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Estimation of Supply and Demand Elasticities of California Commodities

by

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Giannini Foundation of Agricultural Economics

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ABSTRACT

The primary purpose of this paper is to provide updated estimates of domestic own-price, cross-price and income elasticities of demand and estimated price elasticities of supply for various California commodities. Flexible functional forms including the Box-Cox specification and the nonlinear almost ideal demand system are estimated and bootstrap standard errors obtained. Partial adjustment models are used to model the supply side. These models provide good approximations in which to obtain elasticity estimates.

The six commodities selected represent some of the highest valued crops in California. The commodities are: almonds, walnuts, alfalfa, cotton, rice, and tomatoes (fresh and processed). All of the estimated own-price demand elasticities are inelastic and, in general, the income elasticities are all less than one. On the supply side, all the short-run price elasticities are inelastic. The long-run price elasticities are all greater than their short-run counterparts. The long-run price supply elasticities for cotton, almonds, and alfalfa are elastic, i.e., greater than one.

Policy makers can use these estimates to measure the changes in welfare of consumers and producers with respect to changes in policies and economic variables.

Keywords: Consumer Economics: Empirical Analysis (D120); Agricultural Markets and Marketing (Q130); Agriculture: Aggregate Supply and Demand Analysis; Prices (Q110)

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Introduction[1]

California's agricultural sector can be characterized as being in a constant state of flux. On the consumer side of the market there have many changes in recent decades. Demographically, the proportion of married women in the labor force over the past four decades has doubled. In addition, demand patterns have been influenced by health and diet concerns. For example, there has been a 350% increase in sales of organic foods during the past decade. Demands for specialized and niche products are also on the increase.

The structure of fresh vegetable sales are more concentrated with fewer and larger retail buyers, and environmental regulations are being imposed to ensure better food safety. Competition from foreign suppliers is increasing. Technological changes have occurred in the processing of agricultural materials. Morrison-Paul and MacDonald noted that food prices today often appear less responsive to farm price shocks than in the past. Their research, however, found improving quality and falling relative prices for agricultural inputs, in combination with increasing factor substitution, has counteracted these forces to encourage greater usage of agricultural inputs in food processing.

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[1] For an excellent discussion of the changes in California's agricultural sector, see Johnson and McCalla.

On the production side, global markets and trade liberalization has greatly impacted domestic markets. Land lost to urban expansion and an ever-growing pressure on water available impact California producers. The number of farms in California is decreasing while the sizes of farms are getting larger. While the price for California's fruits, nuts and vegetables is determined in domestic and export markets, the profitability of competing field, fiber and fodder crops is influenced by federal subsidies and state regulations. These impacts on California agriculture occur as both demand and supply side policies change.

In order to better understand and evaluate the consequences of these changes on consumer and producer welfare, it is essential to obtain reliable estimates of supply and demand elasticities of California commodities. To the best of our knowledge, there is no current comprehensive study that provides accurate up-to-date supply and demand elasticity estimates of California's major crops. Frequently cited works reporting demand elasticities are Carole Nuckton's Giannini Foundation publications (1978, 1980), "Demand Relationships for California Tree Fruits, Grapes, and Nuts: A Review of Past Studies" and "Demand Relationships for Vegetables: A Review of Past Studies". However, given the significant structural changes noted above, there are many causal factors that need to be updated to generate current supply and demand elasticities.

A more recent article, "Demand for California Agricultural Commodities" by Richard Green in the winter 1999 issue of *Update* reports estimates of own-price elasticities for selected commodities. The commodities included food (in general), almonds, California iceberg lettuce, California table grapes, California prunes, dried fruits (figs, raisins, prunes), California avocados, California fresh lemons, California

residential water, and meats (beef, pork, poultry, and fish). All of the elasticity estimates are reported in research publications by faculty of the Department of Agricultural and Resource Economics at the University of California at Davis. Individual sources for the commodities are given in the reference section.

The primary purpose of this research project is to obtain updated supply and demand elasticity estimates of major California commodities. That is, short and long-run own-price elasticities of supply and own price, cross-price and income elasticities of demand. In this study sophisticatedly simple models are used (Zellner). The models focus on California agriculture. As a consequence, we tried to emphasize the specificity of California supply, contrasting it when possible, with aggregate US or the most relevant competing states' supply. Modeling the demand for California commodities was a challenging task, considering that markets are integrated and often statistics about retail prices do not discriminate products by origin. Also, for most crops we focused on the demand at the wholesale level. Thus, farm gate price may be based on a standard "mark down" of the price paid by the buyers. The modeling of wholesale demand was also convenient for those products (for example nuts) that are consumed mostly as ingredients of final goods. Exceptions to this approach relate to alfalfa and tomatoes. The former commodity is a major input for the California dairy industry so we estimated a derived demand. For fresh tomatoes we estimated the consumer demand at the US level.

Each crop presented specific modeling issues which are described in detail in the following sections. A brief discussion of the theoretical foundations of the models will be given, but detailed theoretical underpinnings of the models can be found in standard microeconomic textbooks.

The analysis will start with some of the most highly valued crops in California: almonds and walnuts, alfalfa hay, cotton, rice, and fresh and processing tomatoes. Future research will examine grapes (including raisin, table, and wine); lettuce (head and leaf); citrus (grapefruit, lemons, and oranges), stone fruits (apricots, nectarines, preaches, plums, and prunes); and broccoli.

Before a discussion of the theoretical models, data sources, econometric techniques, and the empirical results a brief literature review is provided.

Literature Review

1. Some Estimated Demand and Supply Elasticites from Previous Studies

One of the first attempts to compile a table of demand elasticity estimates for California crops was Nuckton (1978). She reported own-price elasticity of demand estimates for several California commodities including apples, cherries, apricots, peaches and nectarines, pears, plums and prunes, grapes, grapefruit, lemons, oranges, almonds, walnuts, avocados, and olives. Table 1 is a compilation of the empirical estimates that Nuckton reported. Estimates for the different studies varied widely, but Table 1 attempts to summarize the results from the main studies.

In 1999 Green published more recent elasticity estimates of California commodities from various sources. The table of elasticity estimates is repeated below in Table 2.

Table 1. Selected Elasticity Estimates of California Commodities[1]

Commodity	Own-Price Elasticity of Demand	Comments
Apples	-0.458 to –0.81	Fresh; some estimates were elastic
Cherries	-4.27	Sweet; retail; based on 20 cities
Apricots	-1.345	Fresh, farm level
Peaches & Nectarines	-0.898	Fresh
Pears	elastic	Based on reciprocal price flexibilities
Plums and Prunes	-0.630	Fresh, farm level
Grapes	-0.327 (-0.267) –0.160	Fresh; table grapes (raisin) wine
Grapefruit	-1.25	Fresh, retail level
Lemons	-0.210 (-0.38)	Fresh (processing)
Oranges	-0.72 (-2.76)	Fresh farm (fresh retail)
Almonds	-1.74 (-14.164)	Domestic shelled (export shelled)
Walnuts	-0.464	Shelled; wholesale
Avocados	elastic	Based on reciprocal price flexibilities
Olives	elastic	Based on reciprocal price flexibilities

Source: Nuckton, C., "Demand Relationship for California Tree Fruits, Grapes, and Nuts: A Review of Past Studies." Giannini Foundation, August 1978.

Table 2. Estimates of Own-Price Elasticities for Selected Commodities[1]

Commodity	Own-Price Elasticity
Food (in general)	-0.42
Almonds	-0.83
California Iceberg Lettuce	-0.16
California Table Grapes	-0.28
California Prunes	-0.44
Dried Fruits (Second Stage or Conditional)	
Figs	-0.23
Raisins	-0.67
Prunes	-0.35
California Avocados	-0.86
California Fresh Lemons	-0.34
Meats(Second Stage or Conditional)	
Beef	-0.84
Pork	-0.79
Poultry	-0.58
Fish	-0.57
California Residential Water	-0.16

Source: Green, R., "Demand for California Agricultural Commodities", *Update*, Department of Agricultural and Resource Economics, Vol. 2, No. 2, Winter, 1999.

Some sources for the entries in Table 2 are as follows: food (Blanciforti, Green, and King); California iceberg lettuce (Sexton and Zhang); dried fruits (Green, Carman, and McManus); California avocados (Carman and Green); California fresh lemons (Kinney, Carman, Green, and O'Connell); and California residential water (Renwick and Green).

2. Examples of Market Conditions for Selected Commodities

A brief review of some recent selected articles illustrates the complexities of the market conditions facing California producers and consumers. In addition, a discussion of some economic factors that influence the supply and demand for certain products is given. The market situation for different crops varies dramatically. For some commodities, export and import markets are important. Other crops are perennial and have to be model differently than annual crops. Expectations of producers have to be incorporated in the supply response functions for these crops and a dynamic rather than a static approach has to be used. Rotation patterns can affect the supply response for certain crops such as alfalfa and cotton. A model for each crop has to incorporate these unique market characteristics associated with that particular crop. A few examples of the characteristic of the markets for a selected number of commodities are given below.

Alston, et al (1995) found an elasticity of demand for California almonds of –1.05. The demand for almonds in the United States is more elastic than almond demand in major importing countries. From a policy viewpoint, the inelastic demand for California almonds in export markets suggest that the industry can raise prices and profits in the short run by restricting the flow of almonds to these markets. In the long, however, this approach would lead to a decline in the almonds industry's share of the world market

as competitors respond to higher prices with increased rates of almond plantings. They found little evidence for good substitutes for almonds among other nuts. Filberts in some European markets are an important exception to this rule. On the supply side, Alston et al (1995) found that almond yields in California are highly volatile, but yields can be predicted with good accuracy as a function of past yields, February rainfall, and the age distribution of almond trees. The major competitor to the California almond industry is the Spanish almond industry. Spanish almonds are a close substitute for California almonds in several European markets. This implies that changes in Spanish almond production have important effects on the California industry. Thus, a model of the almond industry must include both domestic and export markets on the demand side and the perennial nature of almond production (including alternate bearing years) on the supply side. Since there is little evidence of substitutes for almonds in the domestic market, a single-equation demand function can be estimated in order to obtain own-price and income elasticities for almonds.

With respect to table grapes, Alston et al (1997) obtained an estimated domestic own-price elasticity of demand for table grapes of –0.51, an income elasticity of demand of 0.51, and an elasticity of demand with respect to promotion of 0.16. Alston et al's (1997) study was primarily concerned with the effectiveness of promotion of table grapes. Their econometric results provided strong evidence that promotion by the California Table Grape Commission had significantly expanded the demand for California table grapes both domestically and in international markets. They evaluated the costs and benefits of a promotional campaign for various supply elasticity values. The policy implications were that the benefits from promotion were many times greater

than either the total costs or the producer incidence of costs of a check-off program for table grapes. The own-price elasticity of –0.51 is inelastic implying that consumers are not very responsive to changes in prices of table grapes.

Almonds and grapes are two commodities for which international markets exist for the products. Thus, in order to properly model the supply and demand functions for these goods, exports and imports must be taken into account in addition to the domestic markets.

The own-price elasticity of demand for prunes, evaluated at the means, was found to be –0.4 by Alston et al (1998). The corresponding elasticity of demand with respect to income is 1.6, which, as they report, is larger than expected. Their study concludes that results from their analysis of the monthly, retail data support strongly the proposition that prune advertising and promotion has been an effective mechanism for increasing the demand for prunes and returns to producers of prunes. Based on their empirical results, they recommended that the prune industry could have profitably invested even more in promotion during the period of their investigation (September 1992 to July 1996).

Another perennial crop is alfalfa. Knapp and Konyar estimated the perennial crop supply response for California alfalfa. They employed a state-space model and the Kalman filter in order to generate parameter estimates as well as estimates of new plantings, removals, and existing acreage by age group. The estimated price elasticities for California alfalfa supply under quasi-rational expectations were –0.25 for the short run (one year) and –0.29 for the long run (10-20 years). The magnitudes of these supply elasticites appear reasonable with the longer-run elasticity a bit larger, as expected, in absolute value, than its short-run counterpart. In addition, Knap and Konyar found

positive cross-price elasticity estimates for competing crops. Thus, producers react to prices of substitutes and act accordingly. Alfalfa is typically planted for three to four years and then removed from production. Frequently, cotton and alfalfa involve a rotation pattern. To our knowledge no one has attempted to model the rotation phenomena that exists between alfalfa and cotton. One of the models to be developed and estimated in this report incorporates this rotation pattern into the supply response models estimated for cotton and alfalfa.

ALMONDS

Figures 1A-6A in Appendix A provide a graphic overview of the domestic and foreign markets for California almonds for the years 1970-2001 (USDA). The figures contain information on marketable almond production, domestic per capita consumption, export and import of almonds, acreage in California, yield per acre, and grower price (nominal and real). A brief description of the almond industry will be given before the empirical results are presented.

Production of almonds exhibit a well-known alternate bearing-year phenomenon, that is, a high production year is followed immediately by a lower crop year and this pattern continues. Exports of almonds over the years 1970-2001 have continued to increase from less than 100 million pounds in 1970 to over 500 million pounds in 2001. Per capita consumption of almonds has also continued to increase over the same time period (Figure 2A). In 1970 per capita consumption of almonds were less than 0.4 pounds per capita and they increased to over 1 pound per capita in 2001. Acreage of almonds in California rose steadily over the years 1970-2001 from less than 200 thousand acres in 1970 to over 500 thousands acres in 2001. Per acre yield of almonds in

California exhibit a “see-saw” pattern, but the trend from 1970 has been increasing. Nominal grower prices for almonds have been volatile over the 30-year period from 1970 to 2001 reaching a peak in 1995 of $2.50 per pound. The major policy implication from Figure 6A; however, is that the real grower price, adjusted for inflation, has been steadily decreasing over the 1970-2001 period. The 2001 real grower price of almonds was barely over 50 cents per pound down from the peak real price of about $3.00 per pound in 1973. A causal glance at Figures 1A-6A in Appendix A indicates that the almond market is continually changing and a lot of world marketing forces affect California’s production and sales of almonds. Supply and demand models are developed and estimated for almonds and the results are given in the next section.

Some theoretical and data issues must be addressed before the models and estimations are presented. First, should a researcher use a singe-equation approach or a system approach? In this report both approaches are presented, although single equation estimations are usually considered to be less efficient. There are several reasons for considering this model. Based on previous research work by the authors, alternative nuts were found to be weak substitutes for almonds in the United States domestic market. Similar results were also found by Alston et al (1995). Thus, the advantages of imposing theoretical restrictions such as Slutsky symmetry conditions may be of little value in a demand system or subsystem for nuts. In addition, retail prices for almonds do not exist since they are used as ingredients in confectionaries. This has two important implications. First, are the demand functions retail or farm-level demands? Wohlgenant and Haidacher developed the theoretical relationships for the retail to farm linkages for a complete food demand system. Their approach, however, assumes that both retail and

farm-level prices exist. In our case retail prices do not exist so we cannot employ their approach. This limitation of the demand models needs to be considered when interpreting the elasticity estimates. For example, farm-level own-price elasticities are generally more elastic than retail own-price elasticities for food commodities. Second, this may imply that nuts are not weakly separable from other food commodities.[2] This would rule out estimating a nut demand subsystem. The model that we employed uses CPI to account for the prices of other food items and commodities.

