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Transportation and Marketing Efficiency in the California Processing Tomato Industry

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TRANSPORTATION AND MARKETING EFFICIENCY IN THE CALIFORNIA PROCESSING TOMATO INDUSTRY

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SUMMARY

This study develops and applies a nonlinear mathematical programming model to determine the optimal allocation of processing tomatoes from the 13 largest producing counties in northern and central California to the 32 processing facilities located in the area. The mathematical model of the industry incorporates costs of hauling tomatoes from field to processing facilities and distinguishes between plants that process only bulk paste and those that process diversified products including sauces, puree, juice, and whole tomatoes. The study is also the first to incorporate explicitly tomatoes' soluble solids content into the analysis.

A primary goal of the study is to evaluate the efficiency of the allocation of tomatoes from farms to processing plants. Several factors have contributed to long field-to-plant hauls in the California tomato industry. Urbanization has shifted the primary locations of production from the central coast to the central valley. Several coastal processing plants now lack a base of localized production. In addition, production peaks at different times in different producing regions, so processors wishing to extend their processing season must incur long distance hauls. The industry's uniform (as opposed to FOB) pricing structure also encourages long-distance hauls.

Results of the analysis reveal modest departures from efficiency in the prevailing tomato allocation pattern. The average one-way haul under the optimal allocation was 56.7 miles vs. 66.6 miles for the estimated actual allocation, with a resulting loss to the industry of $22 million or 1.9% of gross profits for 1989. Simulation of entry of new processing plants in Fresno and Yolo counties suggests that new large-scale capacity plants in these locations would be among the most profitable tomato processing plants in northern and central California. In general, the simulation results reveal an industry where processors' and producers' fates are closely linked through interregional competition despite their being separated in many cases by long distances and high transportation costs.

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1. INTRODUCTION

Processing tomatoes are an important and growing agricultural industry in California, but the industry is in a considerable state of flux. As we shall document in this study, the industry is undergoing continuous change in the geographic locations and sizes of tomato-producing farms. In turn, these changes are affecting the dynamics of the processing industry. Processing firms located in the highly urbanized San Francisco Bay Area counties now lack a significant base of localized production to draw upon. These processors must often source tomatoes from 100 or more miles away. Meanwhile new processing facilities have been located, most notably in Fresno County, in proximity to the largest concentrations of tomato production.

This geographic evolution of the industry is a dominant force affecting competitive relations among processors and between processors and growers. In the short run, nonalignment of producing areas and processing locations has caused tomatoes to be hauled long distances and haulage costs to represent a major expense to the industry. It has also stimulated considerable interregional competition among processors to procure tomatoes. Over the longer run the industry is responding to the geographic evolution of tomato production by gradually shifting plant locations, through the entry and exit process, to better align plant locations with the available production.

We estimate that the average one-way haul for California processing tomatoes remains in excess of 65 miles. Although this figure represents a long and expensive haul, it is a considerable reduction from the 100 mile haul estimated by Brandt, French, and Jesse (1978) for 1973. Nonetheless, the perception remains among industry participants that tomatoes are allocated inefficiently across processing firms and that reduced haulage and improved industry performance could be attained if a better grower-to-processor allocation of tomatoes were achieved.

This study analyzes the allocation of processing tomatoes in northern and central California and assesses the efficiency of the prevailing allocation pattern. We develop a nonlinear optimization model to determine the optimal allocation of tomatoes from the 13 largest producing counties in northern and central California to the available processing facilities in this region. With information obtained from the California Processing Tomato Advisory Board on the actual allocation of tomatoes, we are able to compare the actual allocation with the estimated efficient allocation and estimate losses to the industry from inefficient allocation of tomatoes across processing firms.

This study represents the first comprehensive analysis of the California tomato industry since the mid 1970s. Brandt, French, and Jesse (1978) and Brandt and French (1978) described demand and supply conditions in the industry through 1976 and developed an econometric model of the industry to evaluate economic impacts of mechanical tomato harvesting and develop projections for industry growth from 1980-90. Chern and Just (1978), also developed econometric models of the industry using both aggregate annual time series data from 1951-1975 for the 10 largest producing counties and by pooling county-level and time-series data. This study also to evaluated the impact of the tomato harvester. Among the conclusions was that observed market responses to the harvester were consistent with an oligopsony market structure in procurement of raw tomatoes.[1]

The antecedent to these studies and the first comprehensive analysis of the California processing tomato industry was analysis of grower-processor integration conducted by Collins, Mueller, and Birch (1959). This study provided the first in-depth analysis of the grower-processors contracts that prevail to this day in the industry.

The present study is distinguished from its predecessors in undertaking an optimization rather than an econometric framework and focusing specifically on the subject of optimal grower-to-processor allocation of tomatoes and transportation efficiency. Chapter 2 provides an updated description of the processing tomato industry, including consumption and trade, farm supply, processing, and marketing arrangements. Chapter 3 develops some conceptual points concerning pricing and transportation in a spatial market. In particular, it is shown that the uniform pricing system employed by the industry is certain to lead to inefficient transportation relative to an FOB pricing system.

Chapter 4 sets forth the optimization model and describes data sources used to parameterize the model. The main analytical results are provided in chapter 5, where optimal vs. actual tomato allocations are presented and compared. Chapter 6 extends the model to look at a long-run equilibrium formulation and to simulate the entry of new processing plants. Finally, chapter 7 offers concluding comments.

2. THE CALIFORNIA PROCESSING TOMATO MARKET

Tomatoes are the second highest valued vegetable crop in the U.S., ranking only behind potatoes. In 1991 California produced 9.89 million tons of processing tomatoes, over 90 percent of the total U.S crop. Processing tomatoes are an integral component of California's agricultural economy. The 1991 crop generated $640.1 million, making processing tomatoes the State's highest valued vegetable crop and eighth highest value agricultural product overall.

Production of processing tomatoes has increased rapidly in California in recent years as Figure 2.1 documents. The 1989 harvest of 8.6 million tons shattered the 1975 record harvest of 7.3 million tons. Production continued to rise until 1991. Production was reduced to 7.9 million tons in 1992, as a consequence of the decline in finished product prices. This chapter describes various dimensions of this important California industry, including consumption and trade, farm supply, the processing sector, and marketing and transportation arrangements.

Consumption and Trade

Processed tomato products form a major part of U.S. vegetable intake, ranking first among fruits and vegetables in contributions to the diet. Per capita consumption of processed tomato products in the U.S. rose from about 62.1 lbs. farm weight in 1970 to 70.3 lbs. in 1990, partly as a result of the increased demand for Italian and Mexican food products.

The increase in value-added products, such as Italian sauces and Mexican foods, produced either for home use or for the food service industry, have altered the composition of production. Bulk paste is now sold commonly as an ingredient to other food manufacturers. Some processors purchase tomatoes from growers and manufacture and sell processed goods such as pasta products. Consumer preferences in breakfast beverages have brought about a decrease in tomato juice production as consumers have shifted to orange juice.

Factors influencing the demand for tomatoes include rising consumer incomes, which generally diminish the demand for canned vegetables while increasing the demand for fresh produce. Demand for convenience foods and food service has increased as household composition has changed. Tomatoes form an important ingredient in the fast food and restaurant industries.

World demand for tomato products is also rising, although per capita consumption rates differ widely across countries. For 1988-90 the U.S. was the largest per capita consumer followed by Italy, Greece, and Canada. Countries that presently consume little processed tomato products include Japan and the UK (8.8 and 18.5 lbs. farm weight per capita, respectively).

Table 2.1 summarizes U.S. import and export volumes for processed tomato products for 1970-91. The U.S. has traditionally been a net importer of both tomato paste and sauce. However, the U.S. export volume of these commodities began to increase rapidly in 1989 coinciding with the series of record California harvests. In 1991 The U.S. was a net exporter of paste for the first time. Sauce has also moved strongly into the net export category after having been a net import prior to 1988.

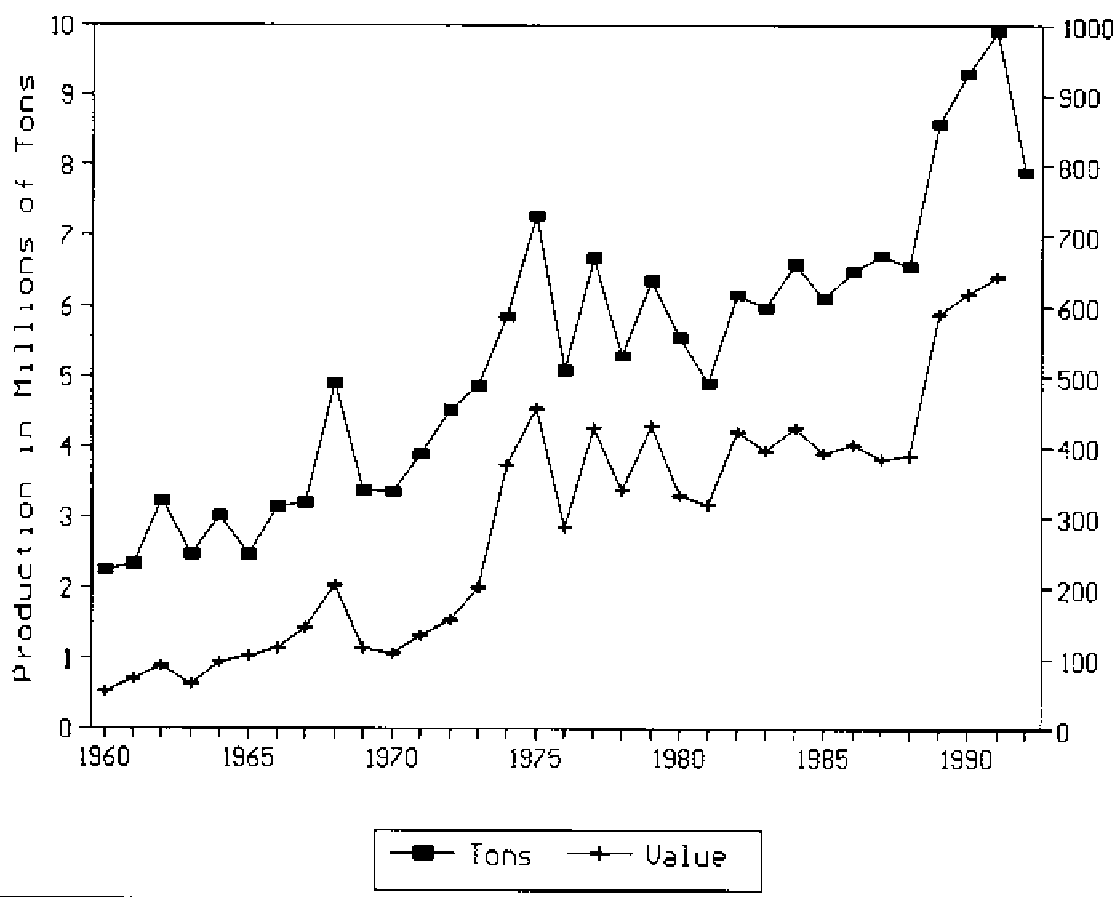
Sullivan (1992) cites strong demand for tomato products among newly industrialized countries in Latin America, the Caribbean, and Asia. U.S. exports, however, have continued to target traditional markets in Canada and Japan, leaving Chile to serve the emerging markets. Paste exports to Canada in 1991 totalled 62.1 million lbs., 64% of total U.S. paste exports. Japan was the second largest paste importer with 16.4 million lbs. Canada also accounted for 64% of U.S. tomato sauce imports--50.5 million lbs, while Japan imported 9.3 million lbs. during 1991.

The U.S. has traditionally imported the greatest amount of tomato products from the European Community. In 1984-85, 51.3% of U.S. tomato paste imports were from the EC. Israel was second in paste imports at 17.3%, with Mexico third at 13.0%. The import situation has shifted dramatically in the past several years, however, due to establishment of production quotas on subsidized European Community production and imposition of higher tariffs (from 13.6 to 100% of value) on imports from the EC to the United States beginning in 1988 in retaliation for the EC's ban on hormone-fed meat products. As a result paste imports from the EC have essentially disappeared and Mexico is now the dominant exporter of paste to the U.S., shipping 59.3 million lbs. in 1991.

Mexico's processing tomato industry is concentrated in the Sinaloa region, where 8 of 10 Mexican processing firms are located. The current industry processing capacity in Mexico is 500,000 metric tons per year (U.S. Department of Agriculture 1992). Investment in processing capacity in Mexico is expected to increase partly due to new Mexican laws that will facilitate investment by U.S. firms.

Mexican yields are only half as high as in California. This factor coupled with high shipping costs and a tariff of 13.6 percent have to date offset

Figure 2.1. California's Processing Tomato Production and Value: 1960-1992



Mexico's comparatively lower processing costs. However, tariffs are scheduled to be phased out under the North American Free Trade Agreement (NAFTA), auguring a significant increase in Mexico's competitiveness for U.S. processing tomato sales.

The final outcome of the GATT negotiations may have little effect on European exports to the U.S., since new foreign producers have begun shipping to the U.S. market at low cost. For example, Chile has emerged as a force on the international tomato products market with a 24.2% share of U.S. paste imports. Israel is now third at 6.2%. Tomato production is also emerging in a number of other locations including Eastern Europe (Bulgaria, Hungary, and Yugoslavia), Asia (India and Taiwan) and South America (Argentina and Brazil). Many of these nations have the soil and climatic conditions necessary for increasing production. However, infrastructure to support efficient and competitive production appears to be a major factor limiting expansion of production in some cases. In addition, high U.S. production levels in the 1990s have reduced world paste prices and, thus, incentives to expand production.

2.2 Farm Supply

As of 1993 there were 486 growers of processing tomatoes in California. The average grower plants around 500 acres of tomatoes annually. The historic peak in harvested acreage for California processing tomatoes was in 1975 at nearly 300,000. In years between 1975 and 1989, harvested acreage remained below 250,000 acres with the exception of a harvest of 278,000 acres in 1977. However, acreage began to boom in 1989 with 276,500 acres and then increased to a new record high of 312,000 acres in 1991. Low prices inspired by three successive large crops prompted a sharp reduction in contracted acreage to only 240,000 acres in 1992.

Yields have also increased. From 1986-91 yield was stable in the 29-32 tons per acre range. By comparison yield in the 1970s ranged from 22-25 tons per acre. Significant improvements in yield and solids content have come with new tomato varieties and improved pest and weed control.

Most tomato growers produce crops in addition to tomatoes. Rotation with other crops maintains productivity of individual fields. Wheat and sugar

Table 2.1. U.S. Imports and Exports of Tomato Products: 1970-1991

Year	Tomato Imports (000 lbs.)			Tomato Exports (000 lbs.)					
	Paste[a]	Sauce[b]	Whole	Pulp & Puree	Paste	Sauce	Juice	Catsup & Chili	Other[c]
1970	91,382		128,534	9,994		4,501	13,427	6,967	19,146
1971	97,570		108,557	6,801		3,467	12,345	7,109	17,381
1972	126,241		158,630	8,161		7,246	13,452	7,534	19,923
1973	118,915		101,146	36,922		6,552	21,429	9,941	24,699
1974	45,218		66,051	48,333		6,419	20,263	10,838	26,651
1975	26,881		68,914	22,176		6,142	32,828	15,014	30,143
1976	55,237		74,160	24,012		8,816	46,982	15,864	23,621
1977	65,198		72,099	28,597		6,117	41,684	14,714	28,295
1978	50,991	7,116	74,165	4,217	26,649	5,739	30,861	18,303	28,195
1979	42,055	2,794	45,567	2,881	38,333	7,395	25,060	18,078	41,685
1980	25,466	1,651	39,881	3,673	25,404	6,421	32,512	23,852	34,952
1981	65,202	9,116	97,230	2,088	24,554	9,014	34,963	27,754	32,194
1982	198,029	21,824	167,018	1,301	22,556	6,315	29,284	27,580	19,987
1983	160,742	23,626	186,709	875	23,964	6,701	18,552	23,455	14,002
1984	151,045	28,000	233,567	761	21,203	5,895	14,032	20,362	11,953
1985	111,400	33,588	220,028	1,398	15,691	4,723	11,984	18,082	15,939
1986	130,625	197,559	197,559	811	17,234	6,187	15,000	18,902	13,902
1987	101,247	178,587	178,587	2,506	20,440	6,479	13,272	23,450	8,040
1988	107,655	175,528	175,528	4,752	26,618	18,662	18,869	26,447	11,842
1989	228,400	111,590	111,590	11,233	30,302	58,781	12,818	25,782	9,124
1990	136,913	137,292	137,292	6,988	84,724	53,883	16,524	35,197	14,189
1991	94,954	114,840	114,840	8,700	97,257	79,145	6,300	35,200	17,600

[a] Includes sauce prior to 1978.
[b] Tomato-based sauces containing additional seasonings not included prior to 1989.
[c] Products not classified elsewhere.

Source: *Vegetables and Specialties: Situation and Outlook Yearbook*, U.S. Department of Agriculture, Economic Research Service, Dec. 1991.

beets are commonly rotated with tomatoes. However, the specific crop used in rotation varies by area of the state. Depending upon the market and local producing conditions, the same field may be planted in tomatoes for consecutive years.

Historically tomato production was quite widespread in California as shown in Figure 2.2, which depicts tomato acreage in the mid 1940s. The darkest-shaded counties represent the greatest number of acres. During the 1940s over 3000 growers produced on average 32 acres of tomatoes for either the fresh or processing markets. The location of production has changed considerably since that time as comparison of Figure 2.2 with Figure 2.3, which depicts acreage levels in the late 1980s, illustrates. Urban expansion has been the primary factor in eliminating processing tomato acreage in Los Angeles, San Mateo, San Diego, and Alameda Counties and reduced it more than 50% in counties such as Sacramento and Santa Clara. Fresno County is now the top producer in the state after having no acres reported in 1960. The rise of production in arid counties such as Fresno is primarily a result of extended irrigation and drainage projects.

Along the California-Arizona border in the Imperial Valley, it is possible to harvest tomatoes almost continually from mid-May to mid-November, although in recent years harvests have ended by July. In general the harvest season lasts 19 weeks with the major part of production occurring between July and September (Moulton and Pradham 1988).

Climate patterns actually allow harvest to begin in the Northern most producing county, Colusa, nearly as early as in Fresno County, over 150 miles to the south. Coastal counties such as Monterey, San Benito, and Santa Clara begin production several weeks later. Late production in all areas is vulnerable to weather problems. Occasionally unseasonable rains affect peak harvest periods as well. In 1976, for example, nearly 34,000 acres were lost as a result of rain in August and September. Figure 2.4 depicts the weekly harvest pattern for the various tomato producing regions in California.

Average time from emergence to harvest is 125 days, but emergence and the percentage of mature (ripe but not overly ripe) fruit at harvest are strongly effected by planting date. Sims et al. (1979) found that tomatoes planted on March 4 took 25 days to emerge for a July 31 harvest date with 85% maturity.[2] Peak maturity of 93% occurred with a May 12 planting date, 9 day emergence, and harvest on September 23.

Since the adoption of the mechanical harvester in the 1960s, there have been only minor changes in production technology. The harvester has enabled larger-scale farming and contributed to alleviating the labor shortages created by the end of the Bracero program[3]. Labor requirements changed from field laborers to sorter laborers, who sit upon the harvester and remove sun-scalded, wormy, and moldy fruit as it passes by them on a conveyor belt. Electronic sorters remove green fruit and dirt (Sims et al. 1979).

Processing tomatoes are grown with specific characteristics for different end uses. Tomatoes with a high solids content produce more output of products which are defined by their solids content including paste, catsup, and sauces. Some varieties provide greater flow consistency which is important in some products including catsup and spaghetti sauces. These varieties can be blended with high solids varieties to provide the proper mix. Varieties with uniformity in size and color are especially important for whole and diced products.

California tomatoes are inspected prior to delivery at inspection stations overseen by the Processing Tomato Advisory Board, a joint board of growers and processors. Two samples from each load of tomatoes are inspected for defects such as sun scalding, under- or over-ripeness, mold, worms, material other than tomatoes, etc., and tested for soluble solids content and color. Excesses in the defect category permit rejection, but typically defects are at a low level, and payment is simply reduced by the percentage of defects over an allowable percentage (0 to 5% depending on type of defect). These penalties provide incentives for the grower to maintain reasonable standards at the field sorting level. Soluble solids content premiums are paid by many processors. These premiums provide incentives for choosing high-solids content tomato varieties and discourage late applications of water which would raise the weight or yield per acre without providing commensurate additional solids.

Information on the characteristics of a load can be used by multiplant processors to determine the best processing site for it. A lost with high soluble solids may for instance be delivered to a plant primarily or wholly devoted to paste manufacture. Alternatively, at the plant level the information may be used to help determine which product line the incoming load of tomatoes will be sent to. In plants that process diverse products--whole tomatoes, sauces, puree, paste, etc.--the tomatoes with a better appearance are usually diverted to whole tomato lines, while tomatoes with high solids content are preferred for use in paste and sauce products.

