40	1.44
1957	23.40	11.00	1.22
1958	23.80	11.60	1.20
1959	26.30	11.50	1.14
1960	24.50	10.80	1.09
1961	20.80	11.00	1.18
1962	23.40	12.30	1.19
1963	28.50	12.30	1.23
1964	24.80	11.30	1.28
1965	24.00	11.40	1.23
1966	28.20	12.20	1.30
1967	29.40	13.00	1.21
1968	25.90	13.70	1.20
1969	28.50	13.50	1.31
1970	30.50	15.40	1.46
1971	32.00	15.30	1.34
1972	34.50	14.50	1.75
1973	50.00	22.60	2.87
1974	61.00	48.90	3.56

Source: California Crop and Livestock Reporting Service, *California Field Crop Statistics* (Sacramento, 1951-1974).

APPENDIX TABLE 8

Tomato Crop Harvested by Mechanical Harvester and Price of Ammonium Nitrate
California, 1951-1975

Year	Tomato crop harvested by mechanical harvester, N[a]	Price of ammonium nitrate (April 15), F
	1	2
	percent	dollars per ton
1951	*b*	90.0
1952		94.0
1953		98.0
1954		105.0
1955		100.0
1956		93.0
1957		93.0
1958		94.0
1959		92.0
1960		91.0
1961		92.0
1962	1.0	91.0
1963	1.5	90.0
1964	3.8	91.0
1965	24.7	91.0
1966	65.8	90.0
1967	81.8	89.0
1968	95.1	80.0
1969	99.5	79.0
1970	99.9	78.0
1971	100.0	80.0
1972	100.0	77.0
1973	100.0	84.0
1974	100.0	160.0
1975	100.0	180.0

[a]These figures are the percentages of total tomato crop harvested in bins or bulk units. Since mechanical harvesting generally uses bin or bulk units while boxes are used in hand picking, these ratios are believed to provide a good approximation to the adoption rate of the mechanical harvester.

[b]Blanks indicate zero or insignificant.

Sources:

Col. 1: The actual tonnages of tomatoes harvested in boxes, bins, and bulk units are shown in California Bureau of Fruit and Vegetable Standardization, *Annual Reports to Canners* (Sacramento, 1951-1975).

Col. 2: U. S. Department of Agriculture, Statistical Reporting Service, *Agricultural Prices* (1951 and subsequent selected issues).

APPENDIX TABLE 9

Factors Converting Various Case and Container Sizes to Standard Bases
California, 1968

Case and container size	24/2 equivalent cases	24/303 equivalent cases
Tin Containers		
48/Ind. juice can (5½-6 oz.)	0.59	0.72
24/300	0.74	0.90
48/8 oz., short	0.77	0.94
24/303/300	0.79	0.97
24/303	0.82	1.00
12/29/32	0.83	1.01
48/8 oz., tall	0.84	1.03
12/29/32/36 oz.	0.86	1.05
24/2	1.00	1.22
72/8 oz., short	1.16	1.42
96/6 oz. (paste)	1.13	1.38
96/5½-6 oz. (paste)	1.17	1.43
(3 cyl.) 12/46 oz.	1.26	1.53
96/6 oz.	1.28	1.56
96/7 oz.	1.30	1.59
(211 cyl.) 48/12 oz.	1.32	1.61
6/10	1.33	1.62
100/6 oz.	1.34	1.63
1/5 gallon	1.38	1.68
24/2½	1.45	1.77
48/300	1.48	1.80
48/1, tall	1.63	1.99
48/303	1.64	2.00
6/12	1.68	2.05
Glass Containers		
12/12-oz. bottles	0.28	0.34
12/18/20/24-oz. bottles	0.42	0.51
24/12-oz. bottles	0.55	0.67
24/14-oz. bottles	0.62	0.76

Source: Canners League of California, "Conversion Factors" (San Francisco, 1968).