Given the alternate bearing phenomenon of almonds, there is a demand for consumption and a demand for storage. Alston et al (1995) did not find evidence of a stockholding effect. Thus, we followed their approach and assume that the demand function reflects consumption responses and not storage effects.

Finally, there is a calendar year versus a crop year problem involved with data collection. Alston et al (1995), when they estimated the domestic demand for almonds, used total availability (harvest received by handlers) minus US calendar year net exports minus stocks carried out plus carryins as their dependent variable.

Single equation estimation: demand

Based on standard microeconomic theory, it is assumed that an individual (representative) consumer behaves in such a way so as to maximize a well defined quasiconcave utility function subject to a budget constraint (see, e.g., Deaton and Muellbauer). The domestic aggregate demand for almonds can be written as

[2] A reviewer questioned this assumption. Nuts appear to be <u>not</u> weakly separable from other food commodities since they are used as ingredients in other food products. One implication of weak separability is that demands for the weakly separable goods can be expressed as a function of prices within the group and group expenditure. In theory, for example, if the price of cakes decreases, then one would expect that the quantity demanded of cakes would increase and consequently the demand for nuts would increase violating one of the implications of weak separability. Weak separability of nuts could be tested in a demand system if data were available and thus, in principle, is a refutable hypothesis.

$$Q_t = f(AP_t, WP_t, CPI_t, PCIN_t) \tag{3}$$

where Q_t represents per capita almond consumption, AP_t represents the price of almonds, WP_t denotes the price of walnuts, a possible substitute for almonds, CPI_t represents the consumer price index and captures the price of all other goods, and $PCIN_t$ denotes per capita income.[3]

With respect to functional forms for the almond demand equation, Box-Cox flexible functional forms

$$\frac{Q_t^{\lambda}}{\lambda} = \beta_0 + \beta_1 \frac{X_{t1}^{\lambda}}{\lambda} + \cdots + \beta_K \frac{X_{tK}^{\lambda}}{\lambda} + \varepsilon_t \tag{4}$$

were estimated by maximum likelihood procedures where λ can take on any value. All of the estimations in the report are carried out using SHAZAM, version 10. The linear and double logarithmic forms are special cases of the Box-Cox specification. The linear and double-log functional forms in the almond demand equation were tested against the more flexible Box-Cox functional form and in both cases the linear and double-log specifications were strongly rejected. The values of the likelihood ratio statistics were 43.7 for the linear and 14.85 for double-log model. The chi-squared critical value with one degree of freedom is 3.841 at the five percent significance level. Table 1 presents the estimations. The homogeneity condition of degree zero in all prices and income (HOD) does not hold globally in the Box-Cox specification unless the functional form is double

[3] Demand theory describes the behavior of individual consumers. The estimations, however, use aggregate data over all consumers. This can result in aggregation biases. If the observations are time series of cross-section data on randomly selected households, then it can be shown that the aggregate coefficients converge, as the number of households (N) goes to infinity, in probability to the micro coefficients (Theil). The disturbance terms are heteroskedastic, however. White's heteroskedastic-consistent standard errors for the estimated coefficients must be used. A recent excellent and thorough treatment of the conditions needed to avoid aggregation bias including exact aggregation and the distributional approach is given in Blundell and Stoker. They consider heterogeneity of consumers and distribution of income over time.

log.[4] The linear, double-log, and Box-Cox estimated functional forms for almond demand equations are presented in Table 3. In order to make the different models comparable, homogeneity was imposed in the double-log models and the other models were deflated by CPI.

[4] The homogeneity condition is $\lambda = 0 \; and \; \Sigma\beta_j = 0$ where the $\beta's$ are price and income coefficients; see Pope, *et al*. Linear specifications cannot be HOD by construction.

Table 3. Almond Demand Functions[1]

	Linear	D. Log	D. Log-A[2]	Box-Cox	Box-Cox-A[3]
AP[4]	-0.0016	-0.480	-0.377	-0.2671	-2.386
p-value	(0.0036)	(0.0004)	(0.0010)	(0.0004)	(0.0007)
elasticity	-0.351	-0.480	-0.377	-0.477	-0.378
WP[5]	0.0001	0.103	0.002	0.0436	-0.0267
p-value	(0.3898)	(0.5895)	(0.9912)	(0.5948)	(0.9891)
elasticity	0.465	0.103	0.002	0.097	-0.002
PCIN	0.00001	0.870	0.973	0.2911	29.404
p-value	(0.000)	(0.0038)	(0.0120)	(0.0036)	(0.0251)
elasticity	0.465	0.870	0.973	0.864	0.928
Const	-0.403	-5.14	-5.429	-4.270	-78.211
p-value	(0.000)	(0.0042)	(0.0068)	(0.0319)	(0.0394)
R^2	0.62	0.74	0.80	0.74	0.82
lnL	28.484	14.051	17.66	35.91	40.239
λ				0.107	-0.340
ρ			0.49		0.56

[1] *Q* is in pounds per capita, *AP* and *WP* are in cents per pound, and *PCIN* is in dollars.
[2,3] "A" denotes autocorrelated correction models.
[4,5] These are grower prices since retail prices do not exist.

The models were estimated using annual data from 1970 to 2001, a total of 32 observations. The Durbin-Watson values were 1.23 and 1.12 in the linear and double-log functional forms. The critical values are 1.244 and 1.650 at the five percent significance level, thus in the double-log and Box-Cox specifications the models were also estimated with an AR(1) error process. The estimated autocorrelation coefficients were 0.49 (double-log) and 0.56 (Box-Cox) with an estimated asymptotic standard error of 0.15 (double-log) and 0.14 (Box-Cox). The estimated own-price elasticity of domestic demand for almonds ranged from –0.48 to -0.35. The estimated elasticity was -0.38 in the Box-Cox functional form with an AR(1) error process. The estimates were highly significant with small p-values. Also, the estimated cross-price elasticity with walnuts was positive in four of the five models, but none of the coefficients were statistically significant; the smallest p-value being 0.39. The results confirm the absence of gross substitution effects between almond and walnuts. All of the estimated income coefficients were positive and ranged from 0.46 to 0.97 with small p-values. A sequential Chow and Goldfeld-Quandt test was conducted to determine if any structural changes had taken place during this period. No evidence was found of any structural changes.

Additional models were estimated using the dependent variable, US total consumption of almonds plus California exports minus US imports. The dependent variable captures the international demand for US almonds as well as the domestic demand. The ordinary least squares estimated double-log regression had an R^2 of 0.92. The estimated own-price elasticity of demand for almonds was -0.270 with an associated

p-value of 0.022. The estimated model had a positive time trend coefficient of 0.05 (p-value =0.03) income elasticity was 2.10 with a p-value of 0.07.

Single equation estimation: supply

On the supply side, estimated almond acreage, yield, and marketable production functions were estimated for the period 1970 to 2001. The almond acreage was estimated using a partial adjustment model of the form:

$$\begin{aligned} A_t^* &= \alpha + \beta P_t \\ A_t - A_{t-1} &= (1-\gamma)\left(A_t^* - A_{t-1}\right) + \varepsilon_t \end{aligned} \tag{5}$$

where equations (5) are the desired almond acreage and equation (6) is the actual acreage; respectively. By substitution and some simplifications, the model can be estimated as:

$$A_t = (1-\gamma)\alpha + (1-\gamma)\beta P_t + \gamma A_{t-1} + \varepsilon_t \tag{6}$$

where A_t is the almond acreage (in acres), P_t is the average real almond grower price per pound over the previous eight years and, and ε_t is an error term included to capture all omitted factors that affect almond acreage.

This specification was chosen because it incorporates the behavior of producers whom adjust their acreage when they realize that the desired acreage (A_t^*) differs from the actual acreage the previous year (A_{t-1}). The adjustment coefficient, $1-\gamma$, indicates the rate of adjustment of actual acreage to desired acreage. The partial adjustment model is a model that captures producers' behavior (see, e.g., Kmenta). Almond trees take between five and six years to be fully productive. The acreage equation assumes a long-run planning process based on past prices, which are considered a proxy of the farmers' expectations about future prices.

The estimated acreage equation, with all variables expressed in logarithm form and based on 1979-2001 annual observations, is:

$$\ln \hat{A}_t = \underset{(0.31)}{-0.32} + \underset{(0.03)}{0.12} \ln P_t + \underset{(0.04)}{0.97} \ln A_{t-1} . \tag{7}$$

The values in parentheses are standard errors. The coefficient of determination of the regression is R^2=0.97. The Durbin-h statistic is 1.40 which is asymptotically not significant, thus there is no evidence of autocorrelation. The estimated short-run price elasticity is 0.12 with an associated p-value of 0.0016. The estimated coefficient on lagged acreage is 0.97 with an associated p-value of 0.0000. The estimated acreage response equation provides empirical evidence that almond producers respond positively to anticipated price increases in almonds.

The yield equation for almonds is:

$$\ln Y_t = \beta_1 + \beta_2 \ln P_{t-1} + \beta_3 Rain_t + \beta_4 T_t + \beta_5 T_t^2 + \varepsilon_t \tag{8}$$

where Y_t is almond yield in pounds per acre, P_{t-1} is the real grower price of almonds in cents per pound in the previous year, $Rain_t$ is rainfall in inches in March, and T_t is a time trend that is a proxy for technological change.

The ordinary least squares estimated yield equation for almonds for the years 1971-2001 is (equation (9))

$$\ln \hat{Y}_t = \underset{(0.48)}{6.39} + \underset{(0.09)}{0.07} \ln P_{t-1} - \underset{(0.05)}{0.20} \ln Rain_t + \underset{(0.01)}{0.05} T_t - \underset{(0.0003)}{0.001} T_t^2 \tag{9}$$

where the values in parentheses are standard errors. The estimated R^2 is 0.68 which indicates an adequate fit of the model with the data. All of the p-values for the estimated coefficients are less than 0.10 except for one associated with lagged price. The coefficient on lagged price is positive (0.07) but not significant. The coefficient on

March rainfall is negative (-0.20) reflecting the effect of rain on increased brown rot disease and decreased pollination. The coefficient on the time trend is positive (0.05) and significant indicating that, conditioned on all the other variables, yields are increasing over the time period, 1971-2001. The coefficient on time squared is negative (-0.001) and significant reflecting that the time trend is increasing at a decreasing rate. The increasing trend can be due to technology and improvement of production practices. The almond yield equation exhibits an alternate bearing phenomenon since the autocorrelation was negative ($\hat{\rho} = 0.38$) with an asymptotic t-value of 2.26.[5] The model was estimated using the autocorrelation method of Pagan in SHAZAM. The other autocorrelation methods, ML and Cochrane–Orcutt gave similar results.

Finally, a production function for almonds was developed and estimated. The model is:

$$\ln Q_t = \beta_1 + \beta_2 \ln P_{t-1} + \beta_3 \ln Rain_t + \beta_4 \ln Q_{t-1} + \varepsilon_t \tag{10}$$

where Q_t is California almond production in millions of pounds, P_{t-1} represents the lagged price of almonds in cents per pound, $Rain_t$ represents March rainfall in inches, and Q_{t-1} denotes lagged production. The model is a partial adjustment model and includes the effect of alternate crop years and weather. As in the yield equation, the alternative bearing phenomenon is captured by a negative autocorrelation coefficient.

The estimation of the model, correcting for autocorrelation, is

[5] Several methods were used to capture the alternate-year yield phenomenon. For example, a dummy variable was added to the function with zero values for low-yield years and ones for high-yield years. Due to weather conditions and new varieties of trees that started bearing, the data exhibits a high-low pattern for a number of years followed by two high-yield years in a row or two low-yield years in a row. The high-low pattern continues for a few years but the pattern may be reversed. History then repeats itself. It is difficult to capture these phenomena with a dummy variable in the systematic part of the equation. This

$$\ln \hat{Q}_t = -0.44 + 0.19 \ln P_{t-1} - 0.20 \ln Rain_t + 0.97 \ln Q_{t-1} \tag{11}$$
$$(1.24)(0.15) \qquad (0.07) \qquad (0.11)$$

where the numbers in parentheses are estimated standard errors. The R^2 of the model is 0.71. The elasticity of production with respect to the lagged own price (for given values of the production in the previous year, the weather conditions and the alternate crop years) is 0.19 but not significant (p-value= 0.20). The coefficient on March rainfall is negative as explained above and the estimated coefficient on lagged production is positive and highly significant. The alternate crop pattern was capture by a negative autocorrelation coefficient of -0.55 with an associated asymptotic t-value of 3.74.[6]

WALNUTS

Data for the years 1970-2001 are presented in Appendix B for walnuts. California marketable production, total domestic consumption, exports and imports, per capita consumption, acreage, yield, and grower prices, both nominal and real for walnuts are given in Figures 1B-6B in Appendix B. An overview of the walnut industry can be seen by an examination of the Figures. Marketable production of walnuts has slowly increased from just below 100 million pounds in 1970 to over 250 million pounds in 2001. Exports of walnuts exhibit a similar pattern of that to production (see Figure 1B in Appendix B). Per capita consumption of walnuts has remained relatively stable at 0.4 pounds over the period 1970-2001 (Figure 2B). Acreage has slowly increased over the period starting with about 150 thousand acres in 1970 to about 200 thousand in 2001.

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was not the case with walnuts where the alternate pattern was consistent throughout the sample period. See the patterns in the data for almond yields, walnut yields, and walnut production in Appendix C.

[6] Alternative functional forms of the production function were estimated including a Box-Cox specification, models with moving average error schemes, etc. The Box-Cox functional form yielded a price elasticity of 0.29 and a model estimated with a moving average error term yielded a slightly lower price elasticity estimate of 0.23.

Yields of walnuts are more volatile over the period than acreage but with a steady trend upward over the period 1970-2001 (Figure 4B). Real grower prices have decreased over the period from 1970 to 2001 (Figure 6B). Real grower prices reached a peak in about 1978 of $2.00 per pound and have declined ever since to about 60 cents per pound in 2001.

Demand, acreage, yield, and production equations were estimated for walnuts using annual data from 1970 to 2001. The United States domestic demand for walnuts is estimated and reported first.

The model for US per capita consumption of walnuts is

$$Q_t = f(AP_t, WP_t, CPI_t, PCIN_t) \tag{13}$$

where Q_t represents per capita walnut consumption in pounds, AP_t represents the price of almonds in cents per pound where almonds are a possible substitute for walnuts, WP_t denotes the price of walnuts in cents per pound, CPI_t represents the consumer price index and captures the price of all other goods, and $PCIN_t$ denotes per capita income in dollars.