Figure 2.2. Average Acreage by County 1944-1946

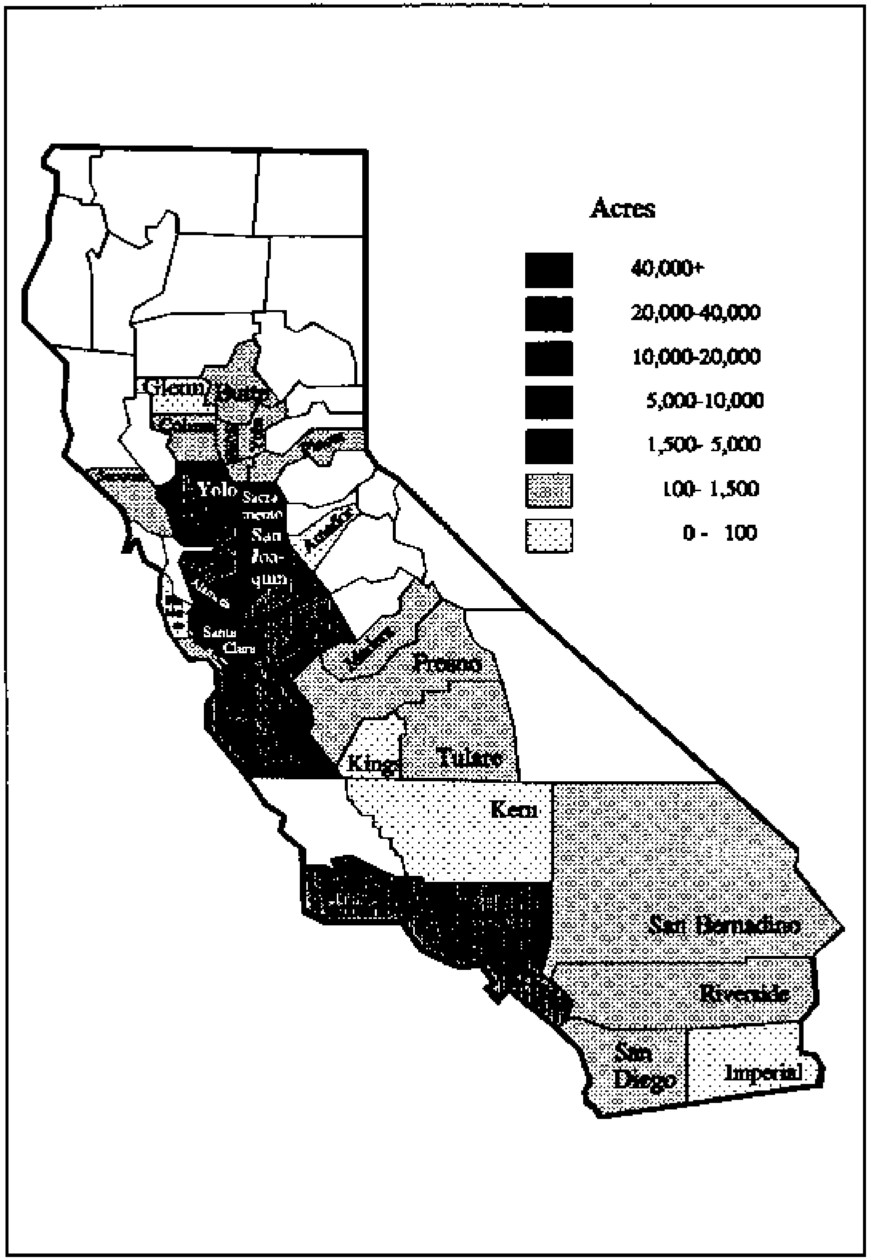


Figure 2.3. Average Acreage by County 1987-1989

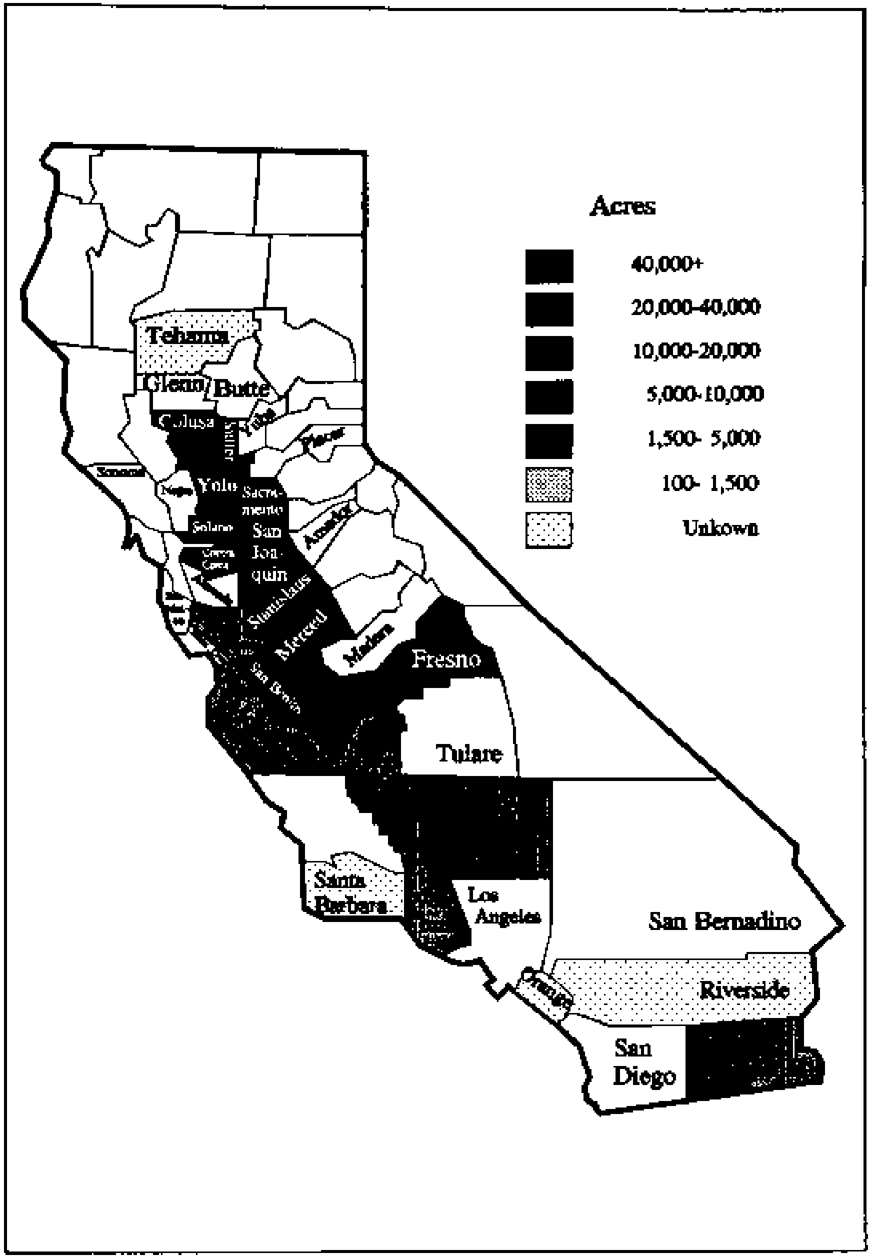
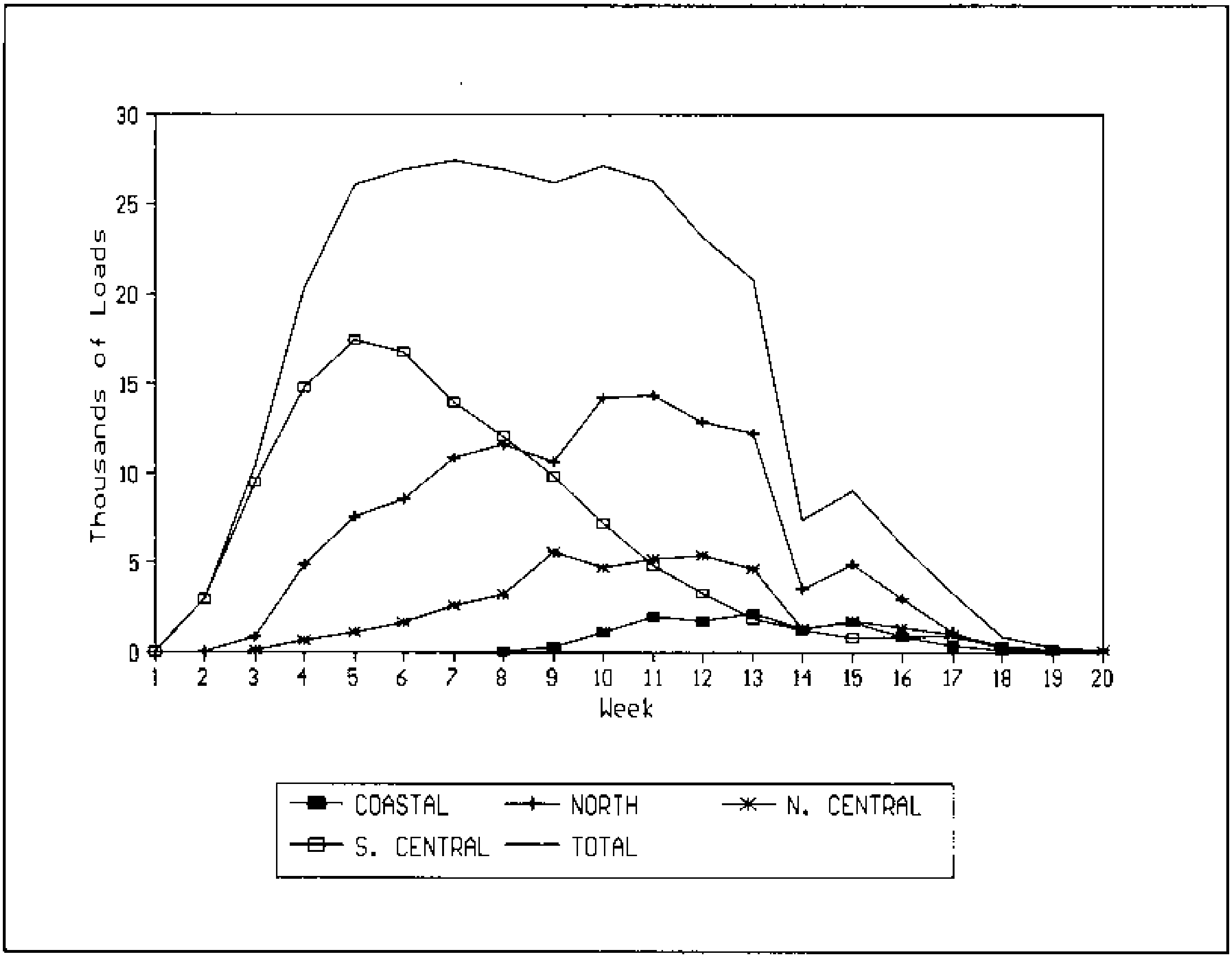


Figure 2.4 Seasonal Variation in California Processing Tomato Production by Region for 1989



2.3. The Tomato Processing Technology

In 1989 24 tomato product canning and paste firms operated 37 plants for processing tomatoes in California, as compared to 57 firms operating in 1955. Since 1989 five plants have opened and six plants have close d. In addition, there are a few firms which use only a few tons of tomatoes annually, including fruit and vegetable dryers and freezers and a liquor manufacturer.

Figure 2.5 depicts the location and various sizes of plants in California. An X, L, M, and S in the figure represent a plant processing over 500,000 raw tons annually, from 360,000 to 500,000 tons, from 210,000 to 350,000 tons, and from 60,000 to 200,000 tons, respectively.

The largest single processed product by volume of input, as well as finished product, is tomato paste. This category includes bulk production to be sold to other food manufacturers. Over 10 million tons of paste are now produced annually in the U.S., representing a doubling of production over the past 20 years. For each year since 1985 between 50-60% of the California processing tomato crop has been packaged as bulk paste. Four of the five new plants built since 1989 process only bulk paste or other bulk products. Bulk processing capacity was also added by diversified-products processors.

Various sauces including puree, ground tomatoes, chile and pizza are the next largest category for direct processing, followed by whole peeled tomatoes. While each of these products are manufactured in California, Midwestern U.S. production has been oriented towards less concentrated products such as whole canned tomatoes and tomato juice. Midwestern disadvantages in production costs are outweighed by lower transport costs to Eastern markets for the less highly concentrated products (Brandt 1977).

Upon arrival at a processing plant the tomatoes are transferred into a water flume which takes the tomatoes through three wash stages and conveys them on to the sorting line. Sorting systems vary according to final products. The first groups of sorters may remove "absolute waste" and totally unusable tomatoes, followed by a group that trims defects.

In diversified-products plants completely sound tomatoes are put into the peeling line, and other fruit is left on the pulping line. The fruit selected for whole products is peeled using either a steam or chemical process and diverted to alternative canning lines. Here cans are filled, syrup is added, and the cans are sealed. Canned items are then cooked and the seams are inspected. Cans are air or water cooled at this point and are then stacked on pallets and prepared for transportation to the warehouse.

Tomatoes to be processed into pulp or paste products are first chopped and then heated. Next the tomato pulp is pumped to a holding tank from which it is fed into a set of first stage evaporators that remove water from the pulp. The product is then fed through "finishers" that extract seeds and skins. Tomato juice is then separated from the concentrate and diverted to holding tanks from which it is subjected to an additional, low-temperature evaporation process. Puree is also pumped to a separate evaporation process. The paste concentrate is diverted to a holding tank from which it is sterilized and flash cooled.

In a plant that processes only paste, the paste is pumped to holding tanks and typically packed into 300 gallon boxes or 55 gallon drums. In plants manufacturing diversified tomato products, the juice is diverted when it reaches the appropriate level of concentration to make alternative end products, such as pizza sauce and tomato catsup. Various ingredients such as spices, sweetener, salt, soybean oil and citric acid are added before the material is canned (Starbird and Ghiassi 1986).

Bulk storage of tomato products has primarily been used for tomato paste. This process has enabled many tomato product manufacturers to economically remanufacture tomato paste into various consumer products such as catsup, spaghetti and pizza sauce, and juice. It also allows many manufacturers to extend processing beyond the harvest season as well as to provide a product which can be remanufactured closer to the consumption point. High quality bulk storage is now possible for whole tomatoes (Gould 1992, p.228,) which should stimulate further restructuring of tomato product manufacturing. A number of plants once specializing in paste manufacturing now produce other bulk products. These other products such as diced tomatoes may also be used as an intermediate input to other products such as spaghetti sauce. A number of Midwestern plants purchase California bulk tomato products and remanufacture them into consumer products.

2.4. Marketing Arrangements

Grower-processor transactions in the processing tomato industry are accomplished almost exclusively by forward contracting. In 1991 98.5% of the processing tomato acreage was under contract. The forward contract specifies the number of tons the farmer may deliver on a weekly basis, and growers may be required to hold tomatoes in the field if over supply exists. Other provisions may specify the field in which the tomatoes are grown and the variety grown. Any premiums or discounts based on tomato quality will also be specified in the contract. These provisions vary across firms. Processors also often offer premiums for late- and sometimes for early-season production. These premiums also vary by processor and sometimes even by plant in the case of multi-plant processors.

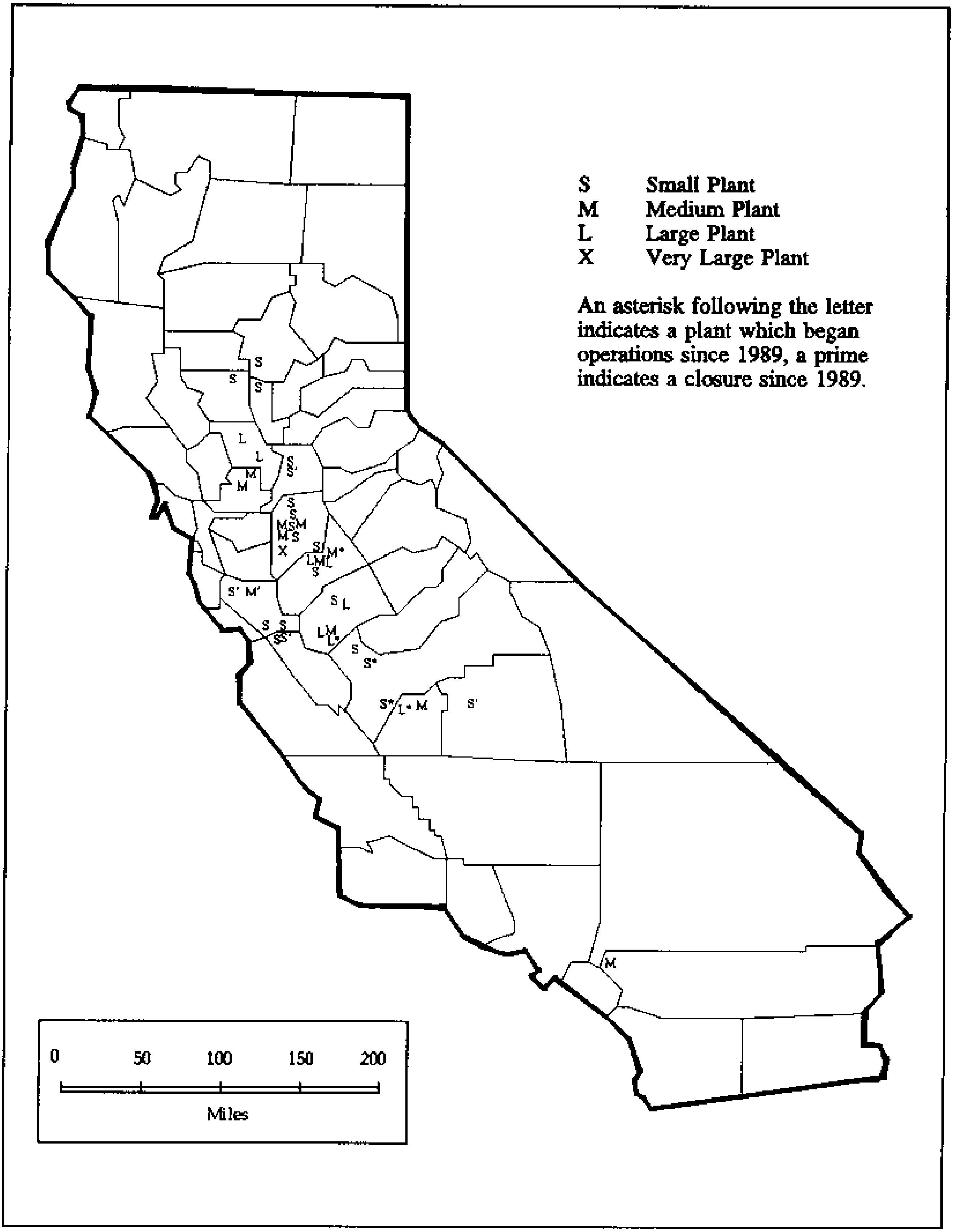
The California Tomato Growers Association (CTGA), a bargaining association, has negotiated on contract provisions since 1973. Brandt (1977) reported 80% membership in CTGA with 70% of production in 1975. The current CTGA membership rate is at 50%.

Figure 2.5 shows that some counties such as San Joaquin, Stanislaus, Merced, and San Benito/Santa Clara, have a substantially higher concentration of tomato processing plants than others. Comparing Figures 2.3 and 2.5 illustrates that processing capacity is not necessarily matched with production, due mainly to the movement of raw tomato production over time as described earlier. Plant closures and openings since 1989 show some improvement in this regard.

Transportation costs comprise a significant component of processing and marketing costs for tomatoes due partly to this geographical mismatch of processing capacity and raw product production. In 1989 there were still four plants operating in the now substantially urbanized and industrialized county of Santa Clara. The first processing plant in Fresno County opened in 1989, even though Fresno County has been California's top tomato producing county since 1982 and a major producer since the mid-1960s. Overall, the processing sector has been slow to follow production, making the efficiency of transportation an important issue for the industry.

Grower-to-processor transportation costs have averaged from 8-12 dollars a ton, roughly 15-20% of the farm price. Trucking rates vary by location and firm and year; a flat fee of $5.00 per ton + 10 cents per ton per mile was typical in the early 1990s. Transportation costs are paid by processing firms. In the literature on spatial pricing, this arangement represents a uniform pricing scheme. Its implications are discussed in the next chapter.

Figure 2.5. California Tomato Processing Plant Locations



While any particular county may spread its production for 10 or more weeks, it is necessary for firms desiring to continue operations for longer periods to procure tomatoes from alternative producing areas. This situation implies a management problem for the processor in terms of balancing transportation costs against additional production and better plant utilization. Firms must decide how long and at what rate to operate, where the operating rate is determined by the number of processing lines opened. A plant can organize to process "quick" products, such as paste, at peak harvest and "slow" products, such as whole tomatoes when harvest rates are low.

A second consideration affecting transport miles is the need to ensure even delivery of tomatoes to the plant. Plants are encouraged to spread purchases across counties to ensure that locally poor yields or damaged crops do not unduly affect processing. For example, in 1989 almost 3% of planted acreage was not harvested in Yolo County. At yields of 30 tons/acre this volume would represent an entire week's processing for some plants.

Thus processors spread their production contracts beyond the distance which is necessary for adequate plant input for 2 reasons: (1) to conduct processing prior to the time when their location comes into production, or after it ceases and (2) to diversify areas of production to safeguard against locally poor yields or damaged crops. Hence, firms do not have exclusive control over local raw product markets in this industry.

3. PRICING AND TRANSPORTATION IN A SPATIAL MARKET

Processing tomatoes are a bulky and perishable product. They are relatively costly to transport. The diffusion of processing tomato production across a large portion of California as detailed in Figure 2.3 and the pattern of processing plant location shown in Figure 2.5 mean that tomatoes are often shipped long distances. In 1989, the base year for our analysis, the average one-way haul for a load of tomatoes under the profit-maximizing allocation was 57 miles, and hence transportation costs comprise a significant portion of the costs of marketing and processing raw tomatoes. This chapter discusses pricing in spatial markets and demonstrates how the choice of a spatial pricing scheme affects transportation costs.

3.1. Spatial Pricing

Spatial considerations complicate firms' decision making. A fundamental issue is how transportation costs affect price schedules and, hence, supply accruing to each processing firm. The prototype mode of spatial pricing is FOB (free on board) pricing. When applied on the selling side of the market, FOB pricing implies that the seller charges a uniform "mill" price to all customers, who then are responsible for transportation costs incurred in shipping the product. The analogue to FOB pricing on the input-buying side of the market is when the processing firm offers a uniform price at the plant gate, and sellers are responsible for costs incurred in getting the product to the factory. Although sellers receive differentiated net prices, FOB pricing represents *nondiscriminatory pricing* in that no seller pays more or less than the costs of transporting his own product. In this sense, FOB pricing is characterized by an absence of *cross subsidies* among growers.

Departures from FOB pricing are common in practice as Greenhut, Norman, and Hung (1987, ch. 14) document. Any pricing scheme that departs from the FOB standard is discriminatory in that it violates the nondiscrimination standard set forth in the previous paragraph. In principle, discrimination can take one of two forms: freight absorption or phantom freight charges. Under freight absorption, the seller is charged less than the full cost of shipping his product. The plant-gate price is set correspondingly lower to reflect the buyer's payment of shipping costs. Pricing schemes that absorb freight discriminate against sellers located near to the processing facility who subsidize distant sellers. When phantom freight charges are subtracted from the seller's price, the plant-gate price can be raised accordingly and, hence, discrimination is against distant sellers.

Phantom freight charges (charges in excess of actual transport cost) can usually be undermined by seller arbitrage, because sellers located near to the processing plant can buy production from distant sellers and acquire the difference between the processor's phantom freight charges and actual cost of transportation. Thus, most attention in spatial price discrimination is focused on freight absorption. A particularly acute form of freight absorption, *uniform pricing* is practiced in the California tomato processing industry, where processors offer a uniform price to growers regardless of the growers' distance from the processing plant.[4] The processor pays nominally for all transportation costs. Of course, the price paid is correspondingly lower than the plant-gate price under an FOB set up, thus generating the conclusion that nearby growers cross subsidize distant growers.

Several factors have contributed to the emergence of uniform pricing in the California tomato industry. First, it is a simple pricing system that probably minimizes contracting costs. Second, processing firms are better poised than growers to deal with trucking firms because of their superior bargaining power relative to growers and because processors' relative fewness in numbers minimizes the contractual costs of dealing with truckers. This pricing system has a long history in the industry. Collins, Mueller and Birch (1959) report that the system was firmly entrenched in 1954, with processors either arranging hauling themselves or paying growers a hauling allowance equivalent roughly to the going truck rate.