APPENDIX TABLE 10

Fresh and Processed Weight Conversion Factors of Processing Tomatoes
California, 1952, and United States, 1965

Product	Farm weight per case of 24/303	
	California	United States
	pounds	
Canned tomatoes	29.52	36.36
Tomato juice	31.16	36.36
Tomato puree	49.20	80.00[a]
Tomato paste	132.84	142.86[b]
Tomato sauce	49.20	[c]
Catsup and chili sauce	54.69	66.67[b]

[a] 11 percent solids.

[b] 33 percent solids.

[c] No data available.

Sources:

For California, see Sidney Hoos and Frank Meissner, "California Canning Tomatoes: Economic Trends and Statistics," University of California, California Agricultural Experiment Station (Berkeley, 1952), 41p.

For the United States, see U. S. Economic Research Service, *Conversion Factors and Weights and Measures*, Statistical Bulletin No. 362 (June, 1965).

APPENDIX TABLE 11

April 1 Canners' Stocks, by Product, California, 1951-1975

Year	Canned tomatoes	Tomato juice[a]	Tomato puree	Tomato paste[b]	Tomato catsup[c]	Total, V
	1,000 24/303 cases					
1951	532	1,814	357	414	589	3,706
1952	3,224	6,468	2,472	1,303	3,291	16,759
1953	6,173	7,061	2,574	2,225	4,302	22,335
1954	5,994	7,705	1,300	1,681	3,641	20,320
1955	2,977	6,199	426	727	2,415	12,744
1956	3,999	5,186	629	691	3,171	13,676
1957	6,434	8,281	2,188	1,951	7,176	26,031
1958	4,182	10,512	2,193	1,728	5,603	24,218
1959	7,648	10,462	2,230	2,871	7,092	30,303
1960	5,230	7,737	946	1,507	4,735	20,155
1961	5,405	7,267	852	791	5,085	19,400
1962	5,683	6,107	1,956	1,283	4,864	19,894
1963	7,841	10,218	3,868	3,727	8,539	34,194
1964	7,128	9,560	3,326	2,610	6,614	29,538
1965	7,516	9,300	2,500	2,755	8,287	30,357
1966	7,678	6,983	2,084	975	6,617	24,337
1967	5,965	7,154	1,738	850	6,642	22,349
1968	7,820	6,433	2,435	1,649	7,327	25,664
1969	13,226	9,882	6,970	6,255	15,989	52,323
1970	11,314	8,635	6,079	5,103	13,080	44,211
1971	12,722	7,223	3,944	3,026	8,745	35,659
1972	10,000	7,940	2,841	1,744	5,422	27,947
1973	10,771	6,016	1,659	2,467	6,620	27,533
1974	8,621	5,217	1,591	1,405	3,621	20,455
1975	9,771	5,962	2,373	3,098	6,398	27,602

[a]The figures for 1968 through 1975 include only tomato juice and tomato juice concentrate, while earlier figures include also vegetable juices containing 70 percent or more of tomato juice and tomato juice concentrate.

[b]Includes only institutional sizes, namely, 6/10's and larger.

[c]The published data since 1968 included only No. 10 and larger can sizes. The reported data for these years have been adjusted by the average percentage of the large can sizes in the period of 1963-1967.

Source: Conversion factors shown in Appendix Table 9 applied to data in actual cases reported in Canners League of California, *Reports of Packs and Stocks of Various Tomato Products* (Sacramento, January, April, July, and December, 1948-1975).