The restriction of homogeneity of degree zero in all prices and income was imposed. When the model for all the years, 1970 to 2001, was estimated by ordinary least squares, the Durbin-Watson value was small (0.796) indicating a possible misspecified model. Consequently, sequential Chow and Goldfeld-Quandt tests were performed and they indicated a structural break in 1983. Two demand functions were estimated, one using data from 1971 to 1983 and one employing data from 1983 to 2001. The estimated models, double-log and Box-Cox functional forms, are presented in Table 4.

Table 4. Walnut Demand Functions

	Pre 1983		Post 1983	
	Double Log	**Box-Cox**	**Double Log**	**Box-Cox**
AP	-0.210	-0.449	-0.082	-0.19E-06
p-value	(0.039)	(0.136)	(0.325)	(0.667)
elasticity	-0.210	-0.197	-0.082	-0.023
WP	-0.284	-0.825	-0.267	-0.26E-07
p-value	(0.068)	(0.113)	(0.063)	(0.051)
elasticity	-0.284	-0.266	-0.267	-0.251
CPI	-1.039	-1.435	-0.633	-0.61E-05
p-value	(0.029)	(0.612)	(0.414)	(0.307)
elasticity	-1.039	-0.677)	-0.633	-0.807
PCIN	1.534	5.349	-0.983	0.10E-09
p-value	(0.007)	(0.339)	(0.201)	(0.398)
elasticity	1.039	1.207	-0.983	0.427
Constant	-7.361	-17.519	-4.50	-0.333
p-value	(0.005)	(0.304)	(0.207)	(0.000)
R^2	0.759	0.763	0.705	0.726
DW	2.563	2,43	2.069	2.507
lnL	15.988	26.029	25.492	44.217
λ	0	-0.15	0	2.06

The R^2 values range from 0.71 to 0.76. The fit of the models to the data was not as good as for the almond demand equations. The Durbin-Watson statistics did not indicate any problems with autocorrelation. The estimated own-price elasticity of demand for walnuts ranged from –0.266 to -0.284 for the time period prior to 1983 and from -0.251 to -0.267 after the year 1983. The p-values were 0.068 (pre 1983) and 0.63 (post 1983) for the double-log models and 0.113 (pre 1983) to 0.051 (post 1983) for the Box-Cox functional forms. The Box-Cox equation post 1983 was estimated with a time trend. Its estimated coefficient was -0.03 with an associated p-value of 0.014. Three of the four estimated income elasticities were positive with only the post 1983 for the double-log specification negative (-0.983). Only one of the estimated almond cross-price elasticities was significant at any reasonable level. Thus, the sample evidence finds little substitution effects between almonds and walnuts. Based on the sample evidence the estimated own-price elasticity of demand for walnuts is inelastic.

What are some economic factors that can explain the structural break around 1982-83? From Figure 6B, real walnut prices dropped dramatically in 1983. There was a large supply of walnuts that year and inventory levels increased significantly. In addition, the United States imposed a tariff on pasta and Italy, one of the largest importers of U.S. walnuts, retaliated by placing an embargo on U.S. walnuts. Exports dropped causing increases in inventory levels.

Another model was estimated where the dependent variable was US total consumption of walnuts plus California exports minus US imports. The dependent variable captures domestic plus net export demand. Again, sequential structural tests indicated a structural break around 1983. The results from this estimated equation

yielded a total own-price elasticity of demand for walnuts of –0.354 prior to 1983 and an estimated value of –0.061 after 1983. The estimated coefficient of determination for this equation was 0.923. The wide difference between the estimated own-price elasticities of demand between the two time periods may be due, in part, to structural changes mentioned above. The primary policy implications are that the demand for walnuts is inelastic with little evidence that almonds are an important substitute for walnuts.

On the supply side, acreage, yield, and production equations were estimated for walnuts, using a partial adjustment model. The estimated acreage equation is

$$\ln \hat{A}_t = \underset{(1.16)}{2.90} + \underset{(0.01)}{0.02} \ln P_t + \underset{(0.00)}{0.00} T_t + \underset{(0.00)}{0.00} T_t^2 + \underset{(0.10)}{0.74} \ln A_{t-1} \tag{14}$$

where A_t represents acreage of walnuts in acres, P denotes walnuts grower prices of walnuts in cents per pound and T is a time trend. Values in parentheses represent standard errors. The estimated coefficient of determination, R^2, was 0.953. The estimated short-run elasticity of acreage with respect to price is 0.02, which implies that acreage is inelastic with respect to the current price. The estimated lagged acreage coefficient was 0.74 and highly significant indicating a partial adjustment by producers of walnut acreage over time. Figure 6 charts the actual acreage of walnuts to the predicted values.

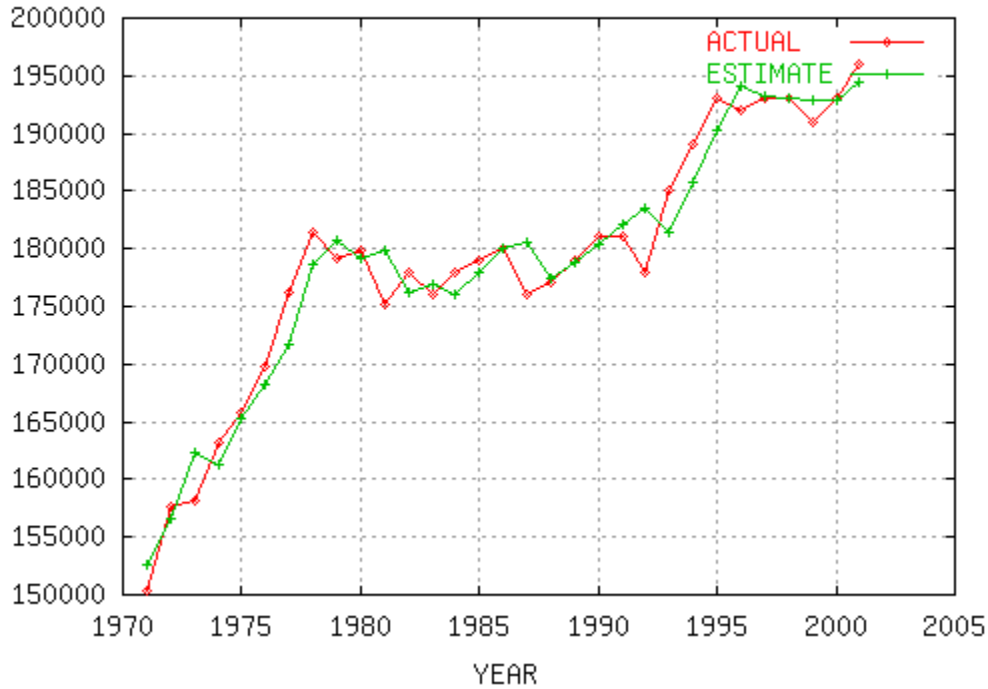

Figure 1: Walnuts acreage. Actual and estimated (in acres).

The value of the Durbin h statistic (-0.37) indicates that autocorrelation is not a problem.

The ordinary least squares estimated yield equation for walnuts, based on the years 1972-2001, is

$$\ln \hat{Y}_t = \underset{(0.60)}{-0.01} - \underset{(0.08)}{0.03} \ln P_{t-1} + \underset{(0.03)}{0.03} TAM_t + \underset{(0.03)}{0.14} D_t + \underset{(0.01)}{0.01} T_t - \underset{(0.0003)}{0.0002} T_t^2 \qquad (15)$$

where Y_t, the dependent variable is yield of walnuts in pounds per acre, P_{t-1} is lagged real grower price of walnuts in cents per pound, T_t is a time trend, TAM_t is the average temperature in March, D_t is a dummy variable that is equal to one in high-yield years and zero for low-yield years (more specifically, D=1 in 1970 and alternates from 1 to 0

throughout the sampling period) and is included to capture the alternate yield-year phenomenon. The coefficient of determination is 0.72. The Durbin-Watson calculated value of 1.78 does not support evidence of negative correlation. The "see-saw" pattern exhibited by walnut yields is more consistent that than for almond yields and thus the dummy variable included in the systematic part of the equation picks up the alternative bearing phenomenon (see Appendix C). The estimated coefficient on D is positive and highly significant as expected and the coefficient on March temperature is positive as expected but not significant. There is a little evidence of a positive time trend. The lagged price coefficient is unexpectedly negative but not significant.

The final estimation for walnuts consists of estimating a production function for the years 1971-2001. The estimated production function, corrected for autocorrelation, is:

$$\ln \hat{PR}_t = \underset{(1.84)}{3.52} + \underset{(0.06)}{0.003} \ln P_{t-1} + \underset{(0.02)}{0.03} TAM_t + \underset{(0.07)}{0.23} D_t + \underset{(0.13)}{0.69} \ln PR_{t-1} \qquad (16)$$

where the dependent variable, PR_t, is walnut production in millions of pounds, P_{t-1} is walnut price in cents per pound, TAM_t is the March temperature, and D_t is a dummy variable that takes on the values of 1 and 0 and accounts for the alternate year production phenomenon. The R^2 of the regression is 0.82. The estimated autocorrelation coefficient is -0.47 with as asymptotic t-value of 2.60. The alternate year dummy coefficient is positive and highly significant as expected is picking up all the alternate production year effect. The estimated coefficient on lagged walnut price is positive but insignificant and the estimated coefficient on lagged production is positive and significant. The positive sign on March temperature is as expected.

SUR Estimation

The results of the estimations suggest that walnuts and almonds cannot be considered as close substitutes or complements because the cross-price elasticities were not significantly different from zero. However, the possible relations across the two markets can be explored using a demand system of *seemingly unrelated equations* (SUR). In this system, correlation in the errors across equations is assumed. Some of the same omitted factors may influence both almond and walnut demands.

The equations are estimated using an iterative SUR procedure to achieve efficiency. Also the properties of symmetry and zero homogeneity were imposed. The estimation of the system (eq. 17) is:

$$\ln PC_t^W = -4.17 - 0.14 \ln P_t^W - 0.20 \ln P_t^A - 0.48 \ln CPI_t + 0.82 \ln PCIN_t - 0.19 T_t - 0.07 D_t$$
$$(3.57)\ (0.14) \qquad (0.08) \qquad (0.07) \qquad (0.78) \qquad (0.01) \quad (0.08)$$
$$\ln PC_t^A = -5.45 - 0.20 \ln P_t^A - 0.18 \ln P_t^W - 0.67 \ln CPI_t + 1.05 \ln PCIN_t$$
$$(1.64)\ (0.08) \qquad (0.17) \qquad (0.40) \qquad (0.29)$$

where numbers in parentheses are standard errors, PC^W and PC^A are the per-capita consumption of walnuts and almond, respectively. PC^w and PC^A are grower nominal prices of walnuts and almonds, respectively, D_t is a dummy variable that takes on the value of zero prior to 1983 and the value of one after 1983. The remaining variables are as defined above except per capita income is also expressed in nominal terms. The system R^2 is equal to 0.81. The estimated own-price elasticity of walnuts is -0.14 and that of almonds -0.20; with only the estimated own-price elasticity of almonds being highly significant. The estimated income elasticity for walnuts is 0.82 and that of almonds is 1.05.

Some Policy Implications

Based on the models estimated for almonds and walnuts the own-price elasticity of US domestic demand for almonds was found to be between –0.35 and -0.48.. These estimates are inelastic and imply that almond producers are vulnerable to large swings in prices of almonds due to supply shifts. Similar estimates of the own-price elasticity of US domestic demand for walnuts were obtained. The estimated own-price elasticities for walnuts ranged from –0.25 to –0.28. Walnut producers face the same marketing situation as almond producers, that is, prices of walnuts fluctuate widely due to shifts in the supply function of walnuts.

The estimated acreage response equation for almonds indicated that producers respond positively to lag prices. The estimated short-run price elasticity of acreage for almonds was 0.12 and significant. This is relatively small but does indicate that producers are responsive to increases in prices over time. For walnuts the estimated short-run price elasticity of acreage was 0.02 and significant. Again, the value is small but positive.

The estimated yield equations for both almonds and walnuts reflected a significant alternate-year phenomenon. For almonds the phenomenon was capture by a significant and negative autocorrelation coefficient. For walnuts it was captured by a dummy variable. Yields for almonds are significantly affected by a time trend. Yields of almonds are increasing over the time period 1979-2001, based on the estimated yield equation. For walnuts, yields were positively affected by temperature in March and a time trend, but neither coefficient was significant.

A SUR demand system was estimated for walnuts and almonds. The domestic own-price elasticity of demand for walnuts was estimated to -0.14 and that of almonds -0.20 with almonds being significant. The estimated income elasticity of demand for walnuts was 0.82 and that for almonds was 1.05 with the estimated income elasticity in the almond equation being significant. The evidence does not support gross substitution between almonds and walnuts.

The primary policy implication based on these results is that almond and walnut producers are facing an inelastic domestic demand for their products. Combine this with the volatility of the supply function due to temperature and rainfall changes, wide variations in prices exist which lead to wide variations in profits from year to year. Storage, improved technology, and an expanding export market are factors that may mitigate the volatile market conditions facing US producers of almonds and walnuts.

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Appendix A: Almonds

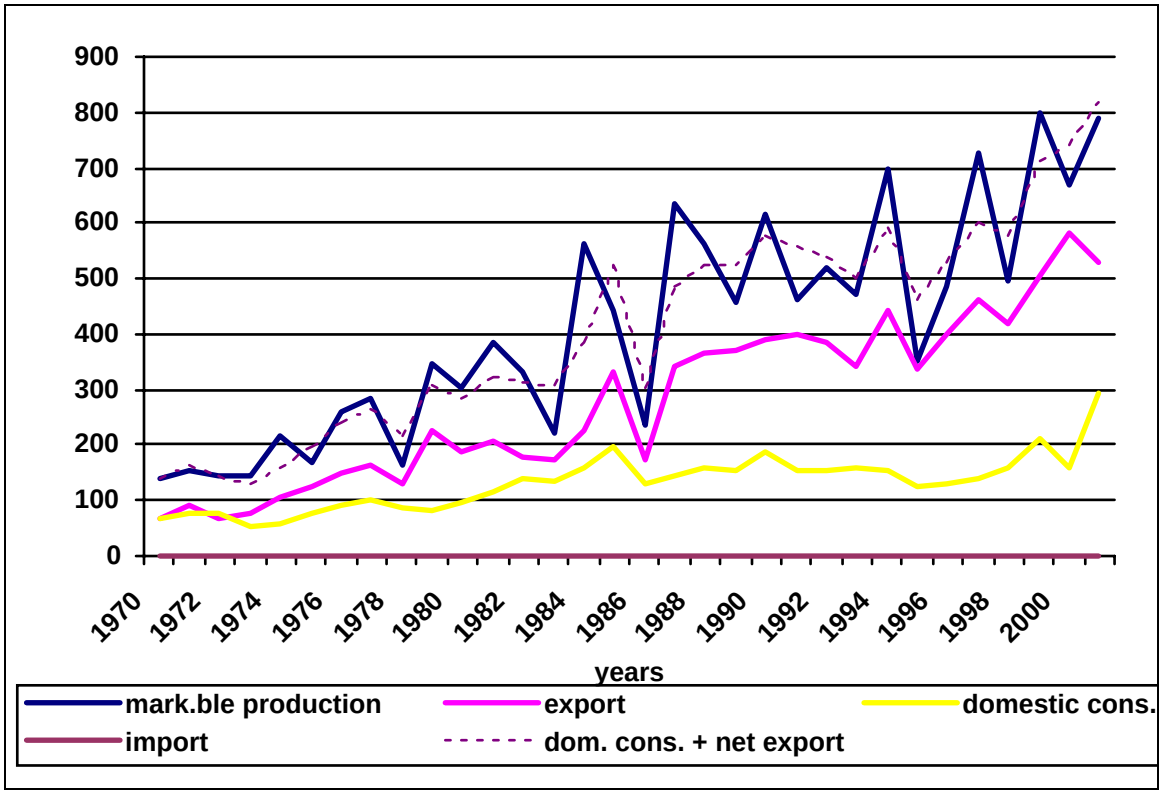


Figure 1A: California marketable production, US domestic consumption, export and import of Almonds. Years 1970-2001(millions of lbs).