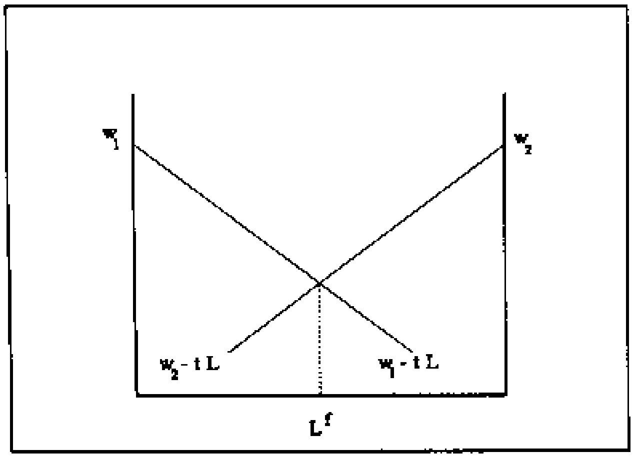
Uniform pricing also reflects the nature of competitive relations in this industry, including overlapping market areas among processors. Under FOB pricing, processors market areas do not overlap. Growers ship to whichever processor offers the highest price adjusted for transportation costs. For example, consider two processors located 1 unit distance apart, let w_1 and w_2 represent the processors' mill prices, and let t denote the per-unit transportation costs. Growers' net price to shipper i under FOB pricing is found by subtracting transportation costs from w_i. The market boundary, L^f, between the two firms is the location where their two net prices are identical:

$$w_1 - tL^f = w_2 - t(1 - L^f)$$

and solving for L^f yields

$$L^f = ((w_1 - w_2) + t)/2t. \quad (3.1)$$

Figure 3.1. Market Boundaries Under FOB Pricing



As illustrated in Figure 3.1 all growers located less than L^f distance from processor 1 ship to that processor and all others ship to processor 2.

A number of competitive factors promote market overlap and, hence the emergence of uniform rather than FOB pricing in the California processing tomato industry. They include processors' desire to (i) extend the processing season by attracting tomatoes from multiple growing regions, (ii) spread risk of crop failure by contracting for tomatoes across a broad geographic area, and (iii) attract tomatoes with special characteristics such as high soluble solids content. In addition, as comparison of Figures 2.3 and 2.5 illustrates, shifts in production have left some processing plants without a significant base of locally grown tomatoes. These processors must necessarily then attract tomatoes from growers in more distant regions.[5]

The key point in terms of choice of a pricing scheme is that in order for firms to succeed in procuring raw product from distant regions that are proximate to rival plants' locations, they must set price competitively in those locations. An FOB price minus long distance hauling costs will not normally be competitive in these situations. A uniform price, on the other hand, enables a processor to compete effectively in distant regions, while exploiting its locational monopsony power over proximate growers.

Under uniform pricing, a processing firm wishes to extend its market until its uniform price w plus transportation costs tL just equal its net marginal revenue from acquiring additional raw tomato production. For example, consider a tomato processing plant that produces paste, which is sold at price P per unit and is processed with constant cost c per unit of output. Finally, let $Q = \lambda R$ denote the fixed ratio at which raw tomatoes, R, are converted to tomato paste, Q ($\lambda = 0.16$ for paste). The processor's market boundary, L^u is then defined by the condition

$$(P - c)\lambda = w + tL^u$$

and, therefore,

$$L^u = [(P - c)\lambda - w]/t. \tag{3.2}$$

Determination of a firm's profit-maximizing uniform or FOB price depends upon several factors, including the elasticity of growers' raw product supply schedules, nature of the spatial surface (e.g., a line vs. a plane), density of producers on the spatial surface, and nature of competition among processors. A detailed discussion of spatial price determination is beyond the scope of this study.[6] A key point to observe, however, is that a discriminatory pricing regime such as uniform pricing can effectively "drive out" nondiscriminatory FOB pricing. The reason is that in spatial markets competition occurs only at firms' market boundaries. Growers located near market boundaries can easily shift their production to alternative processors, whereas a processing firm possesses market power over growers located near its plant because of the relatively high costs of shipping their production to a distant plant. Relative to FOB pricing, uniform pricing exploits this market power by reducing price to nearby growers and raising price to distant growers. Thus, uniform pricing makes a firm more competitive at its market boundaries, and, *ceteris paribus*, will enable that firm to capture market area from its FOB-pricing rivals. To maintain their market shares, these processors have to respond by invoking similar discriminatory pricing schemes and, hence, FOB pricing is driven out.

This conclusion holds as long as there are not multiple processors located at each processing site. The reason is that, when the processor discriminates against nearby growers under a uniform pricing scheme, he is vulnerable to losing these growers to nearby (not distant) rivals if any are available. In other words, an FOB-pricing rival located proximate to the discriminating firm's plant will be able to offer a better net price to local growers than will the discriminating processor who is practicing freight absorption and, hence, discriminating against these growers. In this sense, if there are multiple noncolluding processors located at each production site, FOB pricing is restored as the equilibrium pricing scheme.

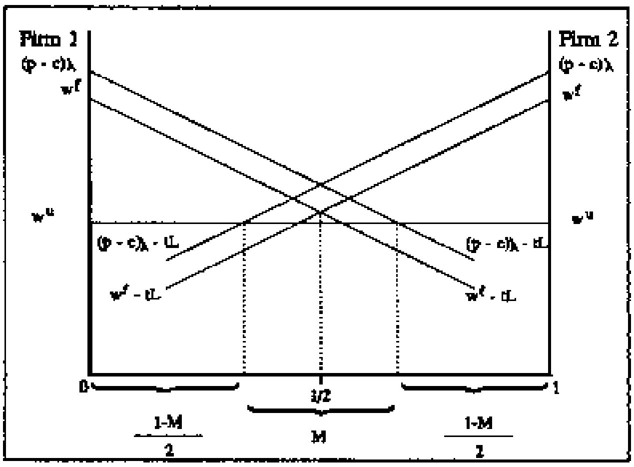
In sum, a variety of efficiency-based and competitive factors have contributed to the emergence of uniform pricing in the California processing tomato industry. The key point for purposes of this analysis is that uniform pricing facilitates the overlap of markets that is also a characteristic of the industry. The implications of uniform pricing for tomato shipping costs are studied in the next section.

3.2. Spatial Pricing and Transportation Costs

Uniform prices and overlapping markets lead to higher transportation costs to allocate a given amount of raw product than would be incurred under a system of FOB prices and nonoverlapping markets, *ceteris paribus*. This point can be demonstrated using a simple model. Consider once again two identical processing firms located at the end points of a line with unit length and farmers located along the line with uniform density. We assume for simplicity that the available supply from farmers is fixed with respect to price, and without loss of generality this total supply can be normalized to 1.0. Each firm produces a homogeneous product Q, say paste, from raw tomatoes R according to the conversion rate $Q = \lambda R$. The firms are price takers in their processed product market, selling paste for price P and incurring per-unit processing costs equal to c.

Under any equilibrium the firms will pay a common price for raw tomatoes. As a result under FOB pricing identical firms will always divide the market equally among themselves. Figure 3.2 illustrates the case

Figure 3.2. Market Boundaries Under FOB and Uniform Pricing



where the firms' mill prices are w^f and the FOB pricing schedule is formed by the equation $w^f - tL$. Total transportation costs, T, can be computed as

T=[avg. distance travelled]x[cost/unit distance]x [volume shipped].

Average distance travelled under the FOB arrangement is easily seen to be 1/4.[7] Thus, given that quantity is normalized to 1.0, the total transportation costs under FOB pricing are merely

$$(3.3) \qquad T^f = (1/4)t.$$

Equation (3.2) defines firms' desired market area under uniform pricing. If $L^u > 1/2$, the markets will overlap. Let $0 \leq M \leq 1$ define the area of overlap. Then $(1 - M)/2$ represents each firm's monopsony market area as indicated on Figure 3.2. Average transportation distance in the monopsony areas is simply $(1 - M)/4$, whereas in the disputed area, it is 1/2.[8] Thus, total transportation costs under uniform pricing are

$$(3.4) \quad T^u = (1\text{-}M)/4 \times (1\text{-}M)t + \tfrac{1}{2}Mt = t(1+M^2)/4,$$

where the first and second terms calculate costs for the monopsony areas and disputed area respectively.

Comparison of equations (3.3) and (3.4) demonstrates that the added transportation costs from uniform pricing depend upon the amount of overlapping market area. For example, if markets are fully overlapped ($M = 1$), transportation costs are double their value for the FOB-pricing regime, whereas as $M \to 0$, transportation costs converge to the same value under either regime. In this sense any exogenous factors that increase L^u (such as an increase in (P - c)) also increase M and, hence, T^u. T^f in contrast remains fixed at (1/4)t.

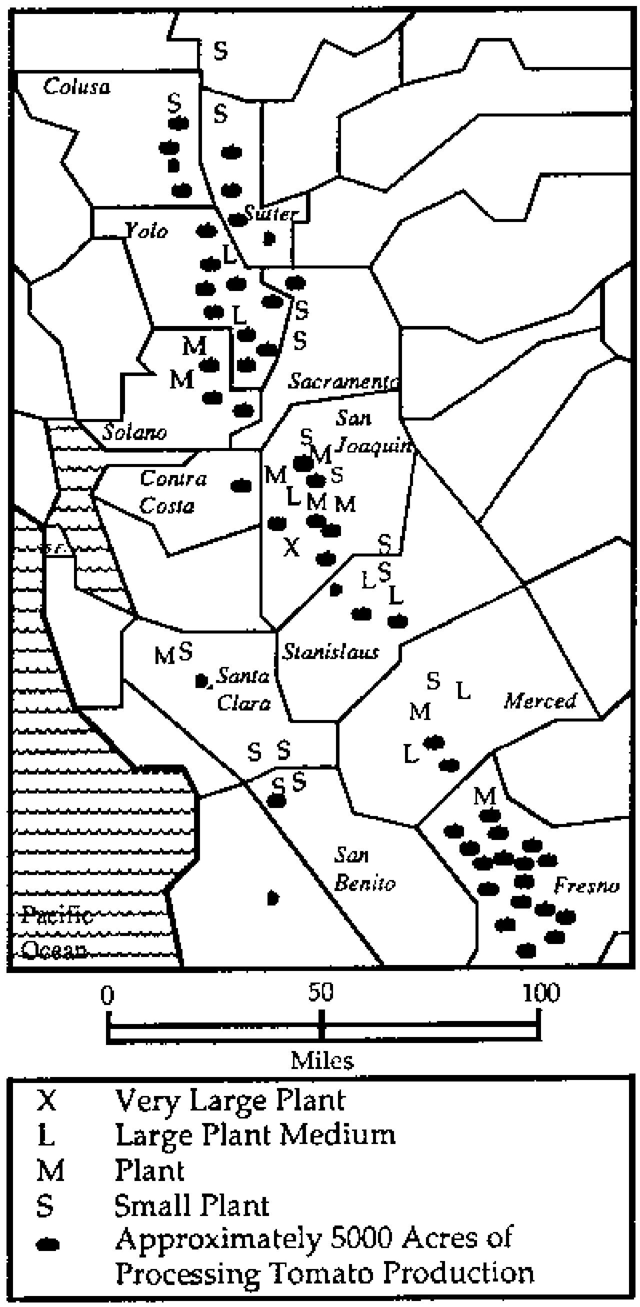
This analysis does not imply that the California processing tomato industry is inefficient because it employs a uniform pricing scheme. Rather, it only indicates that, when uniform pricing leads to market overlap, transportation costs for allocating a given amount of raw product will be higher than under a FOB pricing scheme which generates no market overlap. There may be efficiency-based reasons for markets to overlap as discussed at the outset of this chapter. The challenge in developing an optimization model for the industry is to incorporate these considerations (e.g., seasonality in production, variability in soluble solids content) as well as transportation costs into the model. The efficiency of the industry's transportation pattern can then be re-evaluated within this generalized framework. We discuss construction of this optimization model in the next chapter.

4. THE OPTIMIZATION MODEL

This chapter describes the optimization model used to allocate tomatoes from the growing areas to the processing plants. The model is designed to find the allocation of tomatoes that maximizes variable profit to the industry, given (i) the location and characteristics of raw product production, (ii) the location, capacity, and type of processing plants, (iii) transportation and processing costs, and (iv) selling prices for alternative processed tomato products. Variable profit to the industry is defined as aggregate revenue from processed product sales, less variable processing costs and transportation costs. The analysis treats plant location and capacity as given.[9] Fixed costs of operating the plants do not affect the optimal allocation pattern and are not relevant for short-run industry decision making.

The raw tomato is highly perishable, so harvesting and processing must occur nearly simultaneously, and there is little opportunity to hold raw product as inventory. Thus, it is appropriate to consider tomato allocation within a harvest year as a static problem with multiple periods. The dynamic factor linking the periods is that, once a processing plant begins operation, it operates continuously until shutting down for the season, because the costs of shut down and subsequent start up are in most cases prohibitively high. The subsequent sections in this chapter describe the steps involved in constructing the optimization model.

Figure 4.1. Production and Plant Location



4.1. Raw Product Production

The study included raw product production from the top 13 tomato-producing counties in Northern and Central California. They include Colusa, Contra Costa, Fresno, Merced, Monterey, Sacramento, San Benito, San Joaquin, Santa Clara, Solano, Stanislaus, Sutter, and Yolo Counties. Collectively, these 13 counties supplied 88% of the State's processing tomato production in 1989.[10] Figure 4.1 depicts these counties on the California map, illustrates the major producing areas within the counties, and depicts the location and size of processing plants in this area.

The goal of the optimization program is to allocate tomatoes from these producing areas to the State's processing plants so as to maximize variable profit to the industry. Figure 4.1 viewed in conjunction with Figure 2.4 provides a good overview of the tomato allocation problem. Production is scattered across much of northern and central California, and the harvest varies significantly by week across the major producing counties.[11] Firms wishing to extend their processing season must attract tomatoes from multiple regions.

The soluble solids factor. An additional consideration in establishing contracts for raw tomato production is the characteristics of the tomatoes to be produced, especially their soluble solids content. The amount of processed paste, sauce, and puree that can be obtained from a ton of raw tomatoes is directly proportional to the solids content of the tomatoes. Conversely, production of whole or diced tomato products is not affected by solids content. Therefore, *ceteris paribus*, high solids tomatoes are more valuable to plants that process a greater proportion of paste, sauce, or puree.

The data obtained for this study included the number of loads shipped per week, N_i, from each producing county $i = 1,...,13$, the mean, $S_{i,t}$, and variance, $\sigma^2_{i,t}$, of solids among the loads obtained from county i in each week. In order to incorporate soluble solids considerations into the analysis and yet maintain tractability of the optimization program, a dichotomous classification of shipments into ***high*** vs. *low* solids content was employed. Loads with solids contents above the state average for 1989, $S = 5.306\%$, were classified as high solids, and loads below the average were classified as low solids.

To achieve this classification from aggregate weekly shipments data, we assumed that the solids content of each week's deliveries from a county i in week t was distributed as a normal random variable with the mean $S_{i,t}$ and standard deviation $\sigma_{i,t}$. This information was then used to compute z values from the standard normal distribution: $z = (S - S_{i,t})/\sigma_{i,t}$. The value z was then used to estimate the proportion of loads above the statewide mean, $S = 5.306$. If $N_{i,t}$ is number of loads, the number of low solids loads was estimated as $NL_{i,t} = F(z_{i,t})N_{i,t}$.[12] The estimated number of high solids loads was then $NH_{i,t} = N_{i,t} - NL_{i,t}$. The solids content for each low-solids load was assumed to be the average across all low-solids loads: $S^L = 5.12\%$, and similarly for high-solids loads: $S^H = 5.48\%$.[13] Tables 4.1 and 4.2 give the estimated number of loads of low- and high-solids tomatoes, respectively, produced by week in each county for 1989.

An example illustrates the importance of soluble solids to tomato processing. A ton of low-solids tomatoes can make $2000 \cdot 0.95 \cdot 0.0512/0.31 = 313$ lbs. of 31% paste, where 95% is the proportion of the raw ton assumed to be usable. A high-solids ton yields $2000 \cdot 0.95 \cdot 0.0548/0.31 = 335$ lbs. of 31% paste.[14] The ratio of high- to low-solids paste production is $335/313 = 1.07$. In essence, because a load of high-solids tomatoes contains on average 7% more solids than a low-solids load, it yields 7% more of all final products such as sauces, paste, and puree that are formulated by reducing the raw product into a concentrated form.

Thus high-solids tomatoes are more valuable because they yield more output of paste-type products, but they also lead to correspondingly greater processing costs for those cost items that depend upon the amount of processed product output rather than the amount of raw product input. The key input that is output rather than input dependent is containers. Containers and cartons comprise 87.8% of nonlabor processing costs in the diversified-products plants and 57.5% of nonlabor costs in the paste-only plants. Following the procedures described in the preceding paragraph, these costs are assumed to be 7% higher when a high-solids ton is processed into paste than when a low-solids ton is processed. For a representative diversified products plant which uses 65% of its raw product for sauce, puree, and other paste type products, the increase in cost per ton is 4.55% $[(1.07 \cdot 0.65) + (1.0 \cdot 0.35)]$ higher when a high-solids load is processed.

4.2. Processing Plants

Tomato processing plants in this study were classified according to whether they processed exclusively bulk paste or manufactured diversified products, including whole peeled tomatoes, puree, and sauce, as well as paste. In some cases the classification between paste only or diversified products was ambiguous because plants may process only paste during the harvest season and then later remanufacture it into diversified products. Our rule in classifying these plants was to consider them diversified if remanufacturing occurred locally and to treat them as a paste-only processor if the remanufacturing occurred at a remote site. Based on this criterion, 26 of the 32 plants included in the study manufactured diversified products, while six manufactured only paste.

Our data included 1989 tomato shipments information for the 32 processing plants located in the study region. The raw tomato inspection process described in Chapter 2 provides detailed information on each load of tomatoes produced in the state, including its county of origin and processor destination. These data are gathered under the auspices of the Processing Tomato Advisory Board (PTAB) and are confidential, but permission was obtained to use the data provided that transactions of individual firms were not released. This stipulation necessitated that shipments data be aggregated into six regional groups of firms/plants prior to release. The geographic composition of the regions is indicated in Figure 4.2. The paste only and diversified products plants located in each region are depicted with P and D symbols, respectively.

Two major plants located south of Fresno County declined to participate in the study as did one processor in Stanislaus County. For this reason all tomatoes shipped to plants south of the Fresno and Kings County border (6% of total production) were excluded from

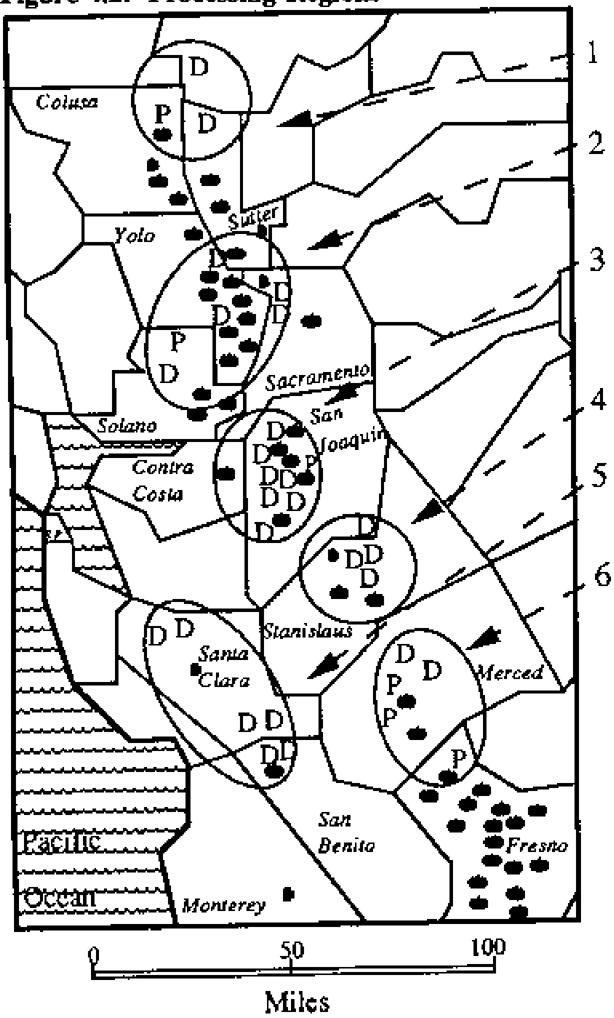
Table 4.1. Available Low Solids Loads

	WEEK																			
COUNTY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COLUSA	0	0	491	1949	1587	1566	1489	1063	452	576	402	369	269	46	85	61	17	0	0	0
CONTRA COSTA	0	0	2	129	254	410	385	514	491	411	265	61	77	1	77	63	38	18	0	0
FRESNO	0	1192	3384	6300	8347	9135	7281	6373	4482	4039	2546	1377	649	512	525	505	476	6	0	0
MERCED	0	0	3	0	6	99	307	451	857	758	820	820	494	450	129	183	211	233	65	0
MONTEREY	0	0	0	0	0	0	0	30	102	154	438	347	445	391	248	259	273	110	55	0
SACRAMENTO	0	1	0	0	0	0	0	60	390	653	636	503	724	385	481	450	231	0	0	0
SAN BENITO	0	0	0	0	0	0	0	0	2	110	260	310	449	287	500	144	68	0	0	0
SAN JOAQUIN	0	0	1	20	24	102	279	530	1372	1567	2066	2021	1927	545	905	969	771	266	69	82
SANTA CLARA	0	0	0	0	0	0	0	0	5	184	230	163	341	212	378	237	1	0	0	0
SOLANO	0	0	0	0	8	113	286	476	1359	939	1115	1162	1455	447	717	786	242	114	0	0
STANISLAUS	0	0	0	0	2	63	463	570	1244	944	928	1121	824	211	54	6	8	0	0	0
SUTTER	0	0	0	0	23	167	129	324	505	531	836	825	919	298	284	166	9	0	0	0
YOLO	0	0	43	221	908	1406	2338	3168	1624	3428	3150	2612	2367	507	1069	590	332	12	0	0

Table 4.2. Available High Soluble Solids

	WEEK																			
COUNTY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
COLUSA	0	0	289	2018	2694	1478	1474	795	326	517	643	679	462	14	34	1	0	0	0	0
CONTRA COSTA	0	0	78	444	666	608	387	420	225	70	29	43	58	0	20	11	0	0	0	0
FRESNO	19	1733	6069	8541	9050	7477	6184	4597	3293	1683	877	651	363	87	69	129	126	10	0	0
MERCED	0	0	19	0	2	24	203	621	1129	681	596	382	296	169	26	14	47	33	3	0
MONTEREY	0	0	0	0	0	0	0	0	27	128	95	67	34	37	11	13	24	8	8	0
SACRAMENTO	0	0	0	0	0	0	0	27	203	537	469	363	316	202	113	109	62	0	0	0
SAN BENITO	0	0	0	0	0	0	0	0	54	320	754	706	696	298	393	85	2	0	0	0
SAN JOAQUIN	0	0	0	61	93	195	381	503	1212	1171	1292	1492	1216	404	589	295	155	36	0	2
SANTA CLARA	0	0	0	0	0	0	0	18	75	187	193	107	148	78	90	116	1	0	0	0
SOLANO	0	0	0	0	14	102	411	446	1582	980	896	848	872	197	528	528	134	0	0	0
STANISLAUS	0	0	0	0	46	271	699	675	1023	520	585	623	543	119	67	19	4	0	0	0
SUTTER	0	0	0	0	17	404	938	1212	2069	2377	2469	2015	1726	834	535	7	1	0	0	0
YOLO	0	0	30	684	2292	3302	3760	4042	2078	3627	3683	3450	3126	608	1034	272	51	1	0	0

Figure 4.2. Processing Regions



D Diverse Plant
P Paste Plant
• 5000 Acres (approximately 150,000 tons) of Processing Tomato Production

this study as were the tomatoes shipped to the Stanislaus County processor (3-5 percent of total production in 1989). Finally, a small amount of production shipped to vegetable freezers and dryers was also excluded.