APPENDIX TABLE 12

Computation of Weighted Average F.O.B. Prices, January-March, 1951-1975

Part 1. Canners' Shipments, January-March

Year	Canned tomatoes	Tomato juice	Tomato puree	Tomato paste	Tomato catsup
	1,000 of 24/303 equivalent cases				
1951	2,122	2,759	318	292	1,406
1952	2,397	2,851	544	494	1,304
1953	3,395	4,787	783	940	2,496
1954	1,547	2,989	325	386	1,531
1955	3,150	3,274	661	836	2,010
1956	3,199	4,371	835	861	2,739
1957	3,537	7,245	812	1,184	2,022
1958	4,518	4,355	869	998	3,449
1959	3,767	4,910	971	952	3,109
1960	4,586	4,728	1,039	1,387	3,290
1961	4,337	3,585	1,077	1,164	2,653
1962	3,769	3,902	1,009	800	2,574
1963	4,217	5,651	1,124	1,159	2,771
1964	5,122	4,526	1,216	1,116	4,282
1965	5,816	5,293	1,433	731	4,357
1966	6,100	3,776	1,806	1,951	4,506
1967	6,327	4,761	1,595	1,042	4,188
1968	6,177	4,820	1,393	701	2,794
1969	9,487	11,240	2,269	1,476	5,385
1970	8,812	5,409	1,864	2,942	5,953
1971	8,391	5,005	1,445	1,199	4,458
1972	9,717	4,517	2,162	2,399	4,338
1973	8,812	4,728	2,415	2,254	2,881
1974	10,961	6,277	2,868	3,540	4,007
1975	8,921	4,606	1,477	2,385	4,313

(Continued on next page.)

APPENDIX TABLE 12--continued.

Part 2. Equivalent Farm Weight of Canners' Shipments, January-March

Year	Canned tomatoes	Tomato juice	Tomato puree	Tomato paste	Tomato catsup	Total
	tons					
1951	31,321	42,985	7,823	19,395	38,447	139,971
1952	35,380	44,419	13,382	32,811	35,658	161,650
1953	50,110	74,581	19,262	62,435	68,253	274,641
1954	22,834	46,569	7,995	24,443	41,865	143,706
1955	46,494	51,009	16,261	55,527	54,963	224,174
1956	47,217	68,100	20,541	57,188	74,898	267,944
1957	52,206	112,877	19,975	78,641	55,292	318,991
1958	66,686	67,851	21,377	66,287	94,313	316,514
1959	55,600	76,498	23,887	63,232	85,016	304,233
1960	67,689	73,662	25,559	92,125	89,965	349,000
1961	64,014	55,854	26,494	77,313	72,546	296,221
1962	55,630	60,793	24,821	53,136	70,386	264,766
1963	62,243	88,043	27,650	76,981	75,773	330,690
1964	75,601	70,515	29,914	74,125	117,091	367,246
1965	85,844	82,465	35,252	48,553	119,142	371,256
1966	90,036	58,830	44,428	129,585	123,217	446,096
1967	93,387	74,176	39,237	69,210	114,521	390,531
1968	91,173	75,096	34,268	46,560	76,402	323,499
1969	140,028	175,119	55,817	98,036	147,253	616,253
1970	130,065	84,272	45,854	195,408	162,785	618,384
1971	123,851	77,978	35,547	79,638	121,904	438,918
1972	143,423	70,375	53,185	159,342	118,623	544,948
1973	160,065	73,662	59,409	144,711	78,781	521,628
1974	161,785	87,796	70,553	235,127	109,572	664,833
1975	131,674	71,762	36,334	158,412	117,939	516,121

(Continued on next page.)

APPENDIX TABLE 12--continued.

Part 3. Average F.O.B. Prices, by Product and Weighted Average F.O.B. Price, January-March