Source: USDA

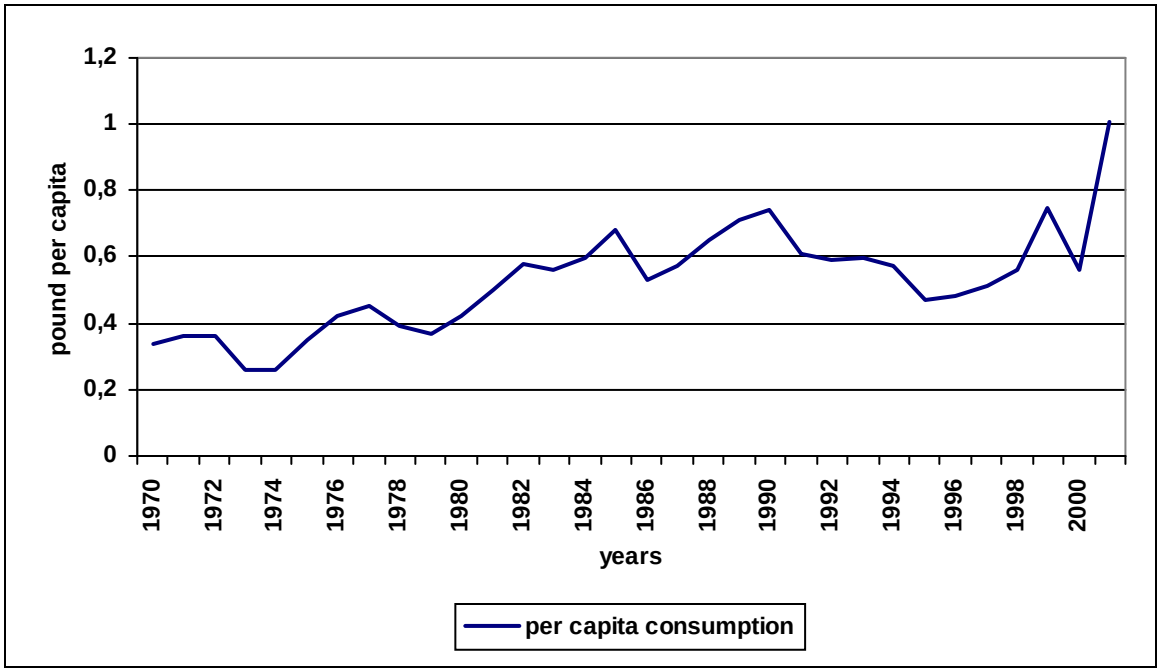


Figure 2A: US per capita consumption of Almonds. Years 1970-2001

Source: USDA

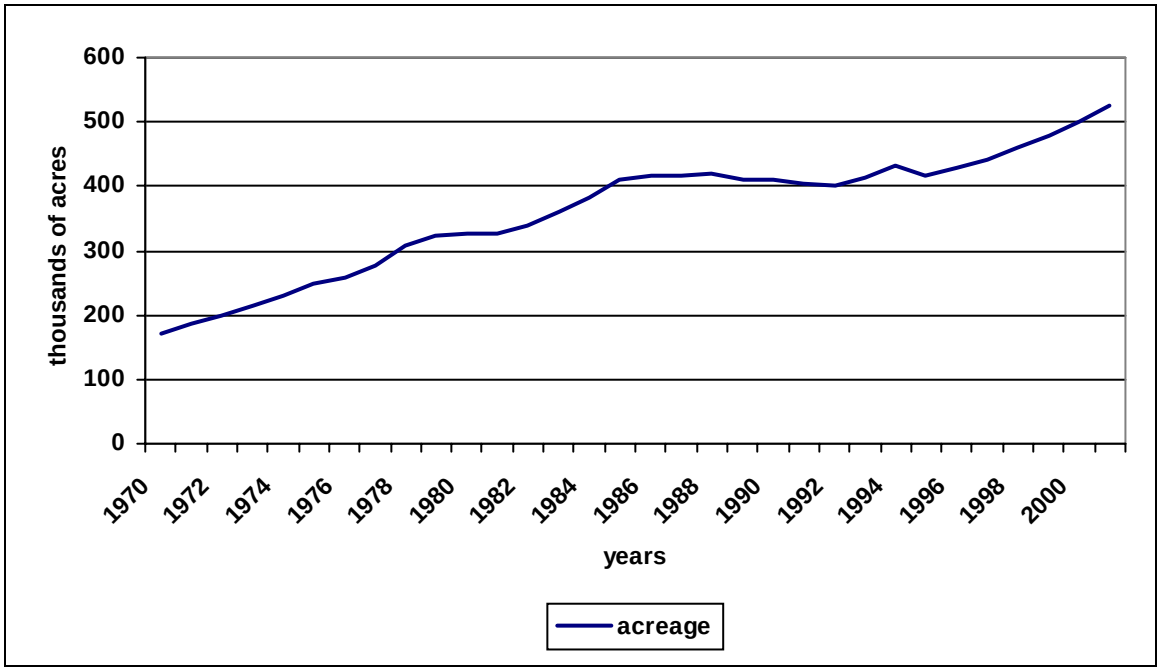


Figure 3A: Acreage of almonds in California. Years 1970-2001

Source: USDA

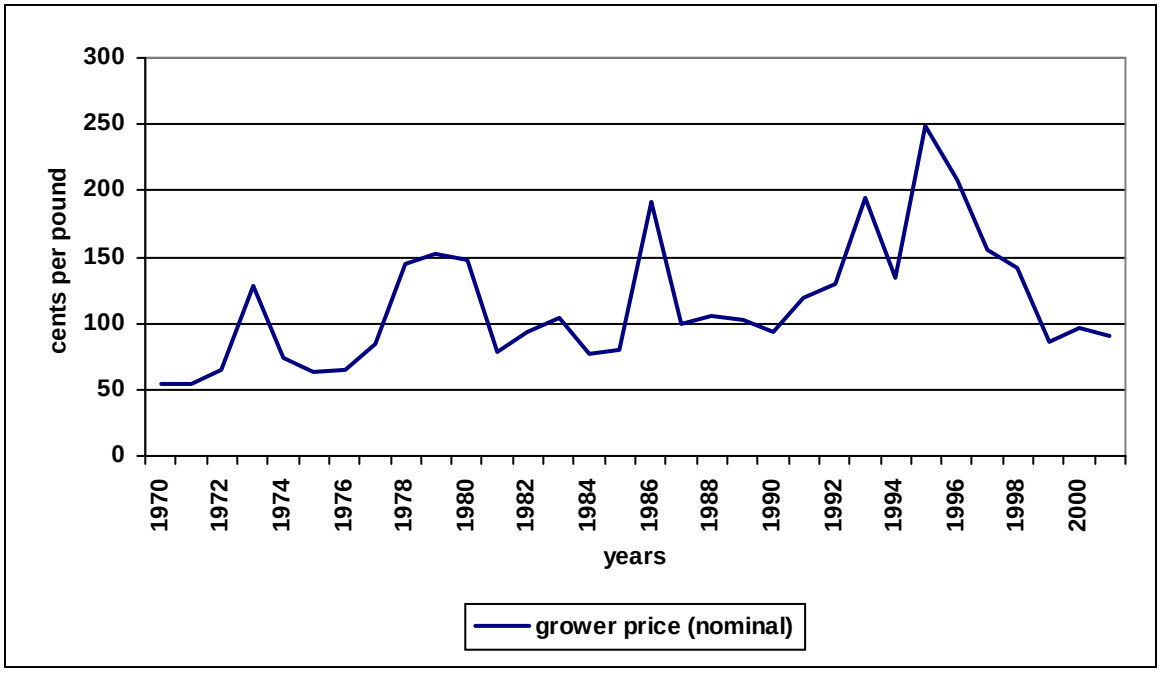


Figure 4A: Grower price for almonds in California (nominal values). Years 1970-2001

Source: USDA

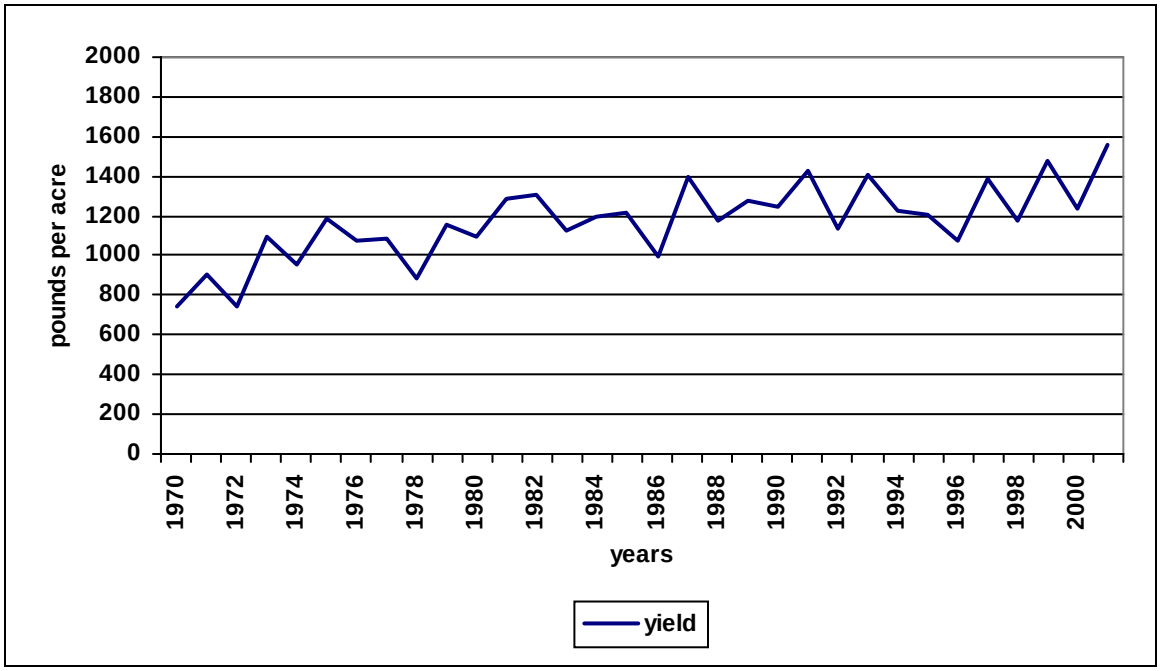


Figure 5A: Yield of almonds in California. Years 1970-2001

Source: USDA

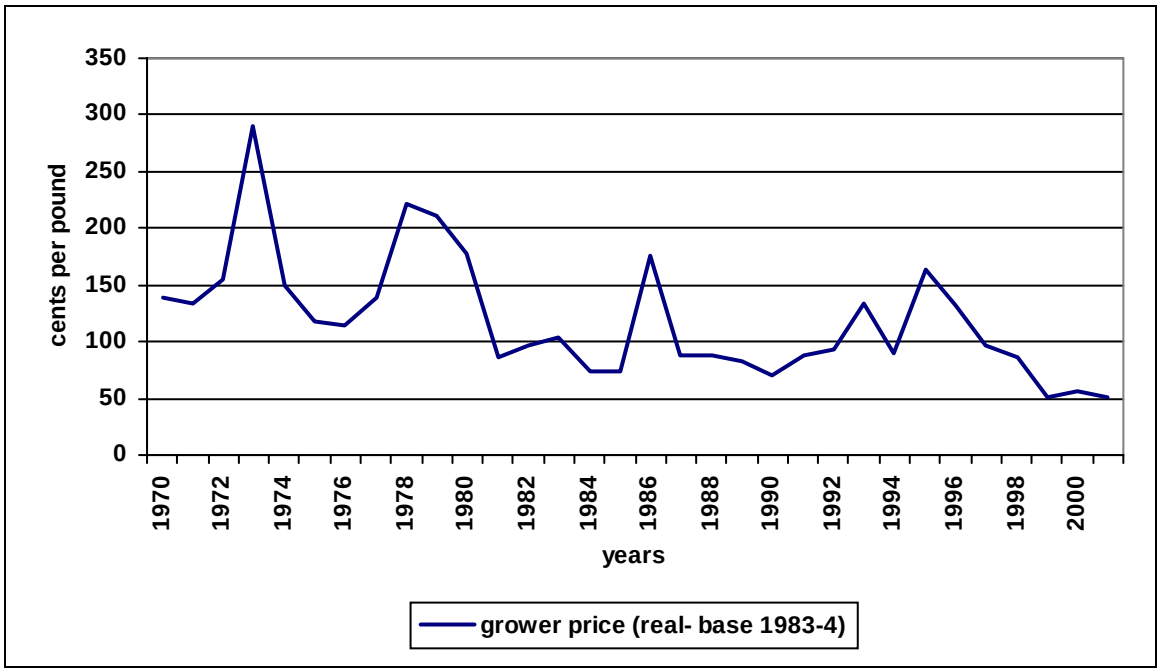


Figure 6A. Real grower price for almonds in California (real values). Years 1970-2001.