The processing plants included in the study, their location, processing region affiliation, processor type, and estimated weekly capacity are listed in Table 4.3. Plant capacities were estimated from a number of sources and confirmed with industry experts. In general, capacities of the various plants are well known throughout the industry, and we do not treat our estimates as confidential.

Estimates of annual production in a plant cannot be translated directly into an estimate of the plant's weekly processing capacity. Typically plants operate at full capacity during the height of the harvest season and at lesser rates early and late in the season. Our estimation of weekly capacities for the various plants took into account the aggregate weekly processing volume observed during the season and general knowledge regarding plant characteristics and scheduling. Specific factors considered in establishing weekly processing capacities were (i) the volume of aggregate peak week deliveries--approximately 7.8% of annual deliveries, (ii) the observation that small plants generally operate for fewer weeks than larger plants and (iii) the volume of total weekly and annual shipments to each processing region. Based on these factors, small, medium, large, and very large plants were assigned weekly capacities of 10%, 9%, 8% and 7%, respectively, of their annual processing volume.

4.3. Transportation and Processing Costs

Transportation costs. Table 4.4 provides estimated transportation mileage from each producing county to the California cities where processing plants are located. These estimates were derived by the authors based on the available transportation network and the approximate location of production in each county[15]. Transportation costs per ton, TC, for each shipment from county i to plant n were computed using these mileages, $D_{i,n}$, according to the formula:

$$TC_i^n = \$5.00 + \$0.10 * D_{i,n} .$$

Processing costs--diversified-products plants. The optimization model requires estimates of processing costs for both paste and diversified plants. Our primary source for diversified plant costs was the study conducted by Logan (1984). Logan obtained labor and nonlabor costs for a moderate-size diversified-products plant in California. The plant operates 12 canning lines, 7 of which process only whole tomatoes, and 5 of which process either sauce, puree, or paste. Production flexibility in the plant is obtained by (i) varying the number of canning lines in operation, (ii) operating from one to three eight-hour shifts, and (iii) operating from five to seven days per week.

Logan developed a computer model to select the lease cost mode of operation, given the amount of raw tomatoes arriving weekly and management priorities on the processed product pack. Logan's analysis illustrates the nature of short-run *operating economies* that exist in the industry. He writes (p. 8):

Table 4.3. 1989 Plants and Estimated Weekly Capacities

Group	Firm Name	Location	Type: P=Paste D=Diverse	Weekly Capacity (000 tons)
1	Colusa County Canning Co.	Williams	P	17.5
	Harter Packing Co.	Oroville	D	17.5
	Pacific Coast Producers	Yuba City	D	12.0
2	Contadina Foods, Inc.	Woodland	D	40.0
	Beatrice/Hunt-Wesson, Inc.	Davis	D	36.0
	Dixon Canning Co. (Cambell)	Dixon	P	27.0
	American Home Food Products	Vacaville	D	27.0
	Campbell Soup Co.	Sacramento	D	11.5
	Sierra Fruit Co., Inc.	Sacramento	D	13.5
3	Heinz U.S.A.	Stockton	D	27.0
	Heinz U.S.A.	Tracy	D	49.0
	Tri/Valley Growers	Stockton	D	20.0
	Tri/Valley Growers	Thornton	D	20.0
	Valley Tomato Products,Inc. (Campbell)	Stockton	P	25.0
	Pacific Coast Producers	Lodi	D	12.0
	Ragu' Foods, Inc.	Stockton	D	27.0
	Quality Assured Packing, Inc.	Stockton	D	11.5
4	Beatrice/Hunt-Wesson, Inc.	Oakdale	D	40.0
	Del Monte Corporation	Modesto	D	31.5
	Escalon Packers	Escalon	D	7.0
	Tri/Valley Growers	Modesto	D	15.0
5	Gangi Brothers Packing Co.	Santa/Clara	D	13.5
	Garden Valley Foods, Inc.	Gilroy	D	11.0
	Gilroy Canning Co.	Gilroy	D	13.5
	San Benito Foods	Hollister	D	13.5
	Sun Garden Packing Co.	San Jose	D	26.0
	Tri/Valley Growers	Hollister	D	15.0
6	Atwater Canning Co.	Atwater	D	14.5
	Ingomar Packing Co.	Volta	P	27.0
	Ragu' Foods, Inc.	Merced	D	37.5
	TOMA-TEK, Inc.	Firebaugh	P	20.0
	Tri/Valley Growers	Volta	P	34.0

Table 4.4. Transportation Mileage from Producing Regions to Processing Plants

County City	Colusa	Sutter	Sacra- mento	Solano	Contra Costa	Santa Clara	San Benito	Mont- erey	Yolo	San Joaquin	Stani- slaus	Merced	Fresno
Oroville	71	49	74	90	142	202	245	273	81	116	162	205	275
Yuba city	50	16	35	94	146	167	210	238	48	81	127	170	240
Williams	17	49	59	86	138	159	202	230	51	105	151	194	264
Woodland	33	31	19	41	119	140	183	211	10	65	111	154	224
Davis	44	42	30	30	108	129	172	200	10	62	108	151	221
Dixon	52	46	33	26	104	125	168	196	10	66	112	155	225
Vacaville	53	60	47	36	86	107	154	182	25	82	128	171	241
Sacramento	56	39	10	55	75	143	167	225	25	42	88	131	201
Thornton	74	59	32	30	45	115	142	166	45	17	66	104	176
Lodi	88	71	46	28	43	113	140	164	57	10	64	102	174
Stockton	102	85	60	37	24	94	121	183	71	24	45	83	155
Tracy	123	106	81	30	45	73	100	162	92	45	42	69	152
Oakdale	134	117	83	71	58	108	129	133	105	48	38	58	88
Modesto	129	112	78	66	53	103	116	120	100	34	25	45	75
Escalon	125	108	74	62	49	99	116	112	96	35	35	55	85
San Jose	139	146	137	106	70	152	56	96	105	99	111	134	153
Gilroy	169	176	167	136	100	23	28	67	135	136	79	55	127
Santa Clara	151	146	131	106	70	15	58	98	111	99	111	134	159
Hollister	184	191	182	151	115	23	10	66	148	132	75	51	123
Merced	154	137	112	99	86	104	90	148	123	67	44	36	55
Atwater	148	131	106	93	80	104	90	148	123	67	44	23	55
Volta	185	168	143	92	116	74	60	117	154	107	35	10	69
Firebaugh	210	193	168	145	132	103	89	146	179	132	72	35	25

Much of the direct labor required in tomato processing operations is more or less constant regardless of the rate of output. For example, most of the labor needed in the receiving and general preparation operations, the general processing operations, the general service functions, the brites (can) stacking, cooling, and finished pack receiving operations remains essentially unchanged no matter how many canning lines are being operated or what final products are being produced.

In contrast to these labor economies, nonlabor inputs such as cans, cartons, energy, water, and various food ingredients such as salt are added to the raw tomato input in approximately fixed proportions. Thus, we considered labor and nonlabor costs separately for both diversified products and paste plants. Nonlabor costs in either case were treated as a constant amount per unit of raw tomato processed.

Logan's labor and nonlabor costs were updated to reflect prices in our base year, 1989. Updated costs by item are provided in Table 4.5.

Table 4.5. 1989/1983 Cost Ratios for Diversified-Products Plants

Cost Item	89/83 Cost Ratio
Labor	1.122
Electricity	1.424
Gas	0.996
Lye	1.092
Salt	1.118
Cans	1.129
Cartons	1.149
Boiler start up	0.996
Evaporator clean up	1.139
Water	1.092

Sources: California Labor Market Bulletin Statistical Supplement 1983, 1989 (labor cost), Bureau of Labor Statistics, Producer Price index 1983, 1989 (electricity, gas, lye, salt, cans, cartons), and Dept. of Water Resources Bulletin 132-89 (water).

Based upon these price changes, nonlabor variable costs per ton were computed as indicated in Table 4.6:

Table 4.6. Nonlabor Input Costs per Raw Ton: Diversified-Products Plants

Cost Item	Cost/low-solids ton	Cost/high-solids ton
electricity	$1.97	1.97
gas	10.32	10.32
lye	0.95	0.95
water	0.41	0.41
salt	1.67	1.75
cans	99.97	104.52
cartons	6.56	6.86
TOTAL	**121.85**	**126.78**

We also needed to extrapolate Logan's analysis to estimate processing costs for larger-size diversified plants. Given updated labor costs, Logan's optimization model was re-run to establish the minimum labor costs for processing weekly volumes up to 18,000 raw tons per week, the capacity of Logan's base plant. Capacity within a diversified-products plant is increased by adding additional canning lines. To estimate costs of operating additional lines, labor costs and clean-up costs from Logan's analysis were modeled as a function of the number of lines and shifts operated per day, 1-12 and 1-3, respectively.[16]

To estimate these costs for larger plants, labor and clean-up cost per day were computed for alternative operating regimes in Logan's base plant. These costs were then modeled as a linear function of first shifts (S1), additional shifts (SA), and lines times total shifts (LS·ST), where ST=S1+SA, operated in the base plant:

(4.1) $LC_D = b_1(S1) + b_2(SA) + b_3(LS \cdot ST)$

This regression equation was estimated with the data obtained from re-running Logan's model with updated cost information. The estimated equation was

(4.2) $LC_D = 28076(S1) + 16546(SA) + 680(LS \cdot ST), \quad R^2 = .996$

Although Logan's model has different operating rates for different lines, it was assumed that the product mix was constant, giving an average of 72.9 raw tons processed per line per shift. This volume was then used to estimate the number of canning lines needed to obtain alternative weekly processing capacities. We estimated labor and clean up costs for plants with 18 lines (27.5 thousand ton weekly capacity), 24 lines (37 thousand tons per week), and 36 lines (55 thousand tons per week) using equation (4.2). In addition to direct cost increases from additional lines operated, shift labor costs (primarily for supervisory and receiving functions) were estimated to increase by 15% relative to Logan's base plant in the 27.5 thousand ton capacity plant, 30% in the 37 thousand ton plant, and 60% in the 55 thousand ton plant. These adjustments reflect higher management costs in larger plants due either to higher-paid managers or more managers being hired.

Given this extrapolation of Logan's analysis to accommodate larger-size plants, the final step in the process of deriving diversified plant labor and clean up costs (LC) was to estimate the relationship between these costs and tons of raw tomatoes processed (TONS). This relationship was obtained by first deriving the minimum labor and clean up cost configuration for processing alternative raw product tonnages in either Logan's base plant or its larger analogues, and then estimating a log linear average cost function:

(4.3) $\ln(LC/TON) = \alpha + \beta \ln(TONS)$.

Choice of this functional form was dictated by the nature of the operating economies apparent in the data as illustrated in Figure 4.3. The estimated function was:

(4.4a) $\ln(LC/TON) = 7.564 - 0.42 \ln(TONS)$, $R^2 = .921$

or

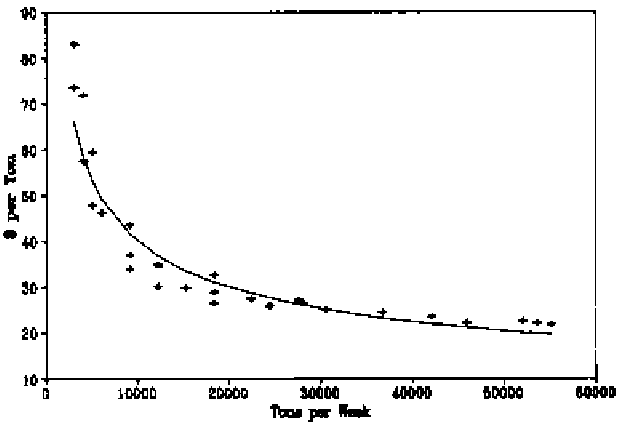
(4.4b) $LC/TON = 1927.5 \cdot TONS^{-.42}$

The estimated curve is depicted in Figure 4.3.

Processing costs--paste plants. Production cost data for a moderate-size (150-200 thousand ton seasonal capacity) paste processing plant was obtained and provided the basic data input into estimation of paste plant processing costs. Paste plants provide a product targeted at other food manufacturers as an ingredient. Bulk paste is usually packed into 55 or 300 gallon containers. Multiple canning lines are not operated as in diversified-products plants, and, hence, paste plants lack some of the operational flexibility of adiversified-products plant. In particular, once a paste plant begins operations, it is usually economical to continue operations at full capacity throughout the processing season. [17] Thus paste plants will typically operate three shifts and run seven days per week throughout the processing season.

Similar to the diversified-products case, it was useful to separate labor and nonlabor processing costs for paste plants. Nonlabor costs include costs for energy, water, supplies, ingredients, and containers. It once again is reasonable to assume that energy, water and supplies are used in fixed proportion to the volume of raw tomatoes processed, and, therefore, that nonlabor costs are constant per unit of raw product

Figure 4.3. Diversified Plant Average Labor Cost Curve



processed. Container costs increase in proportion to the solids content of the raw tomato. Estimated costs per ton for these items are indicated in Table 4.7. The container cost calculations assume that 19% of each raw ton is packed in 55 gallon drums and the remainder in 300 gal. cartons.

Table 4.7. Nonlabor Input Costs per Raw Ton: Paste Plants

Cost item	Cost/low-solids ton	Cost/high-solids ton
electricity	$1.89	$1.89
gas	3.19	3.19
supplies	0.64	0.64
55 gallon drum (19% of each ton)	6.19	6.62
300 gallon carton (81%)	1.70	1.82
weighted average	**13.61**	**14.16**

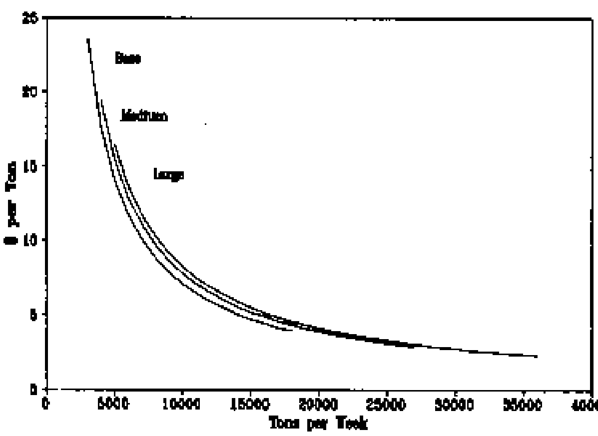
Because of the continuous nature of paste plant operations, labor-cost economies are even more pronounced in paste plants than in diversified-products plants. Once a plant begins operations, labor costs are essentially fixed with respect to the volume processed, so the average labor cost function approximates a rectangular hyperbola--it declines rapidly and then levels out for large processing volumes. To accommodate the different capacity levels of California paste plants, we estimated labor costs for three different capacity paste plants: 18,000 tons per week (the base plant), 27,000 tons per week, and 37,000 tons per week. Costs for the larger-capacity plants were obtained by adjusting costs for the base plant in consultation with industry experts. It is commonly acknowledged that substantial economies of size exist in paste plant operation. For example, one expert suggested that a doubling of plant capacity caused labor costs to rise by only about 15%. The estimated employment requirements and associated costs for each plant are summarized in Table 4.8.

Given the economics of paste processing, a paste plant incurs full labor costs, C^*, per week if it is operating, e.g., $C^* = \$82,135$ per week for the plant with 37,000 raw tons per week capacity, and essentially zero direct labor costs if the plant is not operating. This type of discontinuous cost function caused problems for the nonlinear optimization computer routine used in the analysis. As a consequence, the labor-cost function was "smoothed" by employing the following transformation:

$$(4.5) \qquad LC^P = C^*(1 - e^{-k \cdot TONS}),$$

where k is an appropriately selected parameter. This function asymptotically approaches C^* as TONS processed becomes large. The larger is the parameter k, the faster LC^P approaches its asymptote. Therefore, by setting a high value for k we were able to preserve the reality of operating economies in paste plants while maintaining a smooth labor cost function. Figure 4.4 illustrates the LC^P per ton functions for the base, medium, and large paste plants.

Figure 4.4. Average Labor Cost Curves for Paste Plants



4.4. Processed Products Output

To compute variable profit from tomato processing, we needed to make assumptions about the types of processed products being produced. The output mix, of course, differs for each diversified products plant. Output diversity for paste-only plants is reflected primarily in terms of the bulk container choice.

Each firm's product mix is confidential, so the alternative pursued here was to assume that the final product breakdown for our base diversified-products and paste plants held across all similar plants.[18] The diversified-products plant in Logan's study produced three can sizes of whole tomatoes and paste, and two can sizes of puree and sauce. The allocation of final products (by product and can size) for each raw ton in the Logan base plant and the 1989 selling price are summarized in Table 4.9. This processed product breakdown was used to construct a composite product to establish the value of a ton of raw tomatoes processed into diversified products. Since Logan's study includes no information on soluble solids, it was assumed that the volumes listed in Table 4.9 applied to a low-solids ton of tomatoes. Carrying out the computations from Table 4.9 yields \$355.10 as the FOB value of a low-solids ton of tomatoes in raw product form in the base year. About 35% of raw tomatoes in the base plant were used to produce whole tomato products. Thus, the value of a high-solids ton was $\$355.10 \cdot [(1.07 \cdot 0.65) + (1.00 \cdot 0.35)] = \$371.26$.

The same procedure was used to create a composite paste plant output. The base plant produced 19.04% of a 55 gallon drum and 6.96% of a 300 gallon carton from one ton of low-solids tomatoes. Given 1989 paste prices, the FOB value of a low-solids ton processed as bulk paste was \$181.80. A high-solids ton was correspondingly worth $\$181.8 \cdot 1.07 = \$194.53$.

4.5. The Mathematical Model

The mathematical programming model to determine the optimal allocation of raw tomatoes from northern and central California producing counties to processing facilities consisted of the following components:

(i) Total operating costs per week t, TC_t, at a diversified products plant j.

$$(4.6) \quad TC_t^j = 1927.5 \sum_{i=1}^{13} (XL_{i,t}^j + XH_{i,t}^j)^{0.58} + 108.20 \sum_{i=1}^{13} (XL_{i,t}^j + 1.0455\, XH_{i,t}^j) + 13.65 \sum_{i=1}^{13} (XL_{i,t}^j + XH_{i,t}^j),$$

$$j = 1,\ldots,26, \; t = 1,\ldots,20.$$

Table 4.8. Labor in Small, Medium, and Large Paste Plants

			Small Plant		Medium Plant		Large Plant
Job Function	$/hour	# Employed	Payroll/ Shift[a]	# Employed	Payroll/ Shift	# Employed	Payroll/ Shift
Group Leader	13.82	0	0	0	0	0	0
Mechanic A	12.18	1	97.44	1	97.44	1	97.44
Mechanic B	11.00	0	0	0	0	0	0
Instrument/Electrician	12.18	1	97.44	1	97.44	1	97.44
Boiler Operator	12.18	1	97.44	1	97.44	1	97.44
Raw Material Operator	10.00	0	0	0	0	0	0
Yard Truck Driver	9.68	1	77.44	2	154.88	2	154.88
Tomato Unloaders	8.18	1	65.44	1	65.44	1	65.44
Flume Attendant	9.00	2	144.00	2	144.00	2	144.00
Sorters	8.18	6	392.64	7	458.08	8	523.52
Clean Up	8.18	2	130.88	2	130.88	2	130.88
Tomato Preparation Operator	10.00	1	85.00	1	85.00	1	85.00
Evaporator Operator A	12.18	1	109.62	1	103.53	1	103.53
Evaporator Operator B	11.00	1	88.00	1	88.00	1	88.00
Filler - Weigher	12.18	6	584.64	7	682.10	8	779.52
Fork Lift Operator/Container Handler	9.68	3	232.32	3	232.32	3	232.32
Clean Up	8.54	1	68.32	1	68.32	1	68.32
# of employees/shift		28		31		33	
SUB TOTAL			$2265		$2,504		$2,668
Direct labor costs/shift			3,068		3,393		3,613
Direct Weekly Payroll			64,432		71,246		75,863
Direct Labor Cost/Ton @ Peak Capacity			3.58		2.64		2.11
Total Weekly Payroll (receiving clerks & lab technicians added)			$70,704		$77,517		$82,135

[a] Includes overtime if any.

Table 4.9. **Processed Product Production for Diversified-Products Plants**

Product type	Can size/case	Number of cans produced per ton	1989 price/$ case
Whole tomato	No. 303/24	231.89	8.75
Whole tomato	No. 2½/24	96.79	13.50
Whole tomato	No. 10/6	25.14	12.50
Sauce & puree	No. 10/6	13.96	12.25
Sauce & puree	No. 2½/24	18.10	12.50
Paste	No. 6/48	256.90	13.00
Paste	12 oz./24	82.89	12.35
Paste	No. 10/6	3.25	25.00

The first terms in (4.6) and (4.7) measure labor costs, the second terms measure nonlabor costs that are proportional to processed product output, while the third terms measure nonlabor costs that are proportional to the volume of raw product input (see

Tables 4.6 and 4.7 for derivation of the nonlabor costs for diversified and paste plants, respectively). In (4.7) AE^k is found for small, medium, and large paste plants on the bottom row of Table 4.8.

(ii) Total operating costs per week t at a paste plant k.

$$(4.7)\quad TC_t^k = AE^k\left(1 - e^{(-100\sum_{i=1}^{13}(XL_{i,t}^k + XH_{i,t}^k))}\right) + 7.89\sum_{i=1}^{13}(XL_{i,t}^k + 1.07XH_{i,t}^k) + 5.72\sum_{i=1}^{13}(XL_{i,t}^k + XH_{i,t}^k),$$

$$k = 1,\dots,6,\ t = 1,\dots,20.$$

(iii) Total transportation costs per week, TTC_t, toa processing plant n.

$$(4.8)\quad TTC_t^n = \sum_{i=1}^{13}(XL_{i,t}^n + XH_{i,t}^n)((0.10)D_i^n + 5.00),$$

$$n = 1,\dots,32,\ t = 1,\dots,20.$$

(iv) Weekly total revenue from processed product sales.

$$(4.9)\quad TR_t = P^D\sum_{j=1}^{26}[\sum_{i=1}^{13}(XL_{i,t}^j + 1.0455XH_{i,t}^j)] + P^P\sum_{k=1}^{6}[\sum_{i=1}^{13}(XL_{i,t}^k + 1.07XH_{i,t}^k)],$$

$$t = 1,\dots,20.$$

Variables in the optimization model are defined as follows:

- P^D diversified processed product value per ton of low solids raw tomatoes
- P^P paste product value per ton of low-solids raw tomatoes
- $XL_{i,t}^n$ Tons of low solids raw tomatoes transported from county i to plant n in week t
- $XH_{i,t}^n$ Tons of high solids raw tomatoes transported from county i to plant n in week t
- D_i^n transportation distance from county i to plant n as reported in Table 4.4.
- AE^k labor cost parameter for paste plant k

Combining the model components (4.6)-(4.9), the full optimization model can be written as:

The base optimization model is subject to the following constraints:

(4.10)

$$\max_{XL_{i,t}^{n}, XH_{i,t}^{n}} \Pi_t = TR_t - \sum_{j=1}^{26} TC_t^{j} - \sum_{k=1}^{6} TC_t^{k} - \sum_{n=1}^{32} TTC_t^{n},$$

$$t = 1,...,20.$$

(i) A plant n cannot process more tonnage than its weekly capacity, C^n as indicated in Table 4.3.