Year	Average f.o.b. price (January 1 to April 1)					Weighted average f.o.b. price[a] R
	Canned tomatoes, standard, 2/2½	Tomato juice, fancy, 14/46 ounces	Tomato puree (1.06), 6/10	Tomato paste (30 percent), 6/10	Tomato catsup, fancy, 6/10	
	dollars per case					
1951	4.75	2.56	*b*		6.50	5.41[c]
1952	3.86	2.45	3.94	6.98	4.73	4.30
1953	3.87	2.32	3.48	5.98	4.50	4.06
1954	3.52	2.19	3.10	5.53	4.58	3.72
1955	3.77	2.46	3.25	5.88	4.68	4.18
1956	3.86	2.61	3.65	7.50	5.22	4.68
1957	3.62	2.34	3.54	7.46	4.88	4.33
1958	3.95	2.55	3.25	5.73	4.75	4.22
1959	3.78	2.35	3.13	4.88	4.42	3.78
1960	3.89	2.34	3.59	5.64	4.81	4.24
1961	4.01	2.63	4.14	7.01	5.22	4.84
1962	4.40	2.62	4.55	8.00	5.68	5.07
1963	3.62	2.27	3.57	5.29	4.94	3.95
1964	4.09	2.49	4.03	6.39	5.46	4.68
1965	3.80	2.33	3.95	6.23	5.19	4.25
1966	4.45	2.84	5.42	8.96	6.70	6.27
1967	4.83	2.89	5.73	9.55	6.77	5.96
1968	5.34	3.02	6.35	11.00	7.50	6.23
1969	3.96	2.65	4.63	7.58	5.50	4.59
1970	4.52	2.61	4.24	6.10	4.76	4.80
1971	4.85	3.05	4.80	7.25	5.70	5.20
1972	4.78	3.08	5.20	7.80	6.08	5.77
1973	5.28	3.50	5.60	9.85	7.00	6.65
1974	5.74	3.93	6.60	12.52	8.25	8.37
1975	7.06	5.20	8.12	15.40	12.80	10.70

(Continued on next page.)

APPENDIX TABLE 12--continued.

[a]Weighted by quantities shown in Part 2.

[b]No data available.

[c]Estimated.

Sources:

For Part 1, the data on canners' stocks in actual cases reported in Canners League of California, *Reports of Packs and Stocks of Various Tomato Products* (Sacramento, January, April, July, and December, 1948-1975) were converted by applying the factors shown in Appendix Table 9, *supra,* p. 115.

For Part 2, data derived from Part 1 by applying the conversion factors in Appendix Table 10, *supra,* p. 116.

For Part 3, average f.o.b. price quotations reported in Canning Trade, Inc., *The Canning Trade* (Baltimore, Maryland, 1951, and subsequent selected issues).

APPENDIX TABLE 13

Total Resident Population and Total and Per Capita
Personal Disposable Income, United States
July 1, 1951-52, to July 1, 1975-76

Year beginning July 1	Total resident population, January 1	Total disposable personal income	Per capita disposable personal income
	1	2	3
	1,000 persons	billion dollars	dollars
1951-52	155,259	231.3	1.496
1952-53	157,815	247.3	1.574
1953-54	160,492	254.4	1.592
1954-55	163,654	264.6	1.624
1955-56	166,725	284.8	1.717
1956-57	169,817	301.6	1.786
1957-58	172,809	312.5	1.808
1958-59	175,775	329.4	1.874
1959-60	178,729	344.2	1.926
1960-61	181,629	354.8	1.953
1961-62	184,508	376.1	2.039
1962-63	187,284	393.8	2.103
1963-64	189,973	420.2	2.212
1964-65	192,529	453.3	2.355
1965-66	194,649	494.6	2.541
1966-67	196,596	529.3	2.691
1967-68	198,578	568.5	2.863
1968-69	200,498	610.0	3.041
1969-70	202,717	664.1	3.274
1970-71	205,153	720.2	3.499
1971-72	207,397	767.6	3.692
1972-73	209,123	837.9	4.007
1973-74	210,691	903.7	4.289
1974-75	212,302	983.6	4.633
1975-76	214,047	1,076.7	5.030

Sources:

Col. 1: U. S. Bureau of the Census, *Current Population Reports: Population Estimates and Projection,* Series P-25, No. 439 (1970); see, also, No. 494 (1972) and No. 503 (1973).

Col. 2: U. S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (1951 and subsequent selected issues).

Col. 3: Computed.

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