Source: USDA

Appendix B: Walnuts

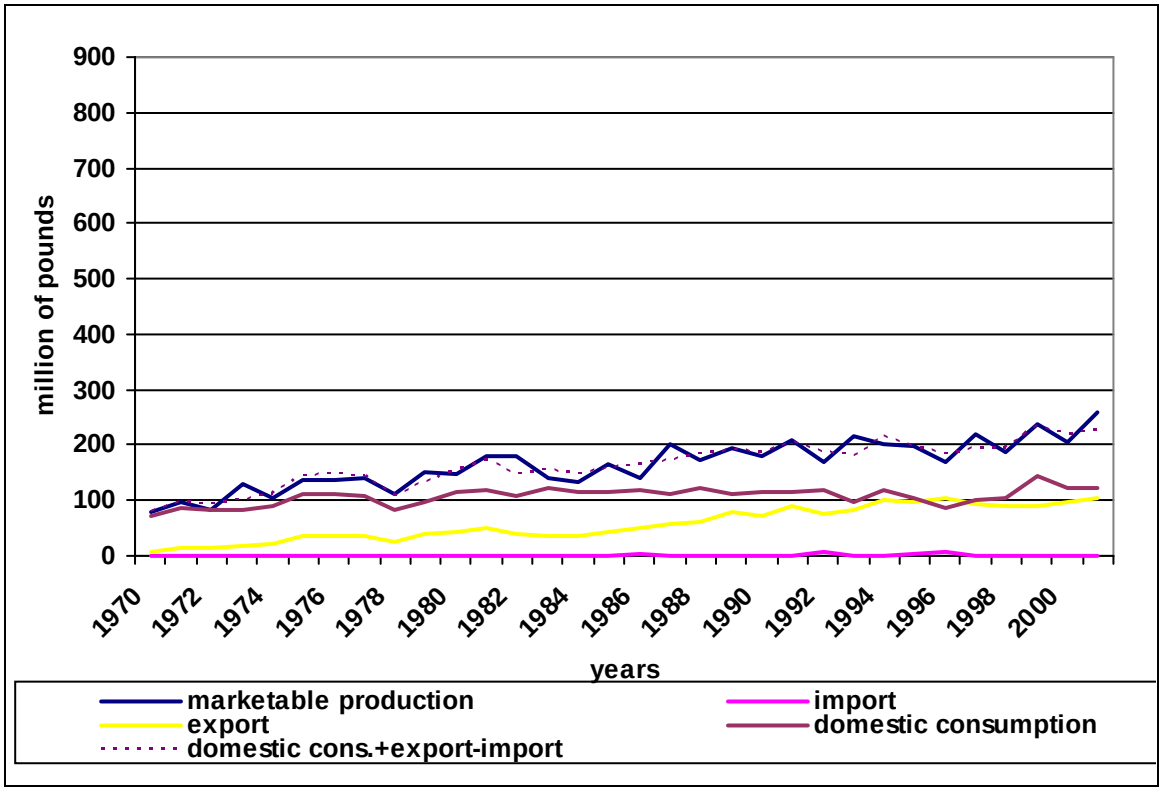


Figure 1B: ***California marketable production, US domestic consumption, export and import of Walnuts. Years 1970-2001***

Source: USDA

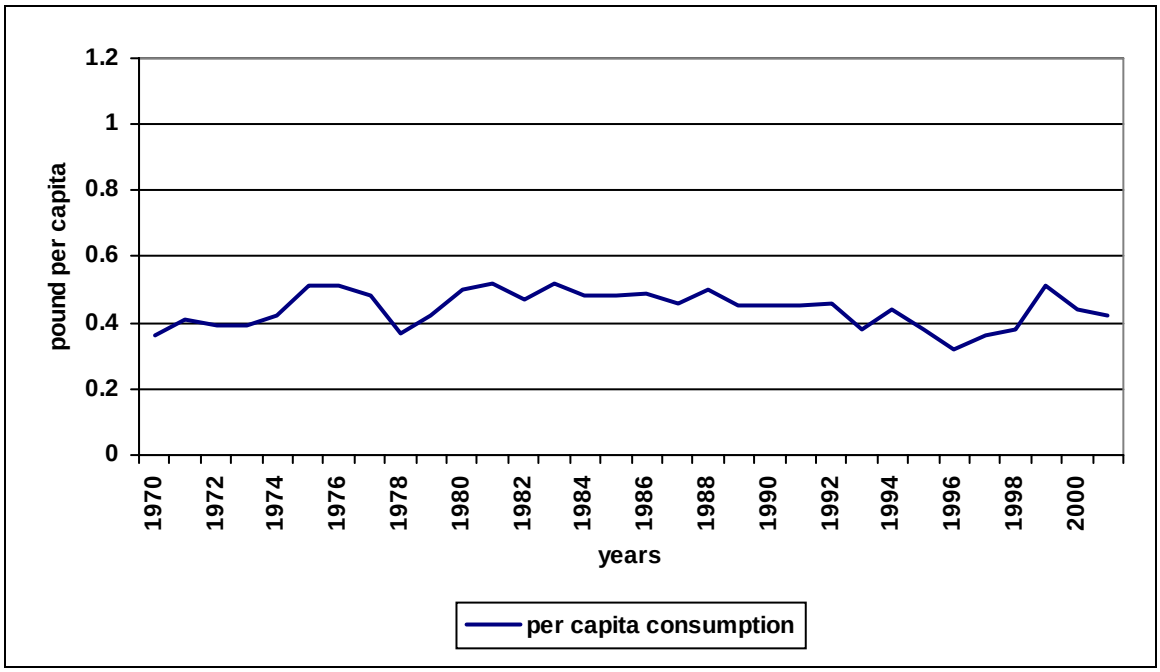


Figure 2B: ***US per capita consumption of Walnuts. Years 1970-2001***

Source: USDA

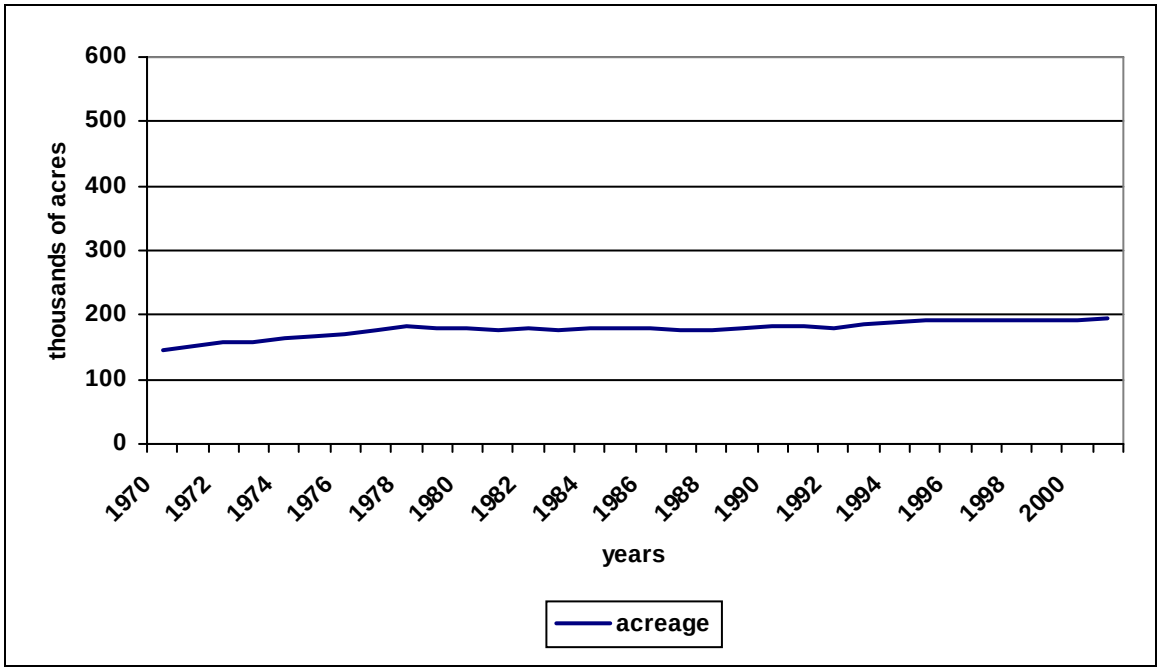


Figure 3B: ***Walnut acreage in California. Years 1970-2001***

Source: USDA

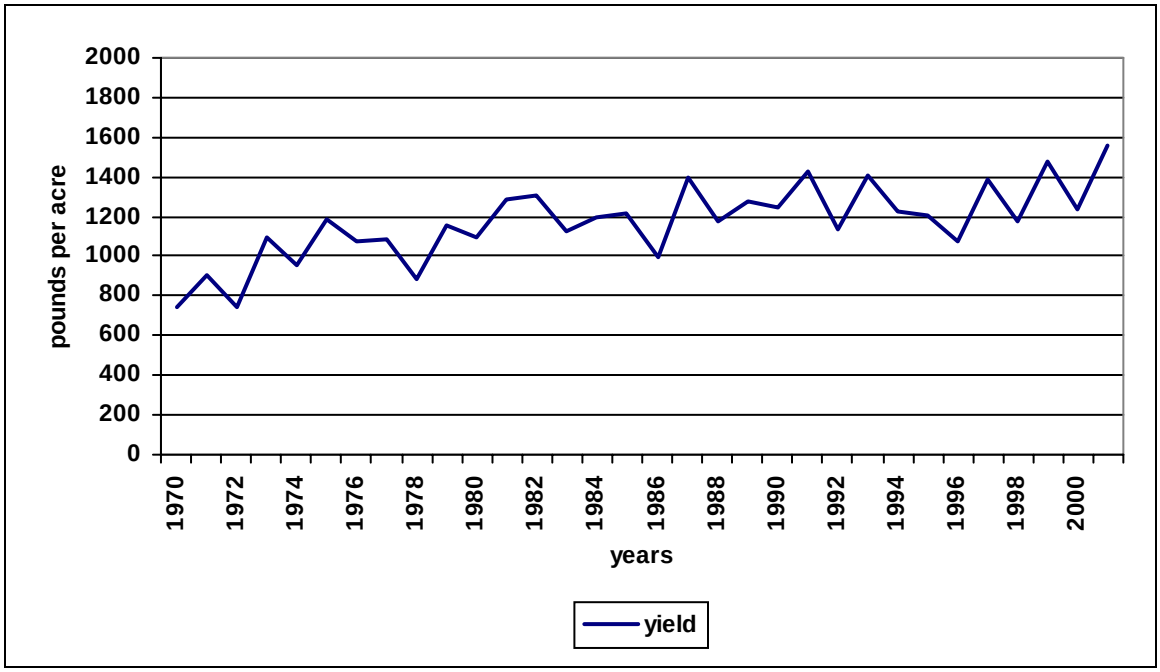


Figure 4B: ***Per acre yield of Walnuts in California. Years 1970-2001***

Source: USDA

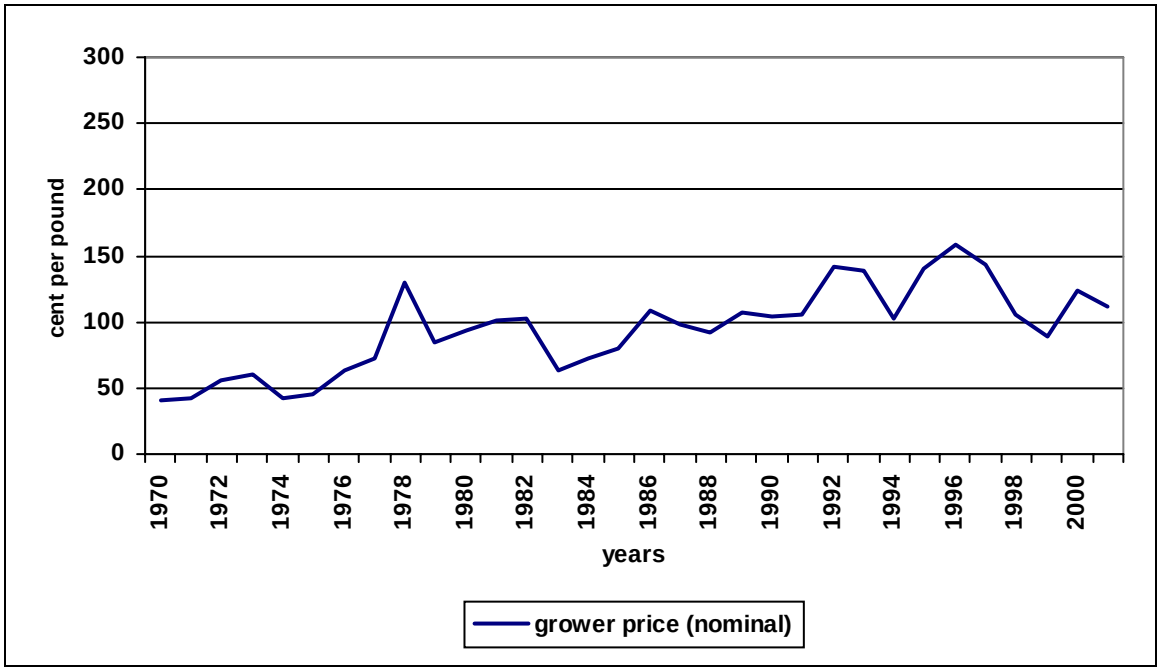


Figure 5B: ***Grower price for walnuts in California (nominal values). Years 1970-2001***

Source: USDA

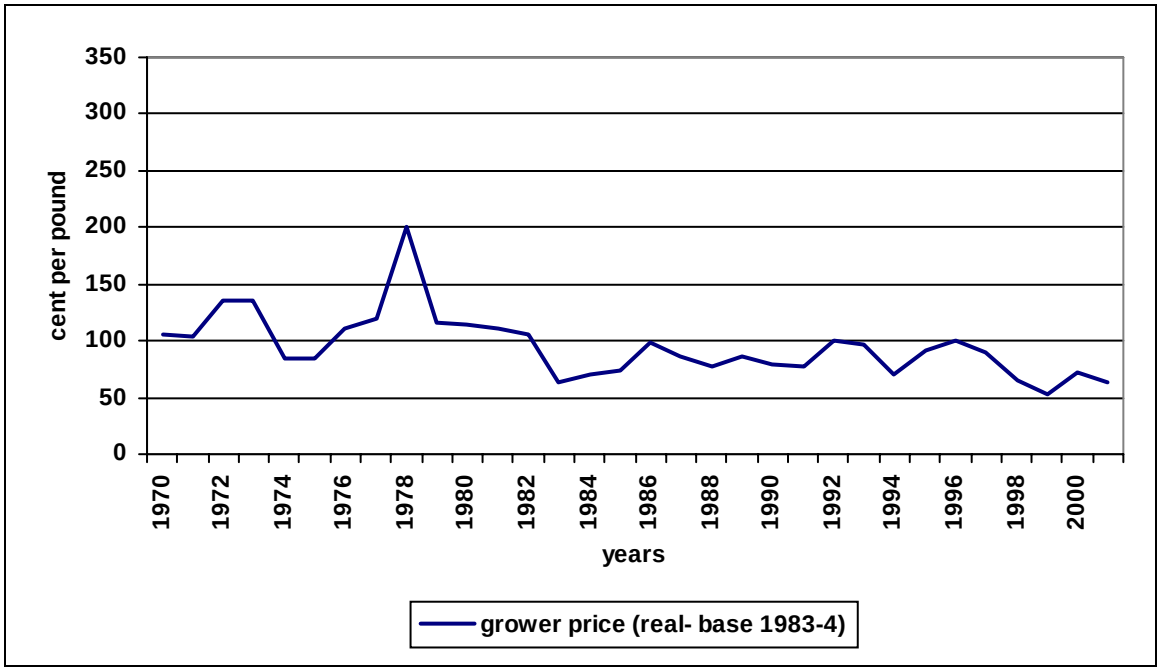


Figure 6B: ***Real grower price for walnuts in California (real values). Years 1970-2001***

Source: USDA

APPENDIX C: Almond Yields, Walnut Yields, and Walnut Production, 1970-2001

Year	Almond Yields (Pounds/Acre)	Walnut Yields (Pounds/Acre)	Walnut Production (Millions Lbs)
1970	877	740	108000
1971	863	900	135000
1972	759	740	116000
1973	726	1100	174000
1974	995	950	155000
1975	748	1190	198000
1976	1100	1080	183000
1977	1130	1090	192000
1978	588	880	160000
1979	1160	1160	208000
1980	985	1100	197000
1981	1250	1290	225000
1982	1250	1310	234000
1983	1020	1130	199000
1984	672	1200	213000
1985	1550	1220	219000
1986	1140	1000	180000
1987	601	1400	247000
1988	1580	1180	209000
1989	1410	1280	229000
1990	1190	1250	227000
1991	1610	1430	259000
1992	1210	1140	203000
1993	1370	1410	260000
1994	1190	1230	232000
1995	1700	1210	234000
1996	885	1080	208000
1997	1190	1390	269000
1998	1720	1180	227000
1999	1130	1480	283000
2000	1130	1240	239000
2001	1740	1560	305000

Source: USDA.