(4.11) $$\sum_{i=1}^{13} (XL_{i,t}^{n} + XH_{i,t}^{n}) \leq C^{n},$$

$$n=1,...,32, \; t=1,...,20.$$

(ii) A county i cannot supply more low-solids tonnage than its low-solids tomato production, production, $NL_{i,t}$, in any week t, as reported in Table 4.1.

(4.12) $$\sum_{j=1}^{26} XL_{i,t}^{j} + \sum_{k=1}^{6} XL_{i,t}^{k} \leq NL_{i,t},$$

$$i=1,...,13, \; t=1,...,20.$$

(iii) A county i cannot supply more high-solids tonnage than its high-solids tomato production, $NH_{i,t}$ in any week t, as reported in Table 4.2.

(4.13) $$\sum_{j=1}^{26} XH_{i,t}^{j} + \sum_{k=1}^{6} XH_{i,t}^{k} \leq NH_{i,t},$$

$$i=1,...,13, \; t=1,...,20.$$

Observe that formulation and solution of the base optimization model does not involve use of the confidential PTAB inspections data on weekly shipments from producing counties to individual processing regions. This information can be incorporated into the program as additional constraints that force the solution to approximate the actual 1989 allocation. The optimal solution and the constrained-optimal solution can then be compared and evaluated. The specific constraint that forces the (estimated) actual allocation is that:

(iv) the total raw tomato tonnage allocation from county i to all plants j = 1,...,R in each processing region r must equal the actual tonnage allocated, $AL_{i,t}^{r}$, to the region for each week t.

(4.14) $$\sum_{j=1}^{R} \left(XL_{i,t}^{j} + XH_{i,t}^{j}\right) = AL_{i,t}^{r},$$

$$i=1,...,13, \; r=1,...,6, \; t=1,...,20.$$

A less restrictive version of this constraint is to require only that:

(v) the total allocation to a region from all counties i = 1,...,13 must equal the actual allocation to the region based on PTAB records.

(4.15) $$\sum_{j=1}^{R} \sum_{i=1}^{13} (XL_{i,t}^{j} + XH_{i,t}^{j}) = AL_t^{r},$$

$$r=1,...,6, \; t=1,...,20.$$

The base model, equation (4.10) subject to (4.11)-(4.13), was solved as a static, multi-period problem using the nonlinear optimization program GAMS.[19] This solution procedure does not incorporate the dynamics that link weeks in the processing season, namely that processors remain in continuous operation throughout their processing seasons. This consideration can be introduced explicitly into the program by defining integer variables δ_t^j as follows:

(4.16) If $\sum_{i=1}^{13} \left(XL_{i,t}^{n} + XH_{i,t}^{n}\right) > 0$, then $\delta_t^n = 1$, otherwise $\delta_t^n = 0$,

$$n=1,...,32, \; t=1,...,20.$$

The consecutive operations constraint can then be imposed as follows:

(4.17) If $\delta_t^j = 1$ and $\delta_{t+2}^j = 1$, then $\delta_{t+1}^j = 1$.

To incorporate this constraint, a base period t* must be established for all plants n where $\delta_{t^*}^n = 1$.
For example, t* could be designated as the peak delivery week in a given processing season. This procedure could be repeated by choosing different base weeks and eventually selecting the solution set that achieves the highest variable profit. Fortunately, in our application of the programming model, the consecutive weeks operation constraint was met (i.e., the constraint was slack) by almost all plants in the base solution to the model, thus vitiating the need to resort to the integer constraints described in (4.16) and (4.17).[20]

5. THE BASE MODEL SOLUTION: OPTIMAL VS. ACTUAL ALLOCATIONS

This chapter presents results for the base optimization model described in the prior chapter and compares the optimal results to solutions obtained by constraining the base model to approximate the actual allocation. The base year for the analysis is 1989. In essence the base optimization problem is to allocate the loads of tomatoes contained in Tables 4.1 and 4.2 to the processing plants with the seasonal capacities noted in Table 4.3 so as to maximize variable profit to the industry. The mathematical problem is expressed as equation (4.10) subject to constraints (4.11)-(4.13).

Imposing constraint (4.14) on the model produces what we shall call *constrained model A*. This allocation requires each processing region to receive its actual weekly allocation from each county based on PTAB records. Constrained allocation A is thus an estimate of the actual allocation of tomatoes to northern and central California processing plants in 1989. *Constrained model B* imposes the less restrictive requirement indicated in (4.15), namely that the total allocation across producing counties to a processing region in 1989 equal its actual allocation.

5.1. Overview of Model Solutions

In total 3,733,600 low-solids tons and 3,720,530 high-solids tons of processing tomatoes as defined in section 4.1 were available to be allocated in 1989 from the 13 major tomato producing counties in northern and central California.[21] Table 5.1 provides an aggregate revenue and cost breakdown comparison for the 1989 solutions to the base model and constrained models A and B.

The gross profit reported in Table 5.1 is calculated as sales revenue less raw product, transportation, and variable processing costs. Excluded are fixed costs such as interest and depreciation on plant capital, administrative costs, and marketing costs. The optimal solution produces $16.14 million (1.3%) more gross profit than constrained model B and $22.96 million (1.9%) more than constrained model A.

Comparison of the base and constrained model solutions reveals evidence of modest inefficiency in hauling tomatoes as many in the industry have suspected and as expected for a spatial industry under uniform pricing--see chapter 3. The average one-way haul in the base model is 56.72 miles, compared to 66.66 miles for constrained model A and 59.28 miles for constrained model B. The extra haulage translates into approximately $7.41 million (9.3%) in additional transportation costs borne by the industry under the estimated actual allocation (constrained model A). In contrast, the transportation cost savings are small, $1.91 million, for the base model compared to constrained model B.

Relative to the base model, constrained model B only insures that each region receives its actual aggregate allocation of tomatoes in each week. The model is free to choose optimally the county of origin. The small increase in transportation costs engendered by adding this constraint suggests that the higher transportation costs observed for constrained model A are due mainly to misallocations of shipments to processing regions based on county of origin rather than to aggregate misallocations of tomatoes among processing regions. In other words, inefficient tomato transportation in California involves processors not always procuring tomatoes from the least-cost producing location, rather than some regions processing too many or too few tomatoes.[22]

The figures on the average one-way tomato haul for 1989 indicate an interesting evolution to the pattern of

Table 5.1. Aggregate Revenues and Costs for Tomato Allocation Models

Revenue/Cost($000,000)	Base Model	Constrained Model A	Constrained Model B
Sales revenue	$2,545.83	$2,507.96	$2,507.99
Raw prod. cost[a]	415.17	415.17	415.17
Trans. cost	79.55	86.96	81.46
Process. cost	824.25	801.93	800.60
Gross profit	1,226.86	1,203.90	1,210.72

[a]Raw product costs are based on prices of $53.90 and $57.50 per ton for low- and high-solids tomatoes, respectively.

tomato shipments in California. Collins, Birch, and Mueller (1959) estimated the average one-way haul to be 31 miles in 1956, but it was estimated to have increased to 100 miles by 1973 (Brandt, French, and Jesse--BFJ 1978). BFJ speculated that haulage costs would continue to increase because expansion of existing processing facilities and long distance hauling was a cheaper method of increasing production than building new facilities closer to production sites. This logic has proven to be incorrect, probably because it ignored the role of entry into the industry. Even though extant producers may prefer expansion of facilities, new entrants have incentive to locate near producing areas, thereby gaining a cost advantage in procuring raw tomatoes.[23]

Higher transportation costs account for 31% of the loss in variable profits from constrained model A compared to the base solution. Conversely, they account for only 6% of the relative profit loss in constrained model B. The rest of the profit gain to the base model is obtained from shipping tomatoes to maximize processing economies in large vs. small plants, efficiently allocating high vs. low solids tomatoes, and expanding relative production of diversified products, which apparently yielded higher profit per ton of raw product than did bulk paste in 1989. In particular, the base solution allocates 882,130 tons to the six paste-only processing plants vs. 1,189,860 tons for constrained model A.

Historically, diversified products such as canned tomatoes have been high profit items for processors (Brandt, French, and Jesse 1978), and our results may reflect a continuation of this tendency to the present time. For example, relatively high profits for diversified products may reflect returns to popular brand names such as Heinz, Ragu, or Hunts, or it may reflect market power of large processors for various processed products.[24] Conversely, the bulk paste market represents a classic competitive industry in that the product is essentially homogeneous, produced by a large number of California processors, and subject to considerable import competition (see Table 2.1).[25]

On the other hand, 1989 prices for paste were high relative to other recent years.[26] Our analysis conceivably understates profitability of paste production by either over estimating costs of producing paste relative to diversified products or failing to account for remanufacturing activities that add value to bulk paste. An additional caveat is our assumption of constant per-unit selling prices for both paste and diversified products. If superior returns to selling diversified products are related to seller market power, then allocating additional tomatoes to these markets as in the base model solution may reduce the price for these products and diminish their profitability advantage.

5.2. Optimal vs. Actual Allocations from Tomato Producing Counties in 1989

The tomato harvest in California may extend up to 20 weeks, from late June to early November. To facilitate reporting results from the model solutions, we identify five "harvest seasons" in California:

Season 1 Weeks 1-3, "early harvest." Rationale: Production in weeks 1-3 is very low, whereas it rises rapidly in week 4 to near industry weekly processing capacity.

Season 2 Weeks 4-8, "early peak harvest." Rationale: Harvest is at or near peak throughout this period, but several coastal counties are not yet producing.

Season 3 Weeks 9-13, "peak harvest." Rationale: Harvest is at or near peak and every county is producing.

Season 4 Weeks 14-16, "late harvest." Rationale: Every county is producing, but harvest is only about 25% of processing capacity for these weeks.

Season 5 Weeks 17-20, "very late harvest." Rationale: Production is very low and only a few counties are producing.

Table 5.2 depicts the base model tomato allocation from producing county to processing region for each of the five processing seasons.[27] The last two columns in the table compare the total base model allocation vs. the estimated actual allocation from constrained model A.

Fresno County is the primary source of early-season tomatoes. Season 1 Fresno County tomatoes are shipped to all processing areas except northern Regions 1 and 2 under the optimal solution. Fresno County attains peak production during season 2, allocating 400 thousand or more tons during this time to each of processing Regions 3-6. Colusa and Yolo Counties also are major sources of tomatoes during season 2. Colusa County production is utilized under the optimal solution primarily in the northern Regions, 1 and 2. Season 2 production in Yolo County is allocated mainly to its local area, Region 2, although 144 thousand tons flow southward into Region 3 (San Joaquin County).

Yolo County becomes the largest producer during season 3, harvesting nearly 750 thousand tons in 1989. Over two-thirds of that production is consumed locally in Region 2 under the optimal solution, with 100 thousand tons flowing south to Region 3 and 120 thousand tons flowing to coastal processing firms in

Table 5.2. Tomato Shipments from Producing Counties to Processing Regions by Season: Optimal vs. Actual Allocations (continues)

County	Processing Region	Season 1	Season 2	Season 3	Season 4	Season 5	Total: Optimum	Total: Actual
				Shipments in 000 tons				
Colusa	1		129.04	62.76			191.80	210.25
	2	19.97	278.73	57.43	6.17	0.44	362.74	292.30
	3		4.72				4.72	56.70
Contra Costa	2	2.05					2.05	45.47
	3		84.04		4.38	1.43	89.85	79.21
	4							19.10
	5		23.91	44.29	0.03		68.23	15.13
	6							1.23
Fresno	2							26.68
	3	48.44	400.26				448.70	764.24
	4	124.97	467.50	151.49			743.96	516.20
	5	48.06	424.33	6.88			479.27	560.00
	6	95.89	584.00	352.60	46.77	15.82	1,095.08	899.93
Merced	2							2.46
	3	0.56	30.82				31.38	3.99
	4			29.30			29.30	67.66
	5		13.03	57.20	2.13		72.36	32.87
	6			88.43	22.73	15.16	126.32	152.37
Monterey	3					0.56	0.56	20.81
	5		0.77	47.03	24.55	9.22	81.57	63.77
	6					2.46	2.46	0.00
Sacramento	1							0.56
	2		2.23	112.35	44.54	7.50	166.62	55.40
	3			10.38			10.38	112.40
	4	0.03					0.03	8.27
	6							0.38
San Benito	2							0.03
	3							6.20
	5			93.72	42.13	1.79	137.64	60.26
	6				1.57		1.57	72.73
San Joaquin	2	0.03			2.43	4.68	7.14	71.80
	3		56.01	263.15	74.66	30.68	424.50	170.42
	4			129.45			129.45	183.12
	5				1.87		1.87	110.08
	6				15.94		15.94	43.37

Region 5, the largest tomato deficit region. Fresno County was the second largest season 3 producer in 1989, allocating two-thirds of its 500 thousand ton production to Region 6 processors in Merced and Fresno Counties, and most of the remaining one-third to Region 4 processors in Stanislaus County. Stanislaus County itself produced about 200 thousand tons during season 3 in 1989, processing three-fourths locally, with the remainder processed in Region 3.

San Joaquin County produced 390 thousand tons of tomatoes during season 3 in 1989. They are allocated on roughly a two-to-one basis to Regions 3 (the local region) and 4, respectively. Sutter County to the north reached peak production of 365 thousand tons in

Table 5.2. (continued)

	Processing Region	Season 1	Season 2	Season 3	Season 4	Season 5	Total: Optimum	Total: Actual
Santa Clara	2							3.15
	3							12.67
	5		0.46	41.80	20.08		62.34	53.35
	6				8.36	0.05	8.41	1.59
Solano	1							0.77
	2				77.04	9.63	86.67	152.86
	3		47.51	262.98	4.96	2.92	318.37	228.81
	4							7.22
	5			23.94			23.94	10.06
	6							29.26
Stanislaus	3		71.40	49.00			120.40	98.34
	4			156.64			156.64	62.00
	5							25.96
	6			8.25	12.19	0.31	20.75	111.48
Sutter	1		71.96	145.00	34.00		250.96	106.39
	2			39.72	20.37	0.26	60.35	314.52
	3		10.32	180.64			190.96	60.08
	4							8.42
	5							7.91
	6							4.94
Yolo	1							88.19
	2	1.87	421.99	524.79	104.45	9.80	1,062.90	673.70
	3		144.31	102.19		0.33	246.83	457.45
	4							134.49
	5			119.14			119.14	40.70
	6							34.33
Regional Total	1		201.00	207.78	34.00		442.78	406.17
	2	23.91	702.94	734.30	255.00	32.30	1,748.45	1638.35
	3	49.00	849.41	868.34	84.00	35.92	1,886.67	2071.38
	4	218.50	467.50	373.38			1,059.38	1006.49
	5	48.06	462.50	434.00	90.78	11.01	1,046.35	980.08
	6	95.90	584.00	449.28	107.56	33.79	1,270.53	1351.60

season 3. The optimal allocation calls for 145 thousand tons to be processed locally in Region 1, and for 180 thousand tons to be hauled southward across Region 2 into Region 3. Sutter County's western neighbor Colusa County provided the other tomatoes necessary to Region 1 processors: Sutter shipped the remainder of its production to Region 2.

Production declines rapidly in season 4 (late September to early October). Few tomatoes were available during this time in Fresno County in 1989. Yolo County remained the largest producer at 104 thousand tons, all of it processed locally in Region 2 under the optimal solution. The second largest producer at 95 thousand tons was San Joaquin County. Most of its production is also processed locally in Region 3 under the optimal solution. The third largest producer during season 4 was Solano County in Region 2, selling just over 80 thousand tons. Most of this volume, too, was processed locally.

Finally, only small amounts of production were available in any county during season 5. The leading producer was San Joaquin County with about 35 thousand tons. Of this volume, 30 thousand tons were processed locally in Region 3 under the optimal solution with the other 5 thousand tons shipped north into Region 2. The regional totals contained at the bottom of Table 5.2 show the aggregate volume of tomatoes processed in each region. The largest volume is processed in San Joaquin County (Region 3) in seasons 2 and 3. In season 4 Region 2, the Yolo and Solano County area, is the largest processor. Four of the six regions extend their processing through all five seasons in the base model solution.

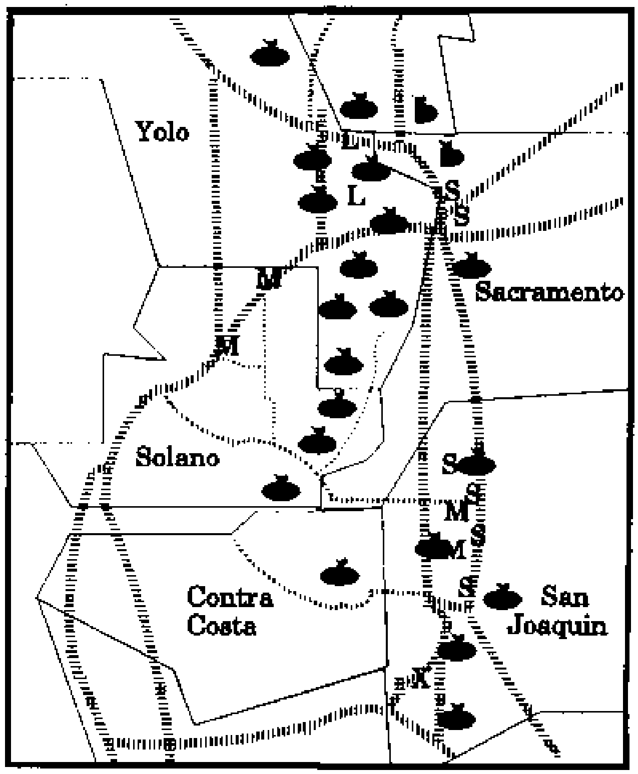
Comparison of the season wide optimal solution with the estimated actual 1989 tomato allocation, columns 8 and 9, indicates that more interregional shipments of tomatoes occurred than was optimal. In general, the base model suggests that more tomatoes should have been processed locally rather than hauled across regions.[28] In Fresno County, 320 thousand tons of tomatoes that were hauled north into Region 3 would, according to the base model solution, have been processed more efficiently in Region 4.

Similarly in Region 3, approximately 260 thousand tons of San Joaquin production hauled into regions 2, 4, 5, and 6 would have been better processed locally. In essence the base model recommends that Region 3 retain its local production rather than importing tomatoes from Fresno County.

Similar conclusions hold for Yolo County in Region 2. The base model recommends that 74% of the 1,429 thousand tons of tomatoes produced in Yolo County be processed locally. In reality only about 47% was processed in Region 2. The difference, roughly 400 thousand tons was hauled north into Region 1 (88 thousand tons) or south into Region 3 (211 thousand tons over the base solution) and Region 4 (134 thousand tons).

The additional Yolo County tomatoes processed in Region 2 under the optimal solution then free up tomatoes from Solano County to flow into Region 3 rather than remaining in Region 2. The optimal solution calls for only 87 thousand tons of Solano County production to be processed locally (vs. 153 thousand actual tons). The difference, along with modest amounts of production actually shipped into Regions 4 and 6, are allocated to Region 3 under the optimal solution. It is not surprising that Solano County production is shipped to Region 3 processors rather than to Region 2 processors, because Solano County production is primarily on the southeast side of the County and is as close, or closer, to a number of the Region 3 plants than to some of those in Region 2. This situation can be observed in Figure 5.1, an enlargement of the map in Figure 4.1, to which the approximate location of the roads by which production is shipped to plants has been added. In this area and in Region 5 geographical features reduce transportation access from producers to plants. In Regions 2 and 3 waterways limit access, and between Region 5 and

Figure 5.1. Roads Linking Region 2 and 3 Processors and Production



Central Valley production areas there are fewer roads due to the coastal range.

Region 5 is the major deficit processing region in northern and central California due to urbanization as discussed in chapter 2. The optimal and actual allocation for Fresno County, the leading supplier to Region 5, are fairly close. However, Contra Costa County production presently shipped north into Region 2 (45 thousand tons) is recommended to be shipped south into Region 5. Other increased allocations into Region 5 are called for from Yolo County (80 thousand additional tons), San Benito County (77 thousand tons presently allocated to Region 6), Merced County (38 thousand tons presently allocated to Region 4), and Monterey County (18 thousand tons presently allocated to Region 3). Conversely, reduced shipments are called for from San Joaquin County (108 thousand tons to be processed locally instead), and Stanislaus County (26 thousand tons also to be processed locally).

The transportation mileage savings from implementing the 1989 base model solution vs. the estimated actual 1989 allocation is indicated in Table 5.3. The longest average hauls are incurred during season 1 when most tomatoes are shipped from Fresno County. The optimal solution achieves an average mileage reduction of 10 during this time. Savings are somewhat smaller, about 7 miles, during the early-peak harvest of season 2. During the peak harvest period,

Table 5.3. Average One-Way Haul for Processing Tomatoes: Actual vs. Optimal Allocations[a]

Region	Allocation	Season 1	Season 2	Season 3	Season 4	Season 5
1	Actual	50.0	46.3	36.7	30.0	—
	Optimal	—	33.0	25.8	16.0	—
2	Actual	75.8	31.1	27.6	31.2	28.0
	Optimal	38.7	24.9	16.1	21.2	28.8
3	Actual	147.3	118.7	60.0	40.7	22.2
	Optimal	151.0	97.0	48.9	16.4	19.0
4	Actual	75.7	79.0	60.7	59.8	50.1
	Optimal	79.7	81.3	50.8	—	—
5	Actual	124.5	134.1	94.7	55.6	92.1
	Optimal	131.8	135.7	65.2	32.4	56.9
6	Actual	51.9	51.5	47.7	73.3	58.5
	Optimal	56.1	57.1	45.2	55.4	52.3
Total	Actual	97.3	80.4	53.1	46.4	55.8
	Optimal	87.8	73.7	41.7	28.4	35.5

[a]Missing values indicate that no tomatoes were processed in that region in that season.

season 3, the optimal solution again reduces the average haul by 11 miles. The largest reduction in haul during this time is achieved in Region 5, with average mileage of 65 under the optimal solution vs. 95 actually. Smaller mileage savings are achieved during this time in Regions 1, 2, 3, and 4. Average mileage savings of 18 and 20 are achieved in seasons 4 and 5, respectively.

Table 5.4 provides an additional perspective on tomato transportation in California. It indicates average weekly shipment mileage for each of the 13 producing counties under the base model solution. To economize on the data reporting, the table is limited to information for the peak harvest seasons, 2 and 3. As the major tomato surplus area, Fresno County ships its tomatoes the greatest average distances throughout season 2, with an average haul of in excess of 100 miles. Conversely, Yolo County tomatoes are shipped on average less than 30 miles during season 2.

With the onset of season 3, coastal counties begin producing and shipping primarily to Region 5, enabling Fresno County's declining production to be consumed primarily in nearby Regions 4 and 6. The average Fresno County haul thus declines to the state average of 55 miles for weeks 11-13. The longest hauls during most of season 3 are incurred in shipping Monterey County's production of 47 thousand tons and Contra Costa County's 44 thousand ton harvest to Region 5 processors. Similarly high mileage is incurred in shipping Sutter County's season 3 harvest, because the optimal solution calls for half to be allocated south into Region 3.

Of course, mileage was generally higher under the actual allocation estimated by constrained model A. The average one-way haul in Fresno County, for example, remains over 100 miles through week 8 and above 90 miles for weeks 9-11. Weekly average hauls of about 150 miles were estimated for Monterey County in weeks 8 and 9 and 90-110 miles in weeks 10 and 12. Actual Yolo County hauls are 5-15 miles more for most weeks than under the base model solution. Conversely, average actual mileages in Contra Costa County are less than the base model mileages, ranging between 46-62 for weeks 7-13.[29]

Table 5.4. **One-way Haul Mileages for California Tomato Producing Counties: Base Model Solution for Peak Production Weeks**[a]

County	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
Colusa	44.5	41.7	37.6	34.8	27.3	23.6	23.3	22.8	22.9	33.0
C. Costa	30.0	32.3	36.4	39.2	71.0	70.6	71.0	71.0	71.0	70.0
Fresno	120.3	107.4	105.2	93.7	81.4	69.0	61.0	52.7	56.4	55.0
Merced		69.0	69.0	69.0	62.4	41.6	33.4	9.1	45.4	34.4
Monterey					67.8	96.0	67.0	68.6	69.0	68.8
Sacramento					10.0	10.1	14.3	13.0	10.4	11.8
S. Benito						10.0	10.0	20.4	18.7	23.1
S. Joaquin	10.0	10.0	10.0	24.0	26.7	20.1	27.4	26.8	36.0	33.0
S. Clara					17.0	17.0	17.3	18.0	18.0	17.0
Solano		28.0	29.6	36.0	37.0	58.6	36.9	37.0	37.0	37.3
Stanis.		42.0	42.8	43.6	42.0	41.4	37.7	38.0	36.6	38.8
Sutter		16.0	16.0	28.5	42.7	31.7	69.2	78.2	55.4	65.3
Yolo	10.0	21.3	19.3	31.7	31.4	14.3	39.0	35.9	41.3	40.3

[a]The optimization model assigns a minimum of 10 miles for each haul, so reported mileages equal to 10.0 denote tomatoes processed in the immediate vicinity of the producing area.

5.3. The Estimated Value of Expanded Tomato Production

Part of the solution to the optimization model summarized in equations (4.10)-(4.13) is a set of values or shadow prices that estimate the increase in the objective function attainable by relaxing each constraint one unit. In this section we examine the prospects for expanding (or, equivalently, reducing) tomato acreage in each of the 13 producing counties. This analysis must also be interpreted with caution. First, growing conditions may simply make it infeasible to expand significantly the time period a county is in production. For this reason, we consider expansion or contraction only for those weeks in which a county was in production in 1989, plus one additional week at the beginning and end of its 1989 harvest season.

Second, the estimated shadow prices report only the incremental variable profit (loss) from growing additional (fewer) tomatoes. They do not consider the availability and opportunity costs of the additional resources, most notably land, that would be required to expand tomato production. High land opportunity costs due to urbanization have, for example, caused the decline in tomato production in the Bay Area coastal counties. Third, the shadow prices report the value of a marginal (literally, one ton) expansion of production. For decision making purposes, the relevant magnitude of production change is often much larger, and the value of a one-unit expansion may not be meaningful in these cases.[30]

Tables 5.5 and 5.6 report the maximum incremental value attainable by the industry from expansion of low- and high-solids tomato production, respectively, in each of the 13 counties. These shadow prices are the sales value of a ton of raw tomatoes in processed product form less costs for transportation and processing, all in terms of their 1989 values.[31] The largest shadow value for each week is indicated with bold lettering.

Table 5.5. Marginal Values ($/Ton) of Expanding Low-Solids Tomato Production

County	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Colusa		188	209	203	162	158	156	157	162	154
Contra Costa		**194**	200	208	166	162	162	162	167	160
Fresno	**140**	193	190	187	155	150	150	154	159	157
Merced			198	206	163	159	159	161	165	162
Monterey							156	160	165	161
Sacramento							160	160	165	158
San Benito		190						165	169	**166**
San Joaquin			206	203	**170**	**164**	**163**	163	165	161
Santa Clara								**167**	**173**	166
Solano				202	168	162	162	162	164	160
Stanislaus				**209**	166	161	161	164	164	162
Sutter		189		207	165	161	158	157	162	155
Yolo			**211**	207	165	161	159	159	164	157

County	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
Colusa	157	163	190	198	202	206	210	197		
Contra Costa	162	168	195	198	203	206	207	202	176	
Fresno	159	166	196	195	205	209	206	199	174	
Merced	162	168	198	197	**207**	**211**	208	201	176	174
Monterey	160	167	193	196	198	201	198	190	171	167
Sacramento	160	166	193	200	203	207	211	201		
San Benito	164	171	197	200	202	206	203	196		
San Joaquin	163	170	197	195	204	207	208	**205**	**179**	**183**
Santa Clara	**168**	**174**	**201**	**204**	206	204	201	195		
Solano	162	168	195	199	203	206	211	203	177	
Stanislaus	164	170	198	196	206	210	207	200		
Sutter	157	163	190	199	202	206	209	199		
Yolo	159	165	192	201	204	208	**213**	201	174	178

Depending upon the week and the producing county, an additional ton of high-solids tomatoes is worth 9 - 13 dollars more than an otherwise equivalent ton of low-solids tomatoes. This information may be valuable in structuring price premia for production of tomatoes with high-solids content. Presently, some processors do not offer such premia, and, among those that do, the magnitude of the premium is often less than the net value of the incremental solids based on our analysis.[32] The difference between high and low solids tomatoes in the model was approximately three tenths of a percent. This difference yields about 7

Table 5.6. Marginal Values ($/Ton) of Expanding High-Solids Tomato Production

County	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Colusa		198	219	213	172	168	166	166	174	167
Contra Costa		**204**	210	217	176	172	172	172	177	170
Fresno	**150**	203	200	197	165	160	160	164	169	169
Merced				216	173	169	169	171	175	175
Monterey								170	175	171
Sacramento							170	170	175	168
San Benito								175	179	**176**
San Joaquin			215	213	**179**	**174**	173	173	175	171
Santa Clara							**174**	**177**	**182**	175
Solano				212	178	172	172	172	174	170
Stanislaus				**219**	176	171	171	174	174	172
Sutter				216	175	171	168	167	172	165
Yolo		201	**221**	216	175	170	169	169	174	167

County	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
Colusa	169	173	200	208	211	216				
Contra Costa	172	178	205	208	213	216	216			
Fresno	170	176	206	205	215	218	216	209	184	
Merced	175	178	208	207	217	**221**	218	211	186	
Monterey	170	177	203	206	208	211	208	200	181	**177**
Sacramento	170	176	203	210	213	217	221	211		
San Benito	174	181	207	210	212	216	213			
San Joaquin	173	179	206	205	214	217	218	**215**	**189**	
Santa Clara	**177**	**184**	**211**	**213**	215	214	211			
Solano	172	178	205	208	213	216	221	213		
Stanislaus	174	180	207	206	216	220	217	210		
Sutter	167	173	200	208	212	216	220			
Yolo	169	175	202	210	**214**	218	**223**	210		

percent more output in products like paste and sauces. The difference between the high and low solids marginal values reflects the amount of product going to these types of products vs. whole tomato products, which in turn depends on the assortment of diversified or paste plant types operating within a region.

Because of the stable premia for high-solids tomatoes, we can focus our discussion of the shadow prices on the incremental values of low-solids production contained in Table 5.5. Very early-and very late-season production was not particularly valuable in 1989 because processors were unable to operate at capacity and often the tomatoes were hauled long distances. During season 2, San Joaquin County production usually had the highest value. San Joaquin County in Region 3 is the location of seven tomato processors with a joint weekly capacity of 191,500 tons (Table 4.3). San Joaquin County, however, produces almost no tomatoes in Season 1 and only 56 thousand tons in season 2. Therefore, considerable volume must be shipped from other producing regions. The gain from decreased transportation costs makes San Joaquin County season 2 tomatoes the most valuable production in northern and central California. San Joaquin County production peaked in 1989 at near 400 thousand tons in season 3, obviating the need for long-distance hauls and reducing the value of additional San Joaquin County production during this time. Finally, San Joaquin County production is again relatively very valuable in weeks 18-20, season 5. This result reflects that San Joaquin County processors have the capability, due to the County's ability to harvest tomatoes well into the fall, to extend their processing season longer than most rival plants.

The most valuable peak-harvest (season 3) tomatoes are grown in Santa Clara County. This result is not surprising because that area, Region 5, is the home of six processors and as we have noted is a significant tomato deficit region. The transportation cost savings from utilizing local production makes it valuable, but the demands of urbanization make it unlikely that tomato production will expand in this area. •

Incremental Fresno County production is among the least valuable in the State, especially through the first three processing seasons. As the area's major surplus producing region, Fresno County tomatoes are often shipped long distances as Table 5.4 indicates. Presently, season 4 and 5 production in Fresno County is very limited, but, as Tables 5.5 and 5.6 show, it is considerably more valuable than early-season production, primarily because it can be used locally in Region 6 rather than shipped elsewhere.

Region 2, the home of Yolo County, is the location for six processors with joint weekly capacity of 155 thousand tons. The incremental value of Yolo County production is also relatively low during most of seasons 2 and 3, reflecting the County's large production and status as an exporter during this time into Regions 3 and 5. Yolo County production is especially valuable during seasons 2 and 5 when, to date, only limited production has taken place.

In general, the shadow prices show a relatively consistent pattern across counties. They are lowest in weeks 1, 19, and 20 due to high processing costs generated by excess capacities. They also tend to be low during the middle period, weeks 5-12, of the processing season, when most plants are able to operate at full capacity during harvest years similar to 1989. The highest marginal values were attained during the early harvest in weeks 2-4 and then again during the late harvest in weeks 13-18. This information may be useful in devising price premia for early- and late-season harvests to give growers appropriate incentives to fill these market windows.[33] Higher late-season prices are needed to compensate for the higher risk of late season production, typically lower solids levels and thus price, and the lower proportion of ripe tomatoes to be harvested.

A final caveat must be noted in examining the change in the shadow prices from season to season. Tomato solids are affected by changes in temperature and day length and so early and late season tomatoes have lower average solids than those harvested during the height of the season. While this is reflected in the model by a reduction in the proportion of high-solids tomatoes available, the shadow values reflect the value of the overall average solids levels (5.12% for low and 5.45% for high-solids tomatoes).

5.4. Optimal Allocations to Processing Plants

In this section we report information on the optimal allocation of the 1989 harvest to the 32 tomato processing plants included in the study. We continue to designate firms according to their regional location and also separate paste vs. diversified-products processors.

Table 5.7 summarizes the operating condition of each of the plants for the 20 week harvest and processing season. An 'O' designates that a plant was operating under the optimal solution during the indicated week, while an 'X' designates that the plant was operating at capacity.[34] The first plants to begin operation under the optimal solution are diversified-products processors in Region 6. This outcome corresponds to the earliest harvest occurring nearby in Fresno County. Twelve plants encompassing five of the six regions are in operation by week 3, including all the plants in the Stanislaus County, Region 4, area. Though hauling distances are long for Region 5 plants they are as close, or closer, to Fresno county production than processors in Region 1, 2, or 3: four of the six Region 5 plants open in week 3, with the remaining two beginning in week 4.

Week 4 marks the onset of season 2 and the peak harvest period. All diversified-products plants in Regions 3-6 are operating at or near capacity during this week and continue to operate at capacity through week 12 under the optimal solution. All diversified-products plants in northern Regions 1 and 2 are operating at capacity by week five and continue to operate at capacity through week 13, meaning that all diversified-products plants in the study operated at capacity for at least nine weeks under the optimal solution for the 1989 harvest.

Table 5.7. Operating Condition for Tomato Processing Plants Under the Optimal Allocation for the 1989 Harvest (continues)

Region	Plant	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
					Diversified Products Plants						
1	1					X	X	X	X	X	X
	2				X	X	X	X	X	X	X
2	1				X	X	X	X	X	X	X
	2				X	X	X	X	X	X	X
	3					X	X	X	X	X	X
	4					X	X	X	X	X	X
	5			O	X	X	X	X	X	X	X
3	1			X	X	X	X	X	X	X	X
	2				X	X	X	X	X	X	X
	3				X	X	X	X	X	X	X
	4				O	X	X	X	X	X	X
	5				X	X	X	X	X	X	X
	6				X	X	X	X	X	X	X
	7				X	X	X	X	X	X	X
4	1			X	X	X	X	X	X	X	X
	2		X	X	X	X	X	X	X	X	X
	3			X	X	X	X	X	X	X	X
	4			X	X	X	X	X	X	X	X
5	1			X	X	X	X	X	X	X	X
	2			X	X	X	X	X	X	X	X
	3			X	X	X	X	X	X	X	X
	4				X	X	X	X	X	X	X
	5				X	X	X	X	X	X	X
	6			O	X	X	X	X	X	X	X
6	1		O	X	X	X	X	X	X	X	X
	2	O	X	X	X	X	X	X	X	X	X
					Paste Plants						
6	1					X	X	X	X	O	O
	2					X	X	X	X	X	X
	3					X	X	X	X	X	X
Other	1					X	X	X	X	O	X
	2					O	X	X	X	X	X
	3						O	O	O		X

Table 5.7. (Cont.)

Region	Plant	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
					Diversified-Products Plants						
1	1	X	X	X							
	2	X	X	X	X	X					
2	1	X	X	X		X					
	2	X	X	X	X	X	X	O			
	3	X	X	X	X	X					
	4	X	X	X							
	5	X	X	X	X	X	X				
3	1	X	X	X							
	2	X	X	X							
	3	X	X	X							
	4	X	X	X		X	X		X	O	O
	5	X	X	X							
	6	X	X	X							
	7	X	X	X	X	X	X	X			
4	1	X	X	X							
	2	X	X	X							
	3	X	X	O							
	4	X	X	X							
5	1	X	X	X	X	X	X	O		O	
	2	X	X	X	X	X					
	3	X	X	X							
	4	X	X								
	5	X	X								
	6	X	X	X	O	O					
6	1	X	X	X							
	2	X	X	X	X	X	O	O	O	O	
					Paste Plants						
6	1	O									
	2	X									
	3	X									
Other	1	X	X								
	2	X	O								
	3	O									

As noted, under the cost and revenue information compiled for this study, bulk paste production was generally less profitable than production of diversified products. Thus, the six paste plants in the study tended to operate fewer weeks than the diversified-products plants. The three paste plants located in Region 6 began operating in week 5, two operated at capacity for weeks 5-11 and all these had ceased operation by week 12. The cessation of operations at this time coincides with a sharp decline in availability of production from Fresno and Merced counties. The other three paste plants are located in Regions 1, 2, and 3. They follow an operating cycle similar to the Region 6 plants. Two begin operating in week 5, and the third in week 6. Two continue operating through week 12, with the other stopping after week 11.

With the onset of season 4 in week 14 a number of diversified-products processors cease operating under the optimal solution. All Region 4 processors shut down for the season during this week. The highest concentration of production during season 4 is in Yolo County. This production is all consumed locally in Region 2 under the optimal solution and is sufficient to sustain two Region 2 processors' operations through week 16.

All but a few processors have shut down by the beginning of the very late Season 5 harvest. The tomatoes that were available to be processed were spread across a large part of the area, including the southern (Fresno County), central (San Joaquin County), Northern (Yolo County), and coastal (Monterey County) regions. The response under the optimal solution to this harvest scenario is essentially to designate one plant in each producing area to receive that area's production. For example, a single processor remains in operation in week 17 in Regions 2, 3, 5, and 6, although with one exception the plants are unable to operate at capacity.[35] Interestingly, the plant that remains open during this time under the optimal solution is not necessarily the largest plant in the region. Based on our size classifications set in chapter 4, two of the plants operating in season 5 are small, one is medium, and two are large.

It is important to use caution in interpreting results when plants are operating considerably under capacity. In these cases the non-linear algorithm used to find the optimal allocation may be unable to "see" an alternative better allocation, even when one exists. The algorithm moves from one allocation to another by choosing to move in the direction which gives the highest improvement in the objective function. Given the benefits to operating at capacity, or more accurately in this case the costs of not doing so, it is possible for the algorithm to get "stuck" on one allocation because decreasing the allocation to one plant increases per unit cost more than the profits gained by moving a single

Table 5.8. Excess Tomato Processing Capacity by Region: 1989 Harvest (000 Tons)

Reg.	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
1	46.0	46.0	46.0	29.0						
2	155.0	155.0	131.1	52.0	20.1					
3	191.5	191.5	142.5	28.1	25.0	22.3	10.2	22.5	25.0	
4	93.5	62.0								
5	92.5	92.5	44.4							
6	132.5	89.6	81.0	81.0					11.0	17.9

Reg.	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
1			17.0	29.0	29.0	46.0	46.0	46.0	46.0	46.0
2		13.7	27.0	79.0	5.2	79.0	122.7	155.0	155.0	155.0
3	14.2	25.0	25.0	171.5	159.5	159.5	171.5	179.5	189.7	189.4
4			0.6	93.5	93.5	93.5	93.5	93.5	93.5	93.5
5			28.5	55.1	52.6	79.0	83.1	92.5	90.9	92.5
6	24.8	81.0	81.0	95.5	95.5	100.4	110.6	123.3	131.3	133.0

ton to another plant. Unfortunately this result can keep the program from testing whether a complete reallocation of tonnage from one plant to the other would be an improvement. Table 5.8 reports weekly excess processing capacity by processing region. A fact of tomato processing is that firms must plan their capacities to meet the peak harvest during seasons 2 and 3. Most plants and regions, therefore, have substantial excess capacity during the other seasons. The industry has moved in two directions to better utilize plant capacities: (1) the harvest has been extended in some cases up to 20 weeks as this report documents, and (2) some plants use nonharvest weeks to remanufacture paste into other products. Our designations of operating condition in Table 5.7 or excess capacity in Table 5.8 refer only to the primary harvest, and do not take account of these remanufacturing activities.

The greatest early-season excess capacity is in the San Joaquin County, Region 3 area. Most Region 3 processors do not begin operating until week 4 under the optimal solution, and modest excess capacity in Region 3 remains through week 9. As the Fresno County harvest begins to decline in season 3, Region 6 becomes the main surplus processing capacity area. Under the optimal solution for the 1989 crop, the three Region 6 paste plants shut down after week 11, while one of the diversified products plants shuts down after week 13. The other diversified-products plant in the Region remains open through week 19 as a destination for late-season Fresno County production.

Excess capacity existed in all six regions beginning in week 13. Regions 4 and 5 had the least excess processing capacity under the optimal solution. Region 4 operates at full capacity for 10 weeks from week 3 through week 12, region 5 operates at full capacity for weeks 4-12, while Region 1 operates at full capacity for weeks 5-12.

Analogous to the shadow prices derived for county-level raw tomato production, the base model solution also includes marginal values on plant capacity constraints. For weeks when a plant j is operating at full capacity, these shadow prices indicate the increment to variable profit obtained by reallocating one additional ton of tomatoes from another plant, one not operating at capacity, to plant j (i.e., relaxing j's capacity constraint by one ton). Thus, the shadow prices measure the value by week of expanding processing capacity in each plant by one ton based on the 1989 harvest.

Table 5.9 reports the plant capacity shadow prices for the peak harvest weeks--seasons 2 and 3. The plant designated in each week as "Mar" is the marginal plant for that week because it is not operating at capacity. In other words, it is the plant that is likely to lose tomatoes under the optimal solution if any of the other plants expanded their capacity. The highest shadow price in each week is indicated by bold lettering. These shadow prices indicate the value of an additional ton of tomatoes to the plant in question net of the loss to the plant which otherwise would have processed it and the additional transportation used to get it from the lowest valued site to the one in question.

The most valuable processing capacity during season 2 is located in Region 6, where additional diversified-products capacity would augment variable profit by more than $55/ton during weeks 5-8. The comparative advantage to a Region 6 processing location during this period reflects the large Fresno County harvest during season 2. With the onset of season 3, Region 2 capacity becomes the most valuable, reflecting Yolo County's status as the leading tomato-producing county during this time.

The value of additional processing capacity for diversified-products plants generally varies between $40-55 per ton during weeks 5-11. The values are usually about 8% lower in Region 5, reflecting the long haul that is necessary to bring tomatoes to this region. The shadow prices exhibit a pronounced decline in week 12 and then again in week 13, reflecting the declining harvest during this period in 1989, especially in Fresno County (see Tables 4.1 and 4.2).

The recurring theme throughout the base model analysis of comparatively lower paste plant profitability is also reflected in Table 5.9. The value of added paste-plant capacity in most weeks is less than one fourth the diversified-products plants. For weeks which paste plants operate, they are the "marginal" plants that would lose tonnage if diversified plant capacity were expanded as envisioned by the shadow price analysis.

Finally, we turn to analysis of transportation mileages for shipping product to the 32 processing plants. Table 5.10 contains the estimated average mileages by season under the base model solution and the overall average across seasons. The overall average mileage from constrained model A, the estimated actual outcome, is also provided as a comparison.