ALFALFA AND COTTON

Introduction

Historically, from 1950-2002, alfalfa and cotton have been among California's top commodities in terms of total value (Johnston and McCalla). In 1950 cotton was ranked third in terms of value of production in California with a value of $202 million. By 2001, cotton had slipped to the eighth most valuable commodity in California in value of production. The trend has been downward during the period 1950-2002. Hay (85% alfalfa) was ranked fifth in 1950 in California with a value of production of $121 million. In 2001, hay was ranked seventh in value of production just ahead of cotton.

Models are developed for California alfalfa and cotton acreage, production, and consumption. Both single equation and systems of equations are estimated. The data consist of 33 annual observations from 1970 to 2002. In some models, there were slightly fewer observations due to lags in the specifications. A brief description of the alfalfa market is given prior to reporting the estimations of the models. In addition, some issues related to the nature of the data are discussed.

Alfalfa

Alfalfa hay acreage in California has averaged about a million acres per year during the past 30 years (Figure 1A). Alfalfa contributes about 85 percent of the value of all hay production in California. Alfalfa is influenced by profitability of alternative annual crops such as cotton, tomatoes, trees, and vines. The demand for alfalfa hay is determined to a large degree by the size of the state's dairy herd, which consumes about 70 percent of the supply. Horses consume about 20 percent. Alfalfa is a perennial crop with a three to five-year economic life. Since it is a water intensive crop, its profitability

is strongly influenced by water and water costs. In addition, alfalfa is important in crop rotations because of its beneficial effects on the soil (Johnston, p. 87).

Alfalfa production in California has been increasing annually since the mid nineties (Figure 2A). It reached a peak in 2002 at 8.1 million tons. The increase in production has been primarily due to the upward trend in yields (Figure 3A) and not to increases in acreage. Alfalfa real grower price in California, using a 1983/84 base, has exhibited a downward trend since the early eighties (Figure 6A). In 2002 the real grower price was about $60 per ton.

Model for Alfalfa Acreage

A partial adjustment model of alfalfa acreage is based on the following equation:

$$\begin{aligned}\ln A_t = {} & \beta_0 + \beta_1 \ln A_{t-1} + \beta_2 \ln P_t + \beta_3 \ln risk_t + \beta_4 crit_t + \beta_5 crit_t * \ln A_{t-1} \\ & + \beta_6 crit_t * \ln P_t + \beta_7 crit_t * \ln risk_t + \varepsilon_t\end{aligned} \tag{1}$$

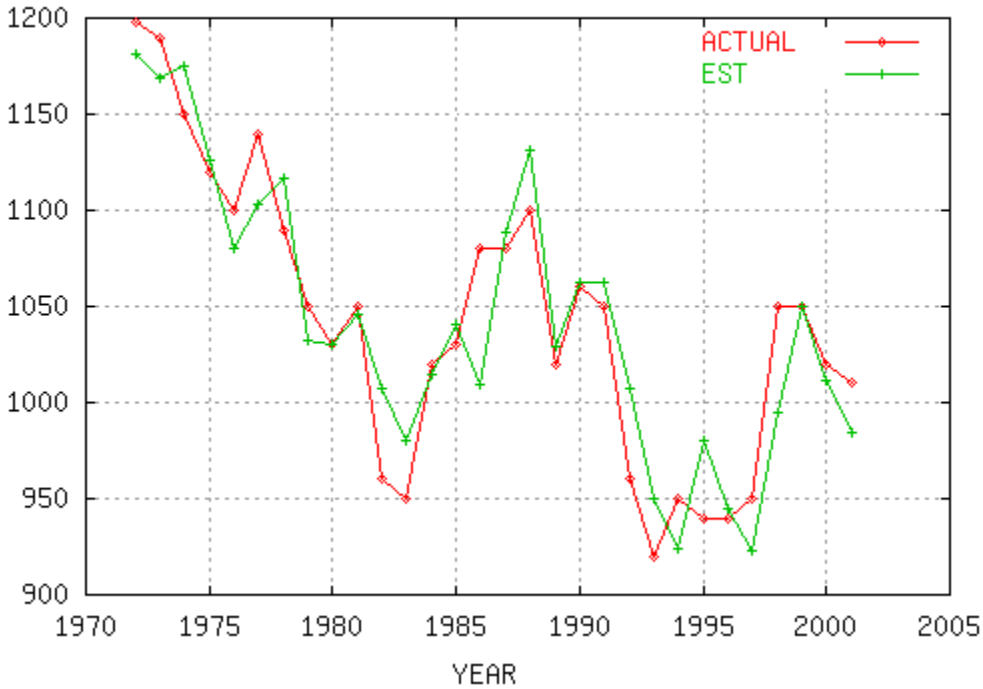
where A_t represents planted alfalfa acreage in thousands of acres, P_t is alfalfa price per ton, $risk_t$ is the variability in alfalfa price (measured by the standard deviation), and $crit_t$ is a dummy variable identifying the *critical years* for water scarcity (i.e., the year when the *Four river index* fell below the value of 5.4). The *Four river index* is an index to measure the water availability in California based on four river flows. The higher the value the more water available. Two interaction terms are also included in the model to capture the effects of water scarcity on prices and risk.

The results of the estimation are (equation 2):

$$\begin{aligned}\ln \hat{A}_t = {} & \underset{(1.66)}{4.08} + \underset{(0.17)}{0.67} \ln A_{t-1} + \underset{(0.16)}{0.35} \ln P_t - \underset{(0.27)}{0.61} \ln risk_t - \underset{(10.95)}{23.80} crit_t + \underset{(1.26)}{2.56} crit_t * \ln A_{t-1} \\ & + \underset{(0.59)}{0.31} crit_t * \ln P_t + \underset{(0.58)}{0.67} crit_t * \ln risk_t\end{aligned} \tag{2}$$

where the numbers in parentheses are estimated standard errors. The estimation supports the hypothesis that alfalfa acreage is influenced by prices, ceteris paribus. The short-run price elasticity of acreage is 0.35 and significant when ample water is available and 0.66 when there is a shortage of water. Acreage increases with price expectations and decreases with increases in perceived risk, as anticipated. Also the availability of water has a significant impact on acreage. An F-test on the joint significance of the variable "crit" and its cross products allows us to reject the null hypothesis of no impact at a 90% confidence level (p-value: 0.0787). The signs of the coefficients are consistent with a reduction of planting of new crop acreage during critical years of water scarcity. Furthermore, the estimated coefficient on lagged acreage is 0.67 and significant supporting the partial adjustment framework.

The regression R^2 is 0.847, indicating a good fit. The Durbin h test indicates that there is no autocorrelation in the disturbance terms. Graph 1 depicts the actual and estimated values for alfalfa acreage:



Graph 1: ***Actual and estimated values of alfalfa acreage (in thousands of acres).***

Model for Alfalfa Yield

Alfalfa yield is modeled by the following equation:

$$\ln Y_t = \beta_0 + \beta_1 \ln P_{t-1} + \beta_3 \ln CP_{t-1} + \beta_4 FRI_t + \beta_5 D_t + \varepsilon_t \tag{3}$$

where Y_t is alfalfa yield in tons, P_{t-1} is lagged alfalfa price per ton, CP_{t-1} is lagged cotton price \$/lb.(the rotation crop), FRI_t is the value of the *Four River Index* (approximating the availability of water) and D_t is a dummy variable identifying the year 1978 as an outlier. The model includes a moving average component of order two.

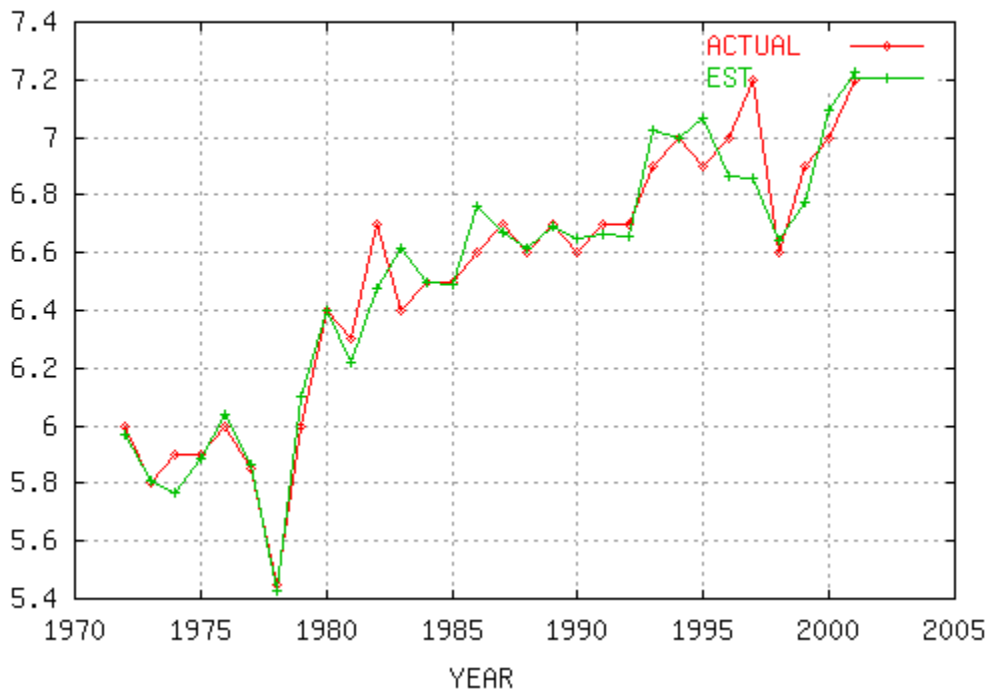
The estimated yield equation is:

$$\ln \hat{Y}_t = \underset{(0.02)}{1.31} + \underset{(0.00)}{0.08} \ln P_{t-1} - \underset{(0.01)}{0.14} \ln CP_{t-1} + \underset{(0.00)}{0.01} FRI_t - \underset{(0.03)}{0.12} D_t \tag{4}$$

where numbers in parentheses are standard errors. The estimated equation indicates that yields respond positively to changes in prices and water availability. Both of these

estimated coefficients are highly significant. Alfalfa yields are negatively related to last year's cotton price since they compete for the same irrigated land.. The estimated coefficient is also highly significant. The 1978 dummy coefficient is negative and significant as expected as it was a major drought year. Including a dummy variable for one year is equivalent to eliminating the 1978 observation.

The regression exhibits a good fit (R^2 is 0.93) and the tests ruled out autocorrelation (the Durbin-Watson statistics is 2.00) in the disturbance terms. . Graph 2 describes the actual and estimated alfalfa yields.



Graph 2: ***Actual and estimated values of alfalfa yield (tons/acre).***

Production

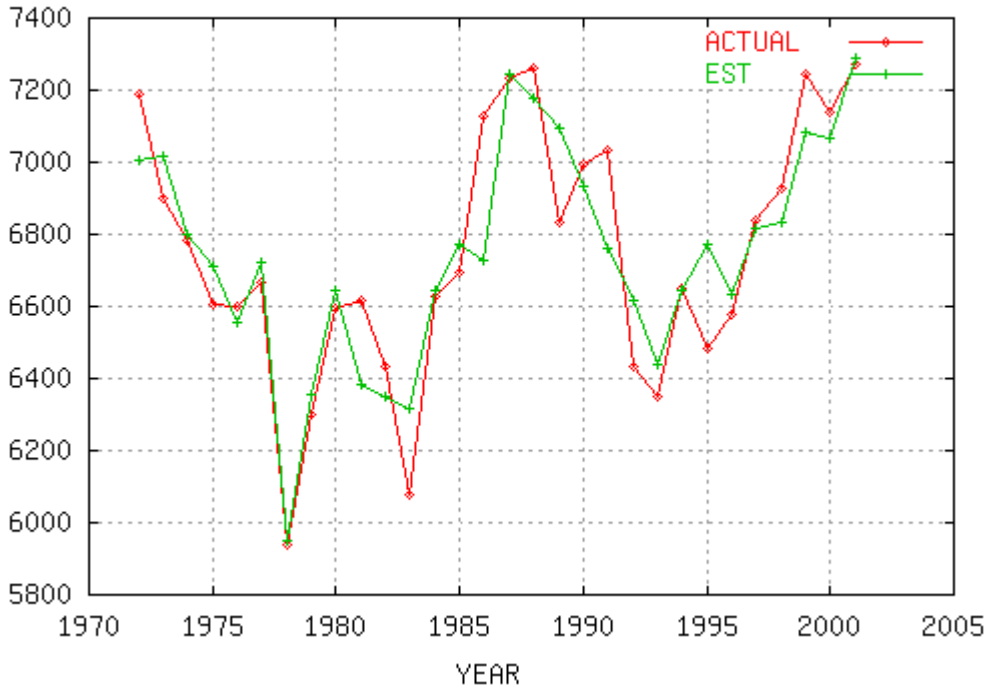
The estimated alfalfa production equation (Table 1) is presented in tabular form in order to better facilitate interpretations of estimated coefficients:

Table 1. Alfalfa Production Equation

Variable	Coefficients	Standard errors
Constant	4.87	1.98
Lag of Log Production	0.69	0.21
Lag of Log Alfalfa Price	0.44	0.17
Lag of Log Alfalfa Risk	-0.75	0.28
Lag of Log Cotton Price	-0.07	0.03
Dummy for *critical years*	-12.07	5.77
Crit*Lag of Log Production	1.33	0.74
Crit*Lag of Log Alfalfa Price	-3.87	1.27
Crit*Lag of Log Alfalfa Risk	3.61	1.02
Crit*Lag of Log Cotton Price	0.13	0.08
Dummy for outlier (1978)	-0.08	0.03

The estimated own-price elasticity is 0.44 and significant at the usual 5% significance level which suggests that alfalfa production is relatively inelastic. Alfalfa production is negatively related to risk (price volatility) and cotton prices. Both estimated coefficients are significant. Water shortages have a negative impact on alfalfa production (see the estimated coefficient of -12.07 on the dummy variable for critical years and is significant).

The regression R^2 is 0.817. The Durbin h statistics (-0.62) indicates that there is no problem with autocorrelation in the errors. Graph 3 plots actual and estimated values of alfalfa production.



Graph 3: ***Actual and estimated values of alfalfa production (thousands of tons).***

Demand

The estimated demand function for alfalfa is a derived demand. Dairies and horse enterprises demand about 90 percent of alfalfa. The assumption made in the estimations is that the market for alfalfa is in equilibrium, that is, that quantity demanded is equal to quantity supplied given the ease of storage this is expected.

The estimated demand equation for alfalfa is given by

$$\hat{Q}_t = -5.904 - 0.107\,price_t + 0.243 milkps_t + 1.736 cows_t + 0.105\,prmix_t - 0.606\,prmilk_t \quad (6)$$
$$(2.626)\ (0.107) \qquad (0.042) \qquad (0.288) \qquad (0.039) \qquad (0.113)$$

where Q_t is the quantity demanded of alfalfa in tons, $price_t$ is the real grower price of alfalfa in \$/ton, $milkps_t$ is the milk price support, cow_t is the number of cows, $prmix_t$ is

the price of a combination of corn and soybeans, and $prmilk_t$ is the real price of milk. All variables are expressed in logarithmic form.

The coefficient of determination, $R^2 = 0.888$, indicates a good fit of the model with the data. The own-price elasticity of demand is -0.107 which is inelastic, but not statistically significant. The estimated coefficient of milk support price is 0.243 implying that the quantity demanded of alfalfa increases as the support price of milk increases. The estimated coefficient on real price of milk is negative. The coefficient on the number of cows is positive and statistically significant. This is reasonable given that about 70% of the demand for alfalfa is from dairies. All of the coefficients in the demand equation are statistically significant at the five percent level of significance except for own price.

System for Alfalfa

A three-equation system for alfalfa was developed and estimated. Iterative three-stage least squares are used to estimate a model consisting of acreage, production, and demand relationships for alfalfa. We assume that the market for alfalfa is in equilibrium, that is, that quantity demanded is equal to production. We further assume that stocks are included in the demand for alfalfa. Thus, the three endogenous variables are: acreage, production, and alfalfa price. The estimators will be asymptotically efficient given that the model is specified correctly. The gain in efficiency is due to taking into account the correlation across equations. And three-stage least squares will purge (asymptotically) the correlation that exist between endogenous variables on the right hand side of the equations in the model with the error terms.

The estimated alfalfa system is given by

$$\hat{A}_t = 4.210 + 0.133\,price_{t-1} - 0.277\,risk_{t-1} + 0.532\,A_{t-1}$$
$$(0.097)\ (0.159)\qquad (0.159)\qquad (0.111)$$
$$\hat{Y}_t = 2.630 + 0.601\,A_t + 0.037\,price_{t-1} - 0.088\,pr\cot_{t-1} + 0.199\,Y_{t-1} - 0.109\,D_t \qquad (7)$$
$$(0.834)\ (0.150)\quad (0.015)\qquad (0.021)\qquad (0.128)\quad (0.109)$$
$$\hat{Q}_t = 3.962 - 0.020\,price_t - 0.061\,prcorn_t + 0.037\,prsoy_t + 0.475\,Q_{t-1} - 0.114\,D_t + 0.091\,cow_t$$
$$(1.227)\ (0.015)\qquad (0.036)\qquad (0.037)\qquad (0.108)\quad (0.027)\quad (0.101)$$

where A_t represents acreage of alfalfa, Y_t denotes production of alfalfa, Q_t is the quantity demanded of alfalfa, and the remaining variables are defined above. The own-price elasticity is 0.133 in the acreage response equation but is not statistically significant at the five percent level of significance. Acreage response decreases as risk increases as measured by the standard deviation of alfalfa monthly prices. Production of alfalfa is positively related to alfalfa price, is negatively related to cotton prices, and positively correlated to past acreage and production. Alfalfa demand has a very low own-price elasticity of demand of -0.020. Alfalfa demand is negatively related to price of corn but positively related to soybean prices. Demand is positively related to the number of cows. Recall that about 70% of the demand for alfalfa is from dairies. The majority of the estimated coefficients are statistically significant at the 5% level.

Cotton

Cotton is the most important field crop gown in California. Growers in California grow two types of cotton: Upland, or Acala and Pima. Upland cotton makes up about 70 to 75 percent of the California cotton market and is the higher-quality cotton. Upland has a worldwide reputation as the premium medium staple cotton, with consistently high fiber strength useful in many apparel fabric applications. Export markets are important, attracting as much as 80 percent of California's annual cotton production in some years making it California's second highest export crop (Johnston, p. 84). Historically,

California cotton, in terms of value of production, was the third highest ranking crop in California in 1950 below cattle and calves and dairy products. In 2001 cotton was ranked the eighth highest valued crop below milk and cream, grapes, nursery products, cattle and calves, lettuce, oranges, and hay (McCalla and Johnston).

There has been a downward trend in cotton acreage and production in California since 1979. California growers produced 3.4 million bales of cotton on l.6 million acres in 1979. In 2002 they produced about 2 million bales of cotton on 700,000 acres (Figures 10A and 12A). Cotton yields have experienced an upward trend since 1979 (Figure 11A). Nominal producers' prices in California for cotton exhibit an upward trend since the 1970s, but real producers' prices in California has exhibit a downward trend since the mid seventies (Figures 13A and 14A).

Recently the World Trade Organization (WTO) ruled against U.S. cotton subsidies. U.S. cotton subsidies totaled about $10 billion in 2002 and the WTO ruled that the subsidies created an unfair competition for Brazil, which filed the complaint. California producers received about $1.2 billion in subsidies in 2002. California cotton is not as subsidized as cotton in other states, such as Texas, because subsidies are based on price and California's higher-quality cotton is more expensive (Evans, May 3, 2004).

Acreage, production, and demand equations are estimated for California cotton. Single equation and system of equations models are developed and estimated. In this report we aggregated the different cotton varieties. Disaggregated models of cotton were also estimated because of changes in the cotton industry and to allow for different impacts for subsidized and unsubsidized varieties. The number of observations in the

disaggregated models present in the next section are limited due to the relatively recent introduction of Pima in California.

Acreage

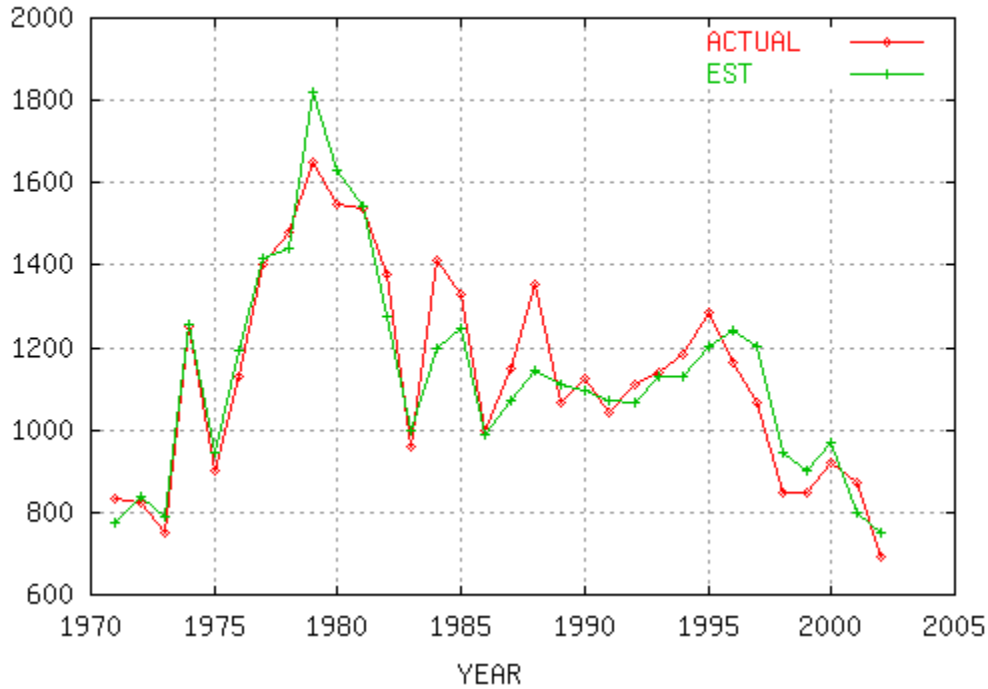
The estimated planted acreage relationship, a partial adjustment model, for California cotton is

$$\ln \hat{A}_t = -4.19 + 0.53 \ln price_t - 0.05 \ln riskc_t - 1.47 \ln pricealf_t + 2.87 \ln riska_t + 0.27 \ln A_{t-1}$$
$$(1.26)(0.06) \qquad (0.03) \qquad (0.26) \qquad (0.42) \qquad (0.07)$$

(8)

where A_t is cotton acreage in thousands of acres, $price_t$ is real cotton price in \$/lb., $risk_t$ is the standard deviation of monthly cotton prices and is a measure of risk, $pricealf_t$ denotes real alfalfa price in \$/ton, and $riska_t$ represents the standard deviation of monthly alfalfa price and is a measure of risk of growing alfalfa. All variables are expressed in logarithmic form.

The estimated coefficient of determination is R^2 =0.899. The short-run own-price acreage elasticity of cotton is 0.53 and is highly significant. Cotton acreage decreases with an increase in risk in growing cotton and as price of alfalfa increases. All of the estimated coefficients are statistically significant at the 1% level except for the risk coefficient associated with cotton which is significant at the 10% level. A graph depicting the estimated acreage equation with the actual cotton acreage is given in Graph 4.



Graph 4: ***Actual and estimated cotton acreage (thousands of acres).***

The Durbin h statistics (1.12) fails to reject the null hypothesis of no autocorrelation in the disturbances.

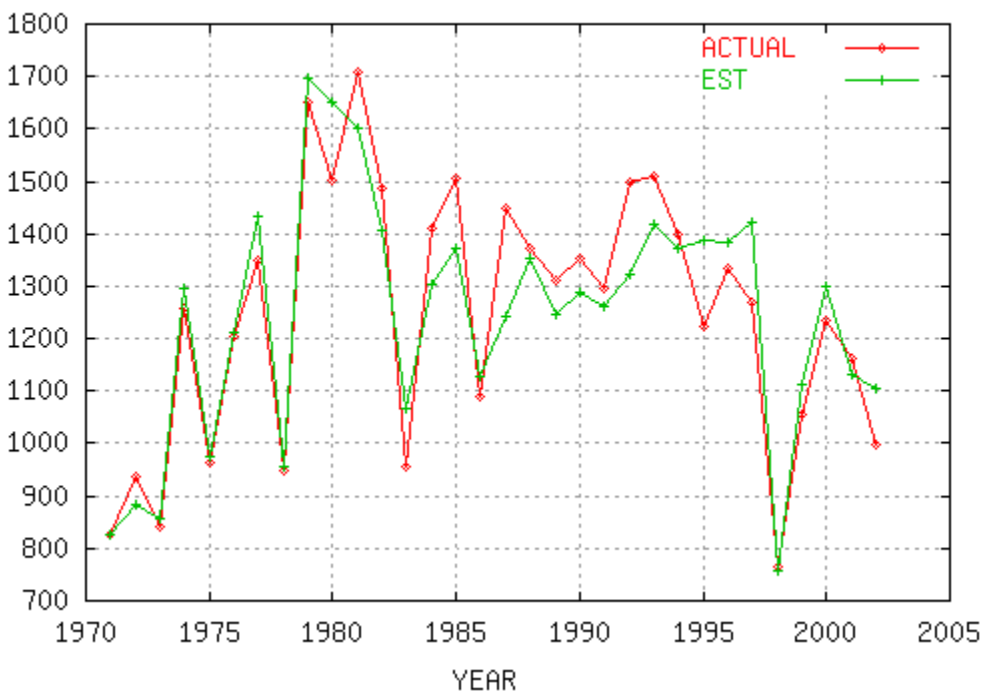
Production

The estimated production relationship for cotton, an adaptive expectations model, is (eq. 9)

$$\hat{Y}_t = \underset{(2.444)}{-7.066} + \underset{(0.115)}{0.497}\, pricec_t - \underset{(0.036)}{0.499}\, riskc_t - \underset{(0.543)}{1.844}\, pricea_t + \underset{(0.880)}{4.067}\, riska_t + \underset{(0.009)}{0.011} Y_{t-1} - \underset{(0.081)}{0.313} D_t$$

where Y_t denotes cotton production in 1000 bales, and D_t denotes a dummy variable for the drought year, 1978. The remaining variables are as defined above. An adaptive expectations models implies a moving average error process of order one and the production function was estimated with a MA(1) error scheme.

The goodness of fit yields an $R^2 = 0.878$. All of the estimated coefficients are statistically significant from zero at the 5% level except for the risk measure for cotton and lagged cotton production. The short-run price elasticity is 0.497 and the long-run price elasticity is 0.503 [0.497/(1-0.011)]. The estimate coefficients on risk and the dummy variable are negative as anticipated. A plot of the estimated production of cotton with the actual production of cotton is given in Graph 5.