The tomato transportation story told by Table 5.10 is consistent with the prior analysis in this chapter. Season 1 hauls are high for most plants operating at this time except those in Region 6, which are proximate to Fresno County production. Mileages during season 2 are highest as expected for Region 5 firms, with one plant recording average mileage in excess of 150 during this season. Several Region 3 processors in San Joaquin County also incur average one-way hauls in excess of 100 miles during this period, reflecting that only 56 thousand tons were

Table 5.9. Marginal Values ($/Ton) of Tomato Processing Plant Capacity During Peak-Harvest Seasons for the 1989 Crop

Region	Plant	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
						Diversified-products plants					
1	1		37.5	41.8	43.6	44.4	39.9	46.4	44.4	38.3	11.3
	2	1.4	42.6	46.9	49.9	50.7	46.1	52.6	50.7	44.6	17.5
2	1	4.4	45.6	49.9	51.7	51.7	46.5	53.6	51.7	45.6	18.5
	2	7.0	48.8	53.1	54.9	54.9	49.8	56.9	54.9	48.8	21.8
	3		40.4	44.7	46.5	46.5	41.9	48.6	46.7	40.4	13.5
	4		38.8	43.1	44.9	44.9	40.4	47.1	45.1	38.8	12.0
	5	8.7	49.9	54.2	56.0	55.4	50.3	**57.4**	**55.4**	**49.3**	**22.3**
3	1	3.2	46.5	50.8	50.8	48.4	48.2	50.3	48.4	42.3	15.2
	2	10.5	42.9	47.2	47.2	47.2	45.7	49.1	47.2	41.1	14.0
	3	0.5	42.8	47.1	47.1	47.1	45.6	49.0	47.1	41.0	13.9
	4	Mar	36.1	41.7	42.2	42.2	40.7	44.2	42.2	36.1	9.1
	5		35.9	40.2	40.2	40.2	38.7	42.2	40.2	34.1	7.1
	6		40.6	44.9	44.9	44.9	43.4	46.9	44.9	38.8	11.8
	7		41.5	45.8	47.6	47.6	44.2	49.6	47.6	41.5	14.5
4	1	19.4	51.8	56.1	56.1	52.6	47.5	49.1	47.1	41.0	13.9
	2	19.3	51.7	56.0	56.0	52.5	47.4	49.0	47.0	40.9	13.9
	3		38.0	42.3	42.3	38.8	33.7	36.2	34.2	28.1	
	4	14.1	46.5	50.8	50.8	47.3	42.2	43.8	41.8	35.7	8.6
5	1		40.8	45.1	45.1	41.6	37.8	40.2	43.1	35.6	9.9
	2		40.4	44.7	44.7	41.2	37.4	39.8	41.3	33.8	8.1
	3		38.3	42.6	42.6	39.1	35.3	37.8	39.2	31.7	Mar
	4	6.2	38.6	42.9	42.9	39.4	34.3	41.2	39.3	33.2	
	5	5.3	37.7	42.0	42.0	38.5	33.4	40.3	38.4	32.3	
	6	5.6	42.7	47.0	47.0	43.5	38.4	45.4	43.4	37.3	10.3
6	1	15.3	47.7	52.0	52.0	48.5	43.4	43.4	43.0	36.4	6.4
	2	**22.4**	**54.7**	**59.0**	**59.0**	**55.5**	**50.4**	50.4	50.0	43.4	13.1
						Paste plants					
6	1		Mar	6.2	6.2	Mar					
	2		6.2	10.5	10.5	7.0	1.9	3.5	1.5		
	3		2.0	6.3	6.3	3.9	Mar	Mar	Mar		
other	1		3.9	5.7	5.1		7.1	5.1			
	2		2.9	Mar	Mar		5.9	3.9			
	3						2.0				

harvested during season 2 in San Joaquin County during 1989.

Production is widespread across the state during season 3, causing the average haul under the base model solution to decline relative to season 2 for all firms except one Region 3 paste processor. The longest hauls are still recorded by Region 5 processors, but the highest average haul for any region is under 70 miles during this period.

Late season haulage distances in seasons 4 and 5 are generally low, as most of the harvest is processed by local firms under the optimal solution. Region 5 firms who remain in production during this period, however, generally continue to incur the longest hauls.

Table 5.10. Average Shipment Mileages for Tomato Processing Plants by Season: Optimal vs. Actual Allocation

Reg.	Plant	Season 1	Season 2	Season 3	Season 4	Season 5	Total: Optimum	Total: Actual
				Diversified Products Plants				
1	1		60.8	49.0			54.2	74.0
	2		30.1	16.0	16.0		21.9	31.0
2	1		40.6	25.0	36.0		33.1	38.1
	2		12.4	10.0	20.4	28.8	14.3	18.7
	3		24.4	10.0			16.4	44.6
	4		26.0	17.4			21.2	65.9
	5	38.68	32.0	20.0	18.5		24.9	31.1
3	1	151.05	114.4	73.9			99.2	124.3
	2		108.7	36.0			72.3	87.7
	3		109.0	51.3			80.2	91.7
	4		59.3	10.0	10.0	20.2	29.1	49.9
	5		84.0	30.6			57.3	88.7
	6		120.8	38.0			79.4	101.4
	7		41.0	40.9	18.0	17.6	34.5	46.6
4	1	88.0	88.0	47.8			69.7	85.4
	2	75.0	75.0	51.1			65.1	60.4
	3	85.0	85.0	45.2			67.1	54.1
	4	75.0	75.0	60.4			68.4	61.7
5	1	123.0	123.0	18.8	20.1	56.8	63.4	82.5
	2	127.0	112.7	42.6	55.5		78.1	105.5
	3	129.0	128.6	63.9			99.3	112.6
	4		137.4	72.4			108.5	119.4
	5		143.0	97.4			122.8	137.2
	6	153.0	152.5	84.7	27.0		112.5	115.1
6	1	60.0	60.0	55.6			58.1	63.9
	2	55.0	55.0	53.7	55.4	52.3	54.5	59.9
				Paste Plants				
6	1		69.0	63.8			67.9	18.9
	2		25.0	25.0			25.0	10.8
	3		68.0	29.2			51.4	67.4
Other	1		17.0	17.0			17.0	37.8
	2		10.0	10.0			10.0	25.0
	3		29.4	66.6			53.2	52.5

Among the 32 processors, 27 incur shorter hauls under the optimal solution than were actually incurred based on the solution to constrained model A. The one-way haul savings for the two Region 1 diversified-products processors are each 10-20 miles. In Region 2 the savings vary across processors, ranging from a high of 45 miles to a low of about five miles. The optimal haul mileages in Region 3 are 10-25 miles less than the actual allocation for five of the seven diversified-products processors; one is estimated to save over 30 miles.

Mileage in Region 4, the Stanislaus County area, is not reduced significantly under the optimal solution. In fact, three of the four processors incur longer hauls under the optimal solution. Although the base model solution differs in a number of respects from the actual allocation for Region 4 (see Table 5.2), the upshot is that this centrally located Region can procure tomatoes from Fresno, Merced, San Joaquin, and (southern) Yolo Counties without affecting haulage costs in a significant way.

The average mileage savings for optimal vs. actual allocations in Region 5 also vary considerably. Mileage is reduced by about 15 for four of the six diversified-products plants, while it changes little for the other two. In Region 6 the two diversified products plants achieve modest mileage savings under the optimal solution because more Fresno County production is allocated to them. However, two of the three Region 6 paste plants end up with longer hauls under the optimal solution than recorded in actuality.

5.5. Conclusions

Analysis of the base model solution for allocation of the 1989 processing tomato crop relative to the estimated actual allocation of the crop revealed modest inefficiency in allocating the crop among processors. In particular, the comparison suggests that too much interregional hauling takes place. The additional variable profit generated by the base model solution works out to $3.08 per ton of raw tomatoes for the 1989 crop. Based on approximately 290 thousand loads of tomatoes harvested from the 13 counties during 1989 and 9.94 average miles of reduced haulage under the base model, we compute that 5.8 million additional miles (round-trip) were traveled hauling tomatoes in 1989 than if the base model solution had been implemented.

Several factors contribute to the divergence between the optimal and actual solutions. Most important perhaps is the industry's use of a uniform pricing structure. As chapter 3 illustrated, uniform pricing almost certainly leads to additional transportation compared to an FOB pricing scheme. In particular, uniform pricing facilitates overlap of market areas and interregional competition among processors. Growers located proximate to processing facilities cross subsidize growers at remote locations under uniform pricing. Indeed, comparison of the base model and actual allocations in Table 5.2 confirms that a greater amount of interregional shipment took place under the actual vs. optimal allocation.

As we have noted in this report, important factors support the industry's use of uniform pricing and interregional hauling. It moderates risks due to local crop failures, a factor our analysis was unable to consider. It also enables processors, such as those located in Region 5, who lack a substantial base of local production, to be competitive in procuring tomatoes from other regions.

Long-standing contractual relationships between growers and processors may also contribute to the divergence between the optimal and actual allocations. Market participants may prefer the stability of these arrangements even though geographical shifts over time in production and processing locations suggest the utility of alternative allocations. Furthermore, our analysis was unable to incorporate unique technological or market advantages that some processors may enjoy. Firms that occupy particularly lucrative niches in the market for processed products or employ superior processing technologies will be able to profitably haul tomatoes longer distances than can the prototype processing firms modeled here.

Thus, this analysis should not be construed as an indictment of present industry practices. Indeed, given all the complicating factors that intervene in the independent production and marketing decisions of nearly 500 growers and 32 processors, it is perhaps remarkable that the variable profit generated by the optimal vs. estimated actual allocations differ by only 1.9%. Rather, the potential utility of this analysis lies in suggesting potential alternatives to prevailing practices. For example, whereas it is probably not feasible to adopt fully the optimal solution, some of the reduction in cross-region hauls produced by the optimal allocation may suggest profitable alternative contracting opportunities for both growers and processors. Similarly, the shadow prices for additional production by location, season, and soluble solids content offer guidelines for structuring price premia to achieve the desired harvest characteristics. Plant capacity shadow prices, in turn, suggest locations, based on the 1989 harvest pattern, where additional production capacity would be best utilized. We extend this analysis in the next chapter by simulating the development of new processing plants at key locations in the state. We also address the dichotomy between paste and diversified-product returns by simulating a long-run equilibrium wherein returns are equated across product forms.

6. EXTENSIONS: LONG-RUN EQUILIBRIUM AND NEW PLANT LOCATIONS

The base model described in chapter 4 and analyzed for 1989 industry conditions in chapter 5 can be altered to perform a variety of "what if" simulations. For example, the effects of changes in the magnitude and location of raw product production can be analyzed, as can the entry and exit of processing plants. Similarly, the effects of changes in economic variables such as processed-product prices, raw-product prices, processing costs, or transportation costs can be simulated. To contain the scope of this analysis, our focus in this chapter is limited to two types of simulations: First, we will examine a long-run equilibrium formulation where paste- and diversified-product returns are equated. Second, we examine the effects of establishing a new processing plant in Region 1 and in Region 6.

6.1. Long-Run Competitive Equilibrium

An important feature of the analysis for the 1989 crop year was that variable profits for processing diversified tomato products exceeded significantly the variable profits from processing bulk paste only. As noted, this profitability differential appears to have persisted in the industry for some time and may reflect the market power of diversified-products processors or rents to well-known diversified-products brands.

In a competitive industry market forces can be expected to react over time to eliminate such profit differential among alternative product forms. Specifically, profit-seeking behavior will cause raw tomatoes to flow into their highest valued processed-product use. This increase in the volume of diversified products supplied and decrease in volume of bulk paste would, in turn, reduce the profitability differential between them until in the long run marginal returns would be equalized across alternative product forms.

Mathematically this notion can be expressed as follows: Let $P_1,...,P_n$ represent finished product prices for n product forms, W represent the uniform raw tomato price, and $c_1,...,c_n$ represent variable processing costs. Finally let $\lambda_1,...,\lambda_n$ represent the ratio at which raw product is converted into processed product for each of the n product forms. Then market forces will work to establish the following long-run equilibrium condition:

$$W = \lambda_1(P_1 - c_1) = \lambda_2(P_2 - c_2) = ... = \lambda_n(P_n - c_n),$$

i.e., processed product prices net of variable processing costs and adjusted for differential raw-to-processed-product conversion are equated across product forms.

In California this movement of tomatoes into diversified tomato products is constrained in the short run by the capacity of the diversified products plants as illustrated in the chapter 5 analysis. Long-run adjustments to equilibrium may require expansion of processing capacity for diversified products or increased remanufacturing of bulk paste into the higher-valued diversified products. Three paste plants undertake currently remanufacturing activities at other California processing plant sites. For purposes of this analysis the adjustment to long-run equilibrium was simulated in a simple way: the bulk paste products price was adjusted upward[36] to equate net returns for processing diversified and paste products in a medium-size plant. This type of market adjustment could, for example, reflect changes in the international market that either increased U.S. paste exports or decreased paste imports.

To facilitate comparison with chapter 5 results, we once again use 1989 values for tomato production, prices, and costs. The most obvious change in the model solution from equating paste- and diversified-product returns is that the six bulk paste plants in the study receive a considerably greater allocation of tomatoes under the optimal solution: 1,057,000 tons vs. 882,130 tons under the solution based on actual prices, which henceforth we refer to as the *base model solution* (BMS). One paste plant in Region 6 (Fresno and Merced Counties) now begins operation in week 3 vs. week 5 under the BMS. The other two still begin operation in week 5; all three operate at peak capacity every week. One plant shuts down after week 10; the other two continue to operate at capacity through week 11.

The two paste processing plants in Regions 1 and 2 initiate operations in week 5, the same as under the BMS, but under long-run equilibrium all open and operate throughout at capacity vs. operating at less than capacity in three instances under the BMS. Only the Region 3 plant ever operates at less than capacity in the long-run equilibrium. In sum, additional output flowing to the paste plants under this scenario is generated by a combination of modest expansions at the beginning of the processing season and, with the exception of the Region 3 paste plant, operation at full capacity throughout the season.

Table 6.1. Allocations and Mileages for Base vs. Long-Run Equilibrium Models

Region	Base Model Allocation		Long-Run Equilibrium Alloc.	
	Total shipment (000 tons)	Avg. one-way mileage	Total shipment (000 tons)	Avg. one-way mileage
1	442.8	28.34	439.9	28.39
2	1748.4	20.91	1780.2	20.80
3	1886.6	71.17	1891.3	69.46
4	1059.4	67.67	1028.6	68.54
5	1046.4	96.49	976.8	96.52
6	1270.5	52.57	1337.3	51.91

The long-run equilibrium solution has little impact on transportation costs for the industry. The average one-way mileage falls to 55.7 vs. 56.7 for the BMS, generating a savings of $780,000. Table 6.1 illustrates the reasons for the reduced haulage. Region 6 paste plants utilize greater amounts of Fresno and Merced County production, resulting in less long-distance haulage into regions 5 and 3. On a lesser scale the same phenomenon applies to Region 2, the other major tomato surplus region. More tomatoes are consumed locally and fewer are exported to Region 5 and elsewhere.

To obtain further information on how the tomato allocation pattern would be affected by equality in paste- and diversified-product returns, we examine the optimal allocation of tomatoes by processing season in Table 6.2. For parsimony of presentation, we examine only the peak processing seasons, 2 and 3, and only those counties where a significant reallocation from the BMS (depicted in Table 5.2) would occur.[37] The

Table 6.2. Allocations by Season for the Base vs. Long-Run Equilibrium Models

County	Region	Season 2 Allocation		Season 3 Allocation	
		Base Model	L.R. Equil.	Base Model	L.R. Equil.
		Shipments in 000 tons			
Contra Costa	3	84.04	103.81		4.38
	5	23.91	4.15	44.29	.03
Fresno	3	400.26	380.26		
	4	467.50	467.50	151.49	146.27
	5	424.33	424.43	6.88	
	6	584.00	604.00	352.60	355.47
Merced	3	30.82	33.54		
	4			29.30	52.38
	5	13.03	10.32	57.20	45.40
	6			88.43	77.14
Solano	2		0.41	5.24	5.24
	3	47.51	47.11	262.98	262.98
	5			18.70	
Yolo	2	421.99	433.58	524.79	530.99
	3	144.31	132.71	99.81	108.13
	5			121.51	106.99

major season 2 reallocation that would occur under long-run equilibrium would involve processing locally about 20,000 tons of Fresno County production that under the BMS were shipped mainly into Region 3, which is replaced by Contra Costa production which had been shipped to Region 5.

In season 3 Fresno County production has begun to wind down and the base model and long-run equilibrium allocations are quite similar. The major change would occur in Region 2, where 15,000 tons of Yolo County production and 18,000 tons of Solano County production would be processed locally rather than be shipped into Region 5. Regions 5 and 6 would lose shipments from Merced County, where 22,000 tons would be processed locally instead.

Because the long-run equilibrium simulation is invoked by raising paste prices to equate variable returns from paste- vs. diversified-products production, the marginal value of raw tonnage correspondingly increases during all weeks when diversified-products plants operate at their joint capacity. Except when transportation cost differentials for allocating a ton of tomatoes between a paste- vs. a diversified-products plant were extreme, the ton would be allocated to the diversified-products plant up to its capacity in the BMS due to its higher variable profit per ton. Thus, during early- and late-season harvests when significant excess processing capacity exists, marginal values of additional raw tonnage were, thus, generally based on their contribution to profit in a diversified products plant. During seasons 2 and 3 when most diversified-products plants operated at capacity, marginal values of additional raw tonnage were based upon their contribution to profit in a paste plant and, thus, were generally lower.

Table 6.3 shows the increase in value for incremental low-solids tomato tonnage in the peak seasons for the long-run equilibrium simulation vs. the BMS. Although the majority of paste processing capacity in the model is located in Region 6 (81,000 tons/week vs. 69,000 tons/week in all other regions), it is interesting to observe that the incremental values of raw product tonnage increase almost uniformly across the 13 major producing counties. This result illustrates the close interlinkages in the industry. Although the immediate impact of increasing bulk paste prices is to increase the value of tomatoes grown near the paste plants, e.g., in Fresno County, tomatoes grown in other areas become correspondingly more valuable as they are reallocated in the optimal solution to compensate for the additional tonnage flowing to the paste plants.

A further effect of increasing returns from paste production relative to diversified products production is that shadow values on capacity constraints decrease for diversified-products plants and increase to about the same level for paste plants. Similar to the county-level raw product shadow values, the marginal values for diversified-products plant capacity decreased nearly symmetrically across plants. In the long-run equilibrium model the two main factors differentiating profitability among plants are (1) access to tomato production and (2) economies of size in processing.

Table 6.3. Additional Marginal Values ($/Ton) of Low-Solids Tomatoes:Long-run Equilibrium vs. Base Model Solution

County	W5	W6	W7	W8	W9	W10	W11	W12	W13
Colusa	25	7	7	16	27	40	34	25	0
Contra Costa	22	7	7	16	26	40	34	25	0
Fresno	22	7	7	16	27	40	34	25	0
Merced	22	7	7	16	27	38	34	25	0
Monterey	22	7	7	16	26	38	34	25	0
Sacramento	25	7	7	16	27	40	34	25	0
San Benito	22	7	7	16	27	38	34	25	0
San Joaquin	20	6	7	16	26	40	34	25	0
Santa Clara	22	7	7	16	26	40	34	25	0
Solano	21	7	7	16	26	40	34	25	0
Stanislaus	22	7	7	16	27	40	34	25	0
Sutter	25	7	7	16	27	40	34	25	0
Yolo	25	7	7	16	27	40	34	25	0

6.2. The Impact of New Plant Entry in California Tomato Processing

In this section we analyze the impact on the processing tomato industry of establishing new processing plants. The hypothetical plants were located strategically in surplus production areas. One plant was located in Region 6 in Ripperdan, near Fresno, while the other was located in Region 1 in Dunnigan (northern Yolo County). Figure 6.1 illustrates the location of the hypothetical plants. Both hypothetical plants were assumed to process diversified products and to have a "large" weekly capacity of 30,000 tons.

For purposes of conducting the new-plant simulations, several changes in the base model were implemented to provide the most realistic assessment of the effects on the industry of new entry. First, production levels and locations were updated to 1990. This year was chosen because it represents updated information from the 1989 base year. Production in 1990 was up somewhat over 1989 levels to 9.3 million tons, which may represent a typical production year for the industry.[38] Second, the existing processing capacity in the industry was updated to account for entry that had occurred between 1989-90.[39] Finally, the new plant simulations were conducted under the assumption of long-run equilibrium (i.e., paste- and diversified-product variable profits were equated). The long-run equilibrium assumption effectively makes the choice of paste only vs. diversified-product production for the new plants unimportant.

To assess the impact on the industry of each hypothetical plant, we compare the optimal tomato allocation for the industry for a 1990 base model without either new plant with the optimal allocation that results when each plant is added to the industry. Despite the addition of the two paste plants in Region 6 in 1990, our analysis suggests that another plant in the Region would also be a magnet for raw tomato production. Under the optimal allocation the Ripperdan plant operated during weeks 1-17 of the harvest season, and operated at capacity for weeks 2-13 and 16. The plant processed 454,000 tons of tomatoes. The hypothetical Dunnigan plant in Region 1 also attracted a significant volume of tomatoes. It operated in weeks 3-13 in the optimal solution with all but the initial week representing capacity operation. Total seasonal tonnage for the plant was 326,500.

The sources of production for the new plants reflects the strategic choices of locations made for them. The Region 6 Ripperdan plant procured its raw tomato supply solely from Fresno County through week 12, at which point it also sourced from Merced County through week 17 with minor help from San Joaquin County. The Region 1 plant was located in Dunnigan in an area where no plants are located presently to give it hegemony over production in Colusa and Sutter Counties. Under the optimal solution the Dunnigan plant was able to procure supply exclusively from Colusa County for weeks 4-8 and 10-12. Tonnage was also drawn from Sutter County in week 9, and Yolo County helps in weeks 3 and 13. In total 95% of the plant's tonnage was obtained from Colusa County.

Among the most interesting and important dynamics of new plant entry are its impacts on the overall optimal tomato allocation pattern and, specifically, on competing processors. Tables 6.4 and 6.5 provide this information. Table 6.4 compares optimal 1990 allocations to each plant for the base model and the models with new plant entry. Table 6.5 indicates optimal 1990 allocations from producing counties to processing regions for the same set of models.

The tables indicate that interregional competition to procure tomatoes effectively links processors across northern and central California.[40] Entry (or, equivalently, exit) in one region affects processors in almost every other region. The hypothetical Ripperdan plant, although located south in Region 6, affects supply to processors in all regions and has significant effects on processors in Region 5 as well as the local Region. The hypothetical northern plant in Dunnigan has only a minor effect on total supply allocated to its Region 1 counterparts because the Region is a significant surplus producer but, rather, affects supply to processors in each of the other processing regions, including the southern Region 6.

In each new-plant simulation, the region losing the greatest volume of tonnage is coastal Region 5, which loses 63 thousand tons (5.5% of total) from entry of the Ripperdan plant and 48 thousand tons (5.0% of total) from entry of the Dunnigan plant. This latter result is particularly striking since Colusa County, which supplies 95% of the Dunnigan plant's tomatoes under the optimal allocation does not supply any tomatoes to Region 5 under the 1990 base model allocation. Rather, the tonnage is lost from Yolo County, where production routed to Region 5 in the base model is allocated to processors that had procured Colusa County production prior to entry of the Dunnigan plant.

These simulation results indicate the comparative vulnerability of Region 5 processors to new competition as a consequence of having to source tomatoes from long distances. The fact that the optimal allocations for the models with entry reduce tomato flows into Region 5 relative to the base model allocation imply that Region 5 processors could be out

Figure 6.1. Hypothetical Plant Locations

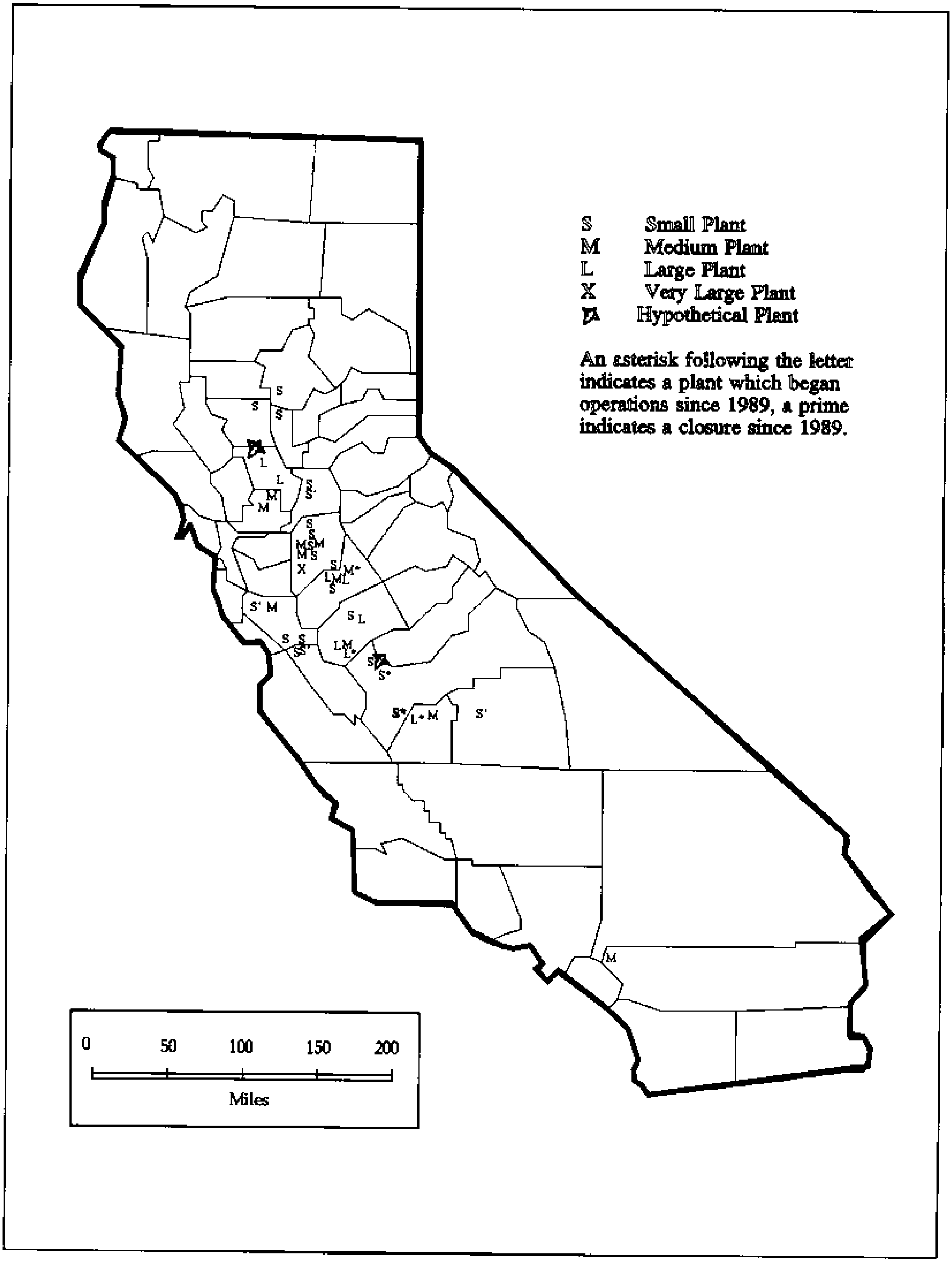


Table 6.4. 1990 Processing Plant Allocations (000 Tons) for Base and New Plant Models

Region	Plant	Base 1990 Solution	New Ripperdan Plant	New Dunnigan Plant
		Diversified-products plants		
1	1	106	108	108
	2	204	204	204
	3			**327**
2	1	297	297	295
	2	504	503	503
	3	135	135	122
	4	115	115	104
	5	547	551	520
3	1	539	539	539
	2	297	297	297
	3	270	270	270
	4	165	148	147
	5	112	86	89
	6	200	200	200
	7	260	280	280
4	1	440	440	440
	2	378	347	378
	3	35	32	42
	4	165	165	165
5	1	194	199	191
	2	165	162	159
	3	79	81	83
	4	150	119	125
	5	96	64	67
	6	285	288	287
6	1	173	174	173
	2	613	500	610
	3		**454**	
		Paste plants		
6	1	162	135	135
	2	180	180	180
	3	306	238	272
	4 (new)	264	264	264
	5 (new)	180	160	180
other	1	153	136	119
	2	216	189	189
	3	148	75	75

bid for these tomatoes in actual competition by processors exploiting locational advantages.

In contrast to the hypothetical Dunnigan plant the Ripperdan plant has a major impact on its direct competitors in Region 6. Whereas 294,000 of the 326,500 tons processed by the Dunnigan plant are lost on net outside of Region 1, only 227,000 of the 454,000 tons processed by the Ripperdan plant are lost on net outside of Region 6. One of the diversified-products processors in Region 6 lost net tonnage to the new plant as did two of the three established paste processors and one of the two new paste processors.

A perhaps unexpected outcome documented in Table 6.4 is that competitive entry actually benefits some existing processors. The optimal solution for either new plant model shows a few processors gaining net tonnage relative to the base model. The reason is that increased competition for raw product tonnage causes some plants to begin processing later and stop processing earlier in the harvest season. Thus, although entry means an increase in overall competition, during some weeks of the season fewer firms on net are competing for tomatoes, enabling some firms to attain a greater volume of product despite entry.

The average one-way hauling distance under the optimal solution for the 1990 base model is 53.7 miles. This mileage is down from the 1989 base model solution due to establishment of the two new paste processing facilities in production-rich Region 6. As bid for these tomatoes in actual completition by unexpected, entry of new plants further reduces haulage costs relative to the base solution. Average one-way mileage with entry of the Ripperdan plant was estimated to be 50.1 vs. 51.4 with entry by the Dunnigan plant. Savings to the industry from reduced haulage are estimated to be $2.8 and $1.8 million for the Ripperdan and Dunnigan plants respectively.

Average mileage for the new plants themselves were near the constrained minimum, 11.7 for Dunnigan and 14.3 for Ripperdan, reflecting the strategic choice of their location in surplus-producing regions. Haulage distances for most established plants were either little changed or decreased under solutions to the models with entry vs. the base model. Reduced haulages most often reflected lower tonnage flowing to plants that did not source distant production in the more competitive market environment.

Region 5 was an exception to this conclusion for the model with entry by the Dunnigan plant. Three processors from this region incurred substantially greater hauls as a consequence of the entry even though two of the three incurred significant reductions in net tonnage. This result again emphasizes the precarious status of the Region 5 processing plants.

Our analysis in this study has focused on variable costs for tomato processing plants, and, lacking detailed information on the capital costs of constructing processing facilities in Ripperdan or Dunnigan, it is beyond our scope to offer a specific recommendation as to the overall profitability of such an investment. Both hypothetical plants, however, generate high variable profits relative to existing plants in northern and central California. The Ripperdan plant generated the fifth highest variable profits among 35 plants in the analysis for the simulation based on 1990 production and prices. The Dunnigan plant generated the ninth highest variable profits in its simulation. Thus, it is evident that processing facilities that (a) locate near surplus producing regions and (b) operate at a large scale to capture available economies in processing, as did the hypothetical plants in these simulations, are capable of performing above the industry norm.

These results raise interesting questions regarding the dynamic evolution of the industry. The shift in production to the central valley has created locational advantages for processors in this area, and, as we have documented, new processing facilities have been located especially in the Fresno region. Yet the analysis in this chapter suggests that additional processing capacity in production rich Fresno and Yolo Counties would apparently be profitable. Why have market forces in this industry been slow to respond to these incentives? The answer lies partly in Brandt, French, and Jesse's contention that in the short run incurring long distance hauls to existing processing facilities is cheaper than building new processing capacity.

For example, capital costs for the prototype paste processing facility described in Chapter 4 were estimated to be about $14 million annually for a processing capacity of 150,000 tons.[41] Depreciation and interest (calculated at 10%) on this investment are about $2,665,000 annually. In order for a processor to realize net cost savings from relocating, the net reduction in average hauling distance would have to be at least 178 miles, based on the haulage charges used in this study.[42] From the 1989 average hauls reported in Table 5.10, it is apparent that extant processors cannot achieve haulage reductions of this magnitude.[43]

This logic does not apply to new entrants. These firms, unburdened by investments in sunk processing capacity, have incentive, *ceteris paribus*, to choose a processing location that minimizes haulage costs. However, it is also plausible that these firms face entry barriers into some segments of tomato processing through the extensive investments incumbents have

Table 6.5. 1990 Optimal Tomato Allocations from Producing Counties to Processing Regions: Base Model and New Plant Solutions (continues)

County	Processing Region	Base 1990 Solution	New Ripperdan Plant	New Dunnigan Plant
		Shipments in 000 tons		
Colusa	1	204	193	449
	2	426	449	215
	3	34	23	
Contra	2	6	2	
Costa	3	93	88	103
	5	87	91	8
	6	5		1
Fresno	2		2	
	3	378	302	389
	4	682	586	686
	5	423	372	417
	6	1555	1782	1553
Merced	3	18	18	18
	4	1	6	38
	5	43	41	42
	6	215	210	178
Monterey	5	76	80	73
	6		3	10
Sacramento	2	136	128	136
	4		1	
San Benito	5	126	127	130
	6	10	12	10
San Joaquin	2	6	5	5
	3	347	317	402
	4	211	258	161
	6	29	12	25
Santa Clara	5	70	73	73
	6	3		
Solano	2	88	88	97
	3	421	420	395
	5	14		32
Stanislaus	3	123	92	125
	4	125	126	140
	6	55	85	39

Table 6.5. (continued)

County	Processing Region	Base 1990 Solution	New Ripperdan Plant	New Dunnigan Plant
		Shipments in 000 tons		
Sutter	1	268	255	291
	2	44	59	57
	3	154	142	102
	6			6
Yolo	1			10
	2	1112	1054	1222
	3	421	494	364
	5	130	12	67
Reg. Total	1	463	448	757
	2	1814	1790	1732
	3	1990	1895	1897
	4	1018	984	1025
	5	968	914	912
	6	1878	2105	1813

made into product differentiation and brand development for various diversified tomato products. Barriers to entry for generic, bulk paste are, conversely, low.

This analysis comports closely with recent experience in the industry. Since 1988, six processing plants have been built. Five of the plants were built by new entrants. All five of the plants were located in or near Fresno County. Four of the five manufactured bulk paste, with the fifth manufacturing bulk diversified products primarily for the institutional market.

7. SUMMARY AND CONCLUSIONS

This study has developed and applied a nonlinear mathematical programming model to determine the optimal allocation of processing tomatoes from the 13 largest producing counties in northern and central California to the 32 processing facilities located in the area. This optimization framework represents an alternative approach to analysis of this important California industry relative to previous econometric studies conducted by Chern and Just (1978) and Brandt and French (1981).

The mathematical model of the industry incorporates costs of hauling tomatoes from field to processing facilities and distinguishes between plants that process only bulk paste products and those that process diversified products including sauces, puree, juice, and whole tomatoes. The study is also the first to incorporate explicitly tomatoes' soluble solids content into the analysis. The market information needed to implement the model are locations, volume, and soluble solids content of tomato production by county; the location, type, and capacity of processing plants; selling prices for bulk paste and diversified tomato products; variable cost functions for paste and diversified-products processing; and transportation costs for allocating tomatoes from field to plant. The mathematical program was set forth in detail in Ch. 4.

A primary goal of the study was to evaluate the efficiency of the allocation of tomatoes from farms to processing plants in northern and central California. Several factors were noted that contribute to long field-to-plant hauls in the California tomato industry. Due to urbanization, production has shifted from areas along the California central coast to the Central Valley. Thus, several plants, lacking a base of localized production, must incur long hauls to stay in business. In addition, production peaks at different times in different producing regions. As summarized in Table 5.2, early-season production is concentrated in Fresno County with Yolo County becoming the largest producer during the middle of the 20 or so week harvest season. Tomato processing is characterized by substantial economies to size of operation, so processors have incentives to extend their processing season as long as possible. Given the seasonal harvest pattern, meeting this objective often compels long-distance hauls. We also noted in chapter 3 that the uniform (as opposed to FOB) pricing structure employed by the industry facilitates interregional competition among processors and, hence, additional haulage.

These factors were all incorporated into the optimization model which was solved using the GAMS/MINOS algorithm for 1989 industry values and compared to the estimated actual tomato allocation for 1989.[44] The derived optimal solution was shown in chapter 5 to deviate from the estimated actual solution in a number of important respects. In particular, as many industry observers have suspected, the actual allocation involved more interregional cross hauling of tomatoes than did the optimal solution. The average one-way haul under the optimal allocation was 56.7 miles vs. 66.6 miles for the estimated actual allocation. The longest hauls under either solution, often in excess of 100 miles, were incurred by coastal processors in Region 5, with San Joaquin processors also often incurring average hauls of near 100 miles. The loss to the industry from misallocation of tomatoes was estimated to be about $23 million or 1.9% of gross profits.

The nonlinear optimization model treats production volumes and plant capacities in the base year as constraints, thereby enabling shadow prices to be generated that estimate the contribution to industry variable profit from expanding production by county and/or processing capacity. The results of this analysis indicated that the most valuable early-season tomato production occurs in San Joaquin County, with Santa Clara County production being most valuable in middle weeks. Yolo and San Joaquin production assume premium value in later weeks of the processing season.

Not surprisingly the most valuable processing capacity was found in Regions 2 and 6, reflecting those areas status as surplus production regions due to the bountiful harvests in Yolo and Fresno Counties, respectively. Simulations of new plant entry in Northern Yolo and Fresno Counties conducted in chapter 6 suggested that, if large-scale capacity plants were located in either area, they would be among the most profitable in northern and central California. The primary loses of tonnage in either case were projected to be processors located in Region 5.

In general, the results of the various simulation analyses reveal an industry where processors' and producers' fates are closely linked through interregional competition despite their being separated in many cases by long distances and high transportation costs. Among the 13 major producing counties, eight were estimated to ship tomatoes into five or more of the six processing regions. Although the simulated new plants were located at the northern and southern ends of the producing range, either new plant affected production allocated to processors throughout the six processing regions. As noted also in the Durham and Sexton (1992) study, this type of interregional competition among processors to procure tomato production contracts apparently causes this market to be more competitive than would be predicted from the prototype spatial theory with FOB pricing and nonoverlapping markets.

Although transportation costs comprise a significant share of tomato marketing costs and modest departures from efficiency were found, it is worth closing with the observation that haulage distances have declined considerably from the 100 miles estimated for 1973 by Brandt, French, and Jesse (1978). These authors' forecast of even longer shipment distances has not materialized. The decline in haulage distances and costs reflects in our view the important structural dimensions of the market. Firms compete to procure raw tomatoes, and entry into the bulk paste segment of the industry is relatively unimpeded. Entrants have incentive to locate in surplus production areas, as the proliferation of processing facilities in the Fresno County area illustrates. The new plant simulations conducted here suggest that further restructuring of plant locations and attendant decreases in hauling costs are likely to occur.

ENDNOTES

1. Durham and Sexton (1992) investigated oligopsony power in the California tomato industry using some of the data employed in the present study. They concluded, in contrast to Chern and Just, that potential for oligopsony in the industry was limited in large part due to interregional competition among processors.

2. Processing tomatoes may be grown from seed or from transplants. Improvements in weed control may be responsible for increased direct seeding in recent years since weeds compete with young plants. This situation may change if chemical use is restricted.

3. Public Law 78, popularly known as the Bracero program, provided for easy migration of harvest farm labor from Mexico. Within four years of the law's termination in 1964, the mechanical harvester's adoption rate reached 92%. By 1970 harvester adoption was 100%.

4. Uniform pricing in a spatial context means that prices are constant with respect to the distance the product is shipped. Price premiums for soluble solids content and early- or late-season deliveries may be part of a uniform price schedule.

5. Each of the factors cited in this paragraph represents a departure from the prototype model of spatial competition discussed in Greenhut, Norman, and Hung and elsewhere.

6. Most studies of spatial pricing focus on the selling side of the market. Capozza and Van Order (1978) discuss the FOB pricing case, while Gronberg and Meyer (1981) study the uniform pricing case. Sexton (1990) extends the analysis to the input buying side of the market.

7. Identical firm's have identical mill prices and therefore split the market in half.

8. Calculation assumes that growers in the disputed area are shared equally between the two processors.

9. In chapter 6 we consider potential locations for new processing plants.

10. Kern and Imperial Counties located in Southern California are, respectively, the 8th and 12th largest processing tomato producers in California. They were excluded from this study because their production is allocated almost exclusively to plants located in the southern half of the state, who did not agree to participate in the study.

11. This analysis treats the timing of harvests in a county as given. As noted in Chapter 2, processors often pay premiums for early- and late-season harvests. These premiums can be used to somewhat affect the harvest pattern, a factor not modeled here. One output from our analysis, however, is a set of *shadow prices* that illustrate the comparative value of early- and late-season harvests. These shadow prices may provide input into pricing decisions.

12. $F(z_{i,t})$ gives the proportion of the area under the normal curve from $-\infty$ to z.

13. In principle, this procedure could be used to create several classifications of tomatoes based on solids content. The cost in terms of programming complexity is large, however. For example, increasing the solids classifications from 2 to 4 would add 2*13(counties)=26 constraints for each of 20 weeks or 520 constraints to the model. Similarly, the model could incorporate the mean high and low solids levels for each county and/or week but only at the expense of significantly greater complexity.

14. These values over simplify the relationship between solids content and raw-to-processed-product conversion rates. Conversion rates depend on non-soluble solids as well as soluble solids. Total solids are more difficult to test for than soluble solids and thus soluble rather than total solids are reported at inspection, and are thus necessarily the basis for estimating conversion rates in this study.

15. Production locations were based on maps provided by the California Agricultural Statistics Service for the 1989 crop as reported by the County Agricultural Commissioners.

16. Labor costs in Logan's model include differential pay for overtime and require labor payments of at least one full shift 5-day week. Shift labor is then allowed to increase in 4 hour increments up to 24 hours per day. Line labor also has a 8 hour daily minimum but overtime labor on weekends can be reduced to necessary hours. Clean-up costs also depend on days of operation and number of shifts. Clean-up costs are incurred whenever a line is shut down, either each day of operation, if the plant operates less than three shifts, or weekly if the plant operates less than 7 days.

17. Costs of evaporator clean up and boiler start up from shutting down and starting back up are high, making continuous operation the preferred alternative.

18. Costs of canning line operation are quite similar for most canned tomato products, so moderate differences in product mix among processors are unlikely to have a significant impact on per-unit processing costs.

19. A linear version of the optimization model was formulated and solved to provide starting values for the nonlinear program.

20. This outcome is not surprising because simple profit maximization motives are what drive processors to operate in consecutive weeks. Thus, except for abnormal weekly harvests due, for example, to weather problems, the consecutive weeks operation constraint would be expected to be slack in a well-specified model.

21. Each load of tomatoes listed in tables 4.1 and 4.2 converts into approximately 25.6 tons of raw tomatoes.

22. Note that this conclusion takes the location and magnitude of processing capacity in the industry as given.

23. Five firms have joined the California processing tomato industry since 1988, though one has since sold its plant to an existing processor. Each of the plants they built were either in Fresno county or an adjoining county.

24. Concentration in retail tomato products is quite high for all products except whole tomatoes. Four-firm concentration ratios for retail sales of catsup, concentrated tomato products, and spaghetti sauces are in the 75% range or higher. Concentration ratios this high are considered to be indicative of the ability to achieve supra competitive returns.

25. If all processed tomato products were manufactured and sold competitively, the net marginal returns to each product form would be equated in long-run equilibrium. This condition would be generated through competitive arbitrage. Raw tomatoes would flow from low-value uses into high-value uses until the marginal returns were equated across uses.

26. In 1989 January bulk paste prices reached 55 cents a pound, about 45% higher than the average over the previous 3 years. Relative to the same period canned prices had increased between 20-25% for whole tomatoes, 7% for puree, and about 3 % for spaghetti sauce. Prices remained high throughout 1989 declining slowly in 1990. In 1992 paste prices dropped as low as 27 cents a pound.

27. The locations of the six processing regions is illustrated in Figure 4.2, and counties' and firms' regional affiliation is provided in table 4.3.

28. A caveat to this conclusion is the model's failure to account explicitly for risks of crop failure in specific growing areas. For this reason processors may have incentive to spread their contracts across a broad geographic area to limit exposure to this type of risk.

29. Model B which constrains regions to receive the same allocations received in Model A but allows them to source from the most efficient location yields nearly the same mileage savings observed in the optimal model.

30. For example, a one ton expansion of production may not be valuable if it must be processed in a plant with substantial excess capacity. However, an expansion sufficient to enable the plant to utilize fully its capacity may be much more valuable.

31. Note that raw product costs are not deducted. Rather, the shadow prices represent the total value available to the combined producing and processing sector of the industry after incurring variable costs for hauling and processing.

32. In 1989 five processors offered no premium for solids, five offered an extra dollar per ton for each additional tenth of a percent of solids, and the remaining firms offered something in between.

33. While not all processors contract for late season tomatoes, those that do generally begin with a $5/ton premium in mid-September and raise it to $8 or $10 a week or two later. Some processors offer a $12-15 premium by the second week in October.

34. Note that our information on the actual 1989 crop allocation included shipments by region and not by individual plants, so it is not possible to compare results for individual plants under the optimal allocation with what occurred under the actual allocation.

35. The discussion of tomato processing technology in chapter 4 indicated that diversified-products plants have greater flexibility to downsize their operations (through reducing lines and shifts in operation) than do paste plants. The tendency of the diversified products plants to operate during the early and late season harvests while the paste plants operate only during the peak harvest is a function of both relative profitability and the diversified-products plants' superior flexibility.

36. Decreasing diversified products returns to equal paste returns results in a very similar allocation.

37. The season 4 and 5 allocations are unchanged from the BMS because the six paste plants do not operate during this period under either model. The only changes in season 1 are that Fresno County production is mainly processed locally in Regions 4 and 6 vs. being shipped into Regions 3 and 5 under the BMS.

38. 1991 production increased even further to nearly 10 million tons and then, due to sharply falling prices, fell off precipitously in 1992 and 1993. Thus, we view 1990 production levels as more reflective of typical "equilibrium" values than production in 1991-1993.

39. Two paste plants were added in the Region 6 area. One plant located in Helm has a weekly capacity of about 20,000 tons; the other, located near Los Banos, has a weekly capacity of approximately 44,000 tons.

40. Durham and Sexton (1992) reached a similar conclusion in a study of potential oligopsony power in the California processing industry. Even though only a few processors operate in most regions of the state, statistical results indicated that potential interregional competition limited processors' opportunities to exercise oligopsony power in their local markets.

41. This figure comports reasonably with $21 million in fixed assets reported for a 300,000 ton capacity paste manufacturer by Burnett (1989).

42. The savings from reduced haulage is the one-way haul reduction, M, times $0.10 per ton-mile times 150,000 tons. To solve for the breakeven M, set the haulage savings equal to the $2,665,000 annual capital cost of a new plant.

43. Other adjustment costs in addition to new plant construction also would be incurred, including costs of restaffing a new facility and securing production contracts from a new group of growers.

44. On the other hand, possible risk-reduction incentives from spreading tomato procurement across a broad geographic area were not incorporated into the model.

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