Graph 5: ***Actual and estimated cotton production (1000 bales).***

Demand

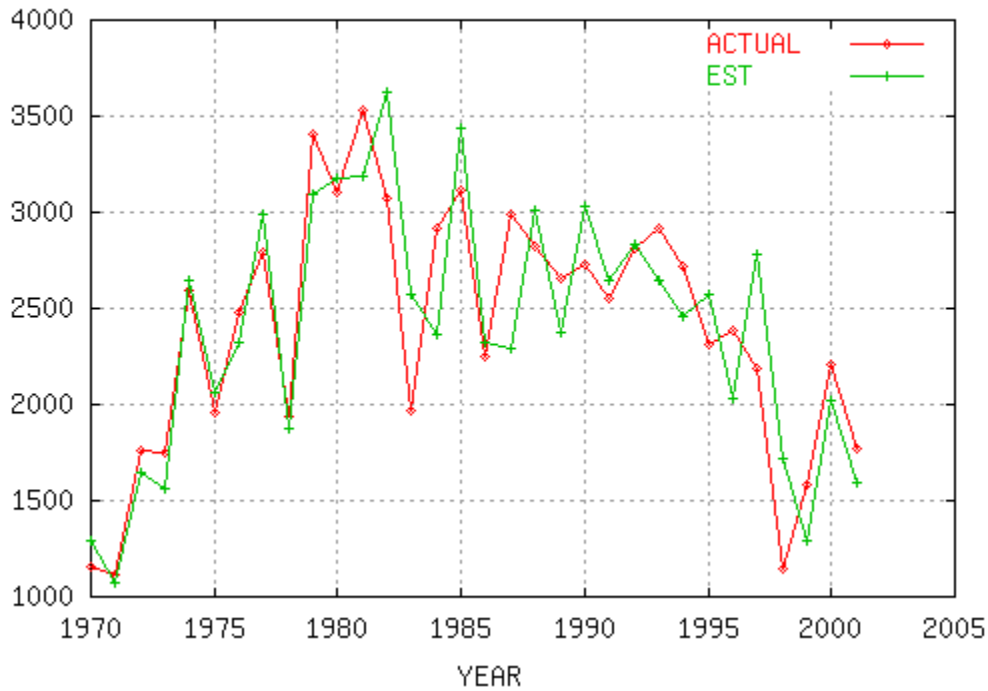
The estimated demand function for cotton is given by (eq. 10)

$$\hat{Q}_t = -12.631 - 0.684\,prc_t + 0.360\,prus_t + 0.827\,prray_t - 0.064\,prpol_t + 0.000\,pop_t$$
$$(13.490)\ (0.228)\quad (0.293)\quad (0.493)\quad (0.544)\quad (0.000)$$
$$-0.217pop_t - 0.070t - 0.004t^2$$
$$(0.100)\quad (0.117)\ (0.002)$$

where Q_t denotes the US disappearance plus US imports of cotton, prc_t denotes the real grower price of California cotton, $prus_t$ represents the United States price of cotton, $prray_t$ denotes the price of rayon, a substitute for cotton, $prpol_t$ denotes the price of polyester, a substitute for cotton, pop_t represents US population, D_t is a dummy variable for the drought year in 1978, and t denotes a time trend. All variables, except the time trend and dummy variable, are expressed in logarithmic form.

The overall goodness of fit was 0.756. The estimated own-price elasticity of California cotton is -0.684 and significant. The positive coefficient on rayon indicates that it is a gross substitute for cotton while the negative sign on polyester indicates a gross complement. There is a negative sign associated with the time trend indicating that the demand for cotton has been decreasing over the sample period

A plot of the estimated and actual demand series for cotton is depicted in Graph 6.



Graph 6: Actual and estimated cotton demand (thousands of bales).

System for Cotton

A two-equation system for cotton was developed and estimated by iterated three-stage least squares (3SLS). The estimated cotton production and demand system (eq.11) is

$$\ln \hat{Y}_t = -1.13 + 0.46 \ln Pc_t - 0.49 \ln Riskc_t - 0.82 \ln Pa_t + 2.14 \ln Riska_t$$
$$(2.49)\ (0.12) \qquad (0.05) \qquad (0.52) \qquad (0.87)$$
$$+0.03 \ln Y_{t-1} - 0.41 D_t$$
$$(0.03) \qquad (0.20)$$

and

$$\ln \hat{Q}_t = 6.89 - 0.95 \ln Pc_t + 1.24 \ln \mathrm{Prus}_t + 0.23 \ln \mathrm{Prray}_t - 0.00 \ln \mathrm{Prpol}_t - 0.05 \ln Pcin_t$$
$$(1.96)\ (0.99) \qquad (0.78) \qquad (0.41) \qquad (0.37) \qquad (0.04)$$
$$-0.24 D_t + 0.07t - 0.03t^2$$
$$(0.23) \qquad (0.02)\ (0.00)$$

where $pcin_t$ denotes per capita income and the remaining variables are defined above. The first equation represents the production equation for cotton and the second equation is the demand function for cotton. All variables are expressed in logarithmic form. The own-price elasticity is 0.46 for the production of cotton and the own-price elasticity of demand for cotton is -0.95. Both elasticities are inelastic and of the correct sign. The signs on the risk variables are as expected. The cross-price elasticity estimates of rayon and polyester indicate that they are both gross substitutes for cotton. The estimated coefficients on time and time squared indicates that the demand for cotton is trending upward at a decreasing rate. The sign on per capita income coefficient is unexpectedly negative, but not significant.

Modeling Variety Substitution

In California, currently two major varieties of cotton are grown: Upland (Acala) and Pima. Variety differentiation is a phenomenon that is relatively recent, because until late 1980s the so-called "law of one variety" allowed California farmers to grow only Upland (Acala). The bill was revised in 1988 and again in 1991 introducing a broader set of choices for farmers. In 2004, 550 thousand acres of Upland and 220 thousand acres of Pima were planted. Figures 7 and 8 summarize the acreage and production trends from 1970 to 2002.

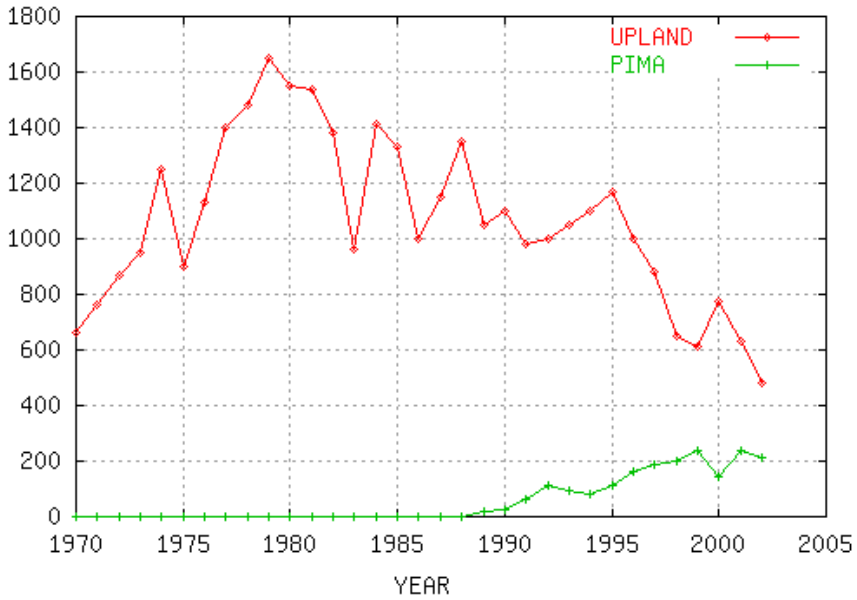


Figure 7: Upland and Pima planted acreage in California (thousand of acres).

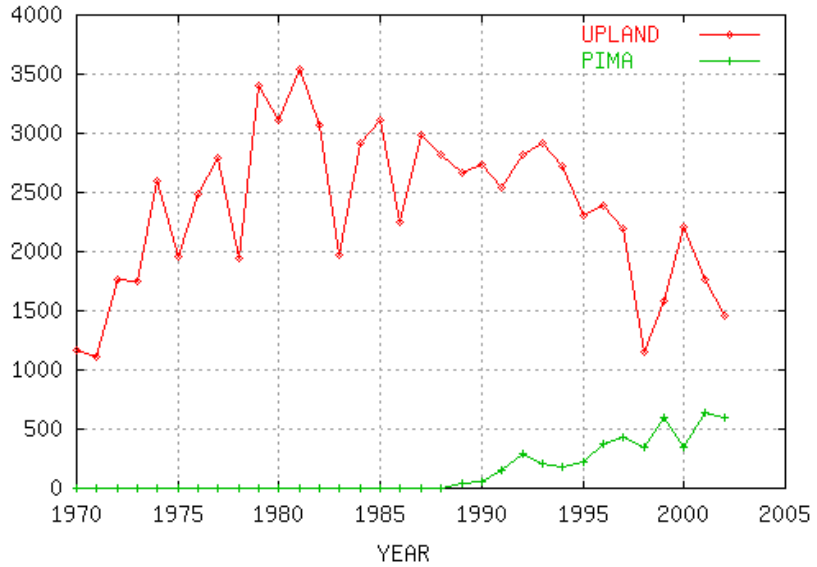


Figure 8: Upland and Pima production in California (thousand of bales).

The graphs show that pima acreage and production are gradually increasing over time. Farmers are gradually adopting the new variety. Since the abolishment of the law of one variety is relatively recent, we have no way to assess if the process has reached a steady state. However, pima cotton is more sensitive to rainfall conditions, and experts

expect that the final crop pattern in California will be a mixture of pima and upland, depending on local weather conditions.

The rationale for the adoption of the new variety can be found, in part, in Figure 9, that reports the real grower prices for pima and upland.

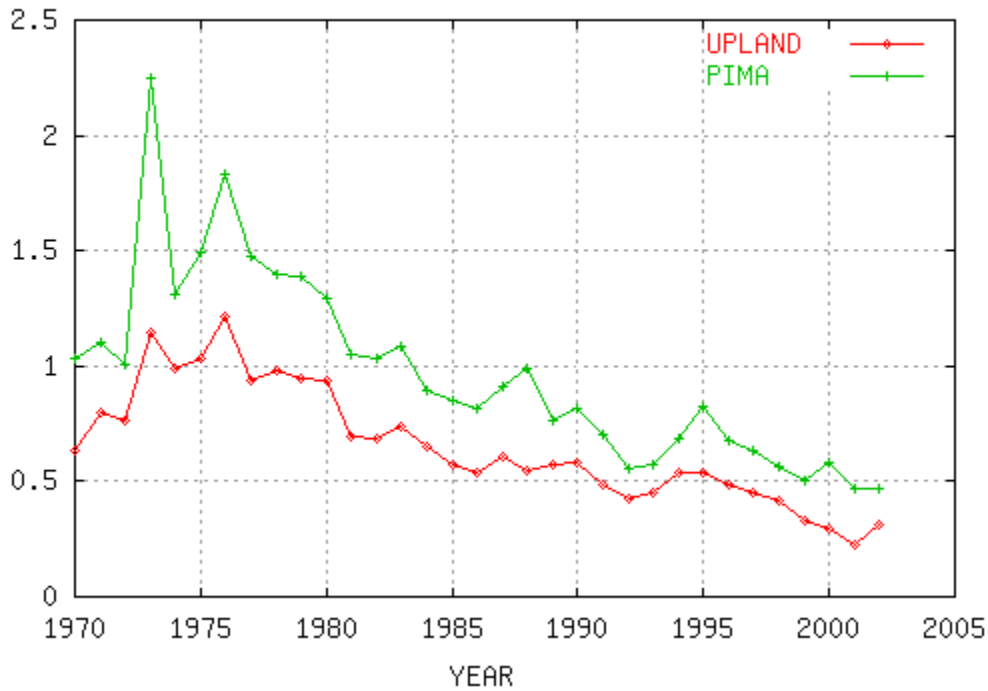


Figure 9: Real prices for Pima and Upland (dollars/lb.).

The graph shows that pima growers benefit from a price premium relative to upland producers. If weather conditions are favorable, pima is considered more profitable. The time trends also show that the price of upland and pima are cointegrated, suggesting a strong theoretical argument for modeling aggregate cotton production regardless of variety (as we did in the previous section).

In this section we adopted a partial adjustment model of the new variety based on relative prices. Given the relevance of the pima production, the model can provide useful indications, however it must be pointed out that: (i) the phenomenon is still too recent to allow reliable statistical analyses based on a time series approach, and (ii) the short time series poses a strong constraint in the number of explanatory variables that can be incorporated into the model.

We designed a model based on an equation for pima acreage and an equation for upland acreage. In both cases we assumed that farmers follow a behavior pattern based on partial adjustments of acreage.

The equations are

$$\begin{aligned} AP_t &= \beta_0 + \beta_1 AP_{t-1} + \beta_2 P_t^P + \beta_3 P_t^U + \varepsilon_t \\ AU_t &= \alpha_0 + \alpha_1 UP_{t-1} + \alpha_2 P_t^U + \alpha_3 P_t^P + u_t \end{aligned} \tag{12}$$

where AP and AU are pima and upland acreage, respectively, P^P and P^U are pima and upland real prices and ε and u are error terms. All the variables are in logarithm form. The model was estimated both as single equations and as a SUR system. The results of the estimation are the following.

Single-equation estimations:

Upland estimation:

$$\begin{aligned} A\hat{U}_t &= -0.66 + 0.91 AU_{t-1} + 1.76 P_t^U - 0.86 P_t^P \qquad R^2 = 0.81 \\ &\quad (2.19)\ (0.32) \qquad (0.75) \qquad (0.39) \end{aligned} \tag{13}$$

Pima estimation:

$$\begin{aligned} A\hat{P}_t &= 4.49 + 0.74 AP_{t-1} + 2.98 P_t^P - 3.86 P_t^U \qquad R^2 = 0.96 \\ &\quad (0.72)\ (0.08) \qquad (0.78) \qquad (1.14) \end{aligned} \tag{14}$$

where the number in parentheses are standard errors. The test statistics for a single coefficient possess a t distribution with 10 degrees of freedom.

Upland cotton prices have a positive impact on acres planted to Upland. When prices of Pima increase, the acres planted to Upland decrease. Thus, Upland and Pima are gross substitutes. Both price coefficients are significant. With respect to the Pima acreage equation, Pima prices have a positive effect on acres planted to Pima. Upland prices have a negative relationship, as expected, with Pima planted acres.

SUR estimation

Upland

$$\begin{aligned} A\hat{U}_t &= -0.74 + 0.71 AU_{t-1} + 1.92 P_t^U - 0.57 P_t^P \qquad R^2 = 0.78 \\ &\quad (2.16)\ (0.32) \qquad (0.82) \qquad (0.40) \end{aligned} \tag{15}$$

Pima

$$\hat{AP}_t = 4.42 + 0.78AP_{t-1} + 2.89P_t^P - 4.26P_t^U \qquad R^2 = 0.96$$
$$(1.11)\ (0.05) \qquad (1.00) \qquad (1.72) \tag{16}$$

The two procedures (single-equation approach and SUR) give similar estimations. In the SUR results the coefficient of Pima prices is insignificant in determining Upland acreage. However, it must be noted that the explanatory variables have a high degree of multicollinearity.

The model confirms the hypothesis that the relative prices of Upland and Pima are driving forces in the adoption process at the state level in California.

Conclusions

The estimated models indicate that the short-run own-price elasticity of alfalfa acreage is inelastic (0.35) but more elastic (0.66) when ample water is available. By applying water marginally through out the growing period, a producer can obtain more cuttings of alfalfa. Alfalfa yields are also responsive to increases in prices. The own-price elasticity of yields is 0.08 and highly significant. Alfalfa yields are negatively related to the previous year's cotton price. Production is positively related to own price with an estimated elasticity of 0.44 and significant. Production was negatively related to risk with an elasticity of risk equal to -0.75. Demand for alfalfa is a derived demand and is positively related to the number of cows and milk price support and negatively related to its own price.

The estimated own-price elasticity of cotton acreage is 0.53 and highly significant. Cotton acreage decreases with an increase in risk in growing cotton and as price of alfalfa increases. The short-run own-price elasticity of cotton production is

0.497 and the long-run estimate is 0.503. The own-price elasticity of cotton demand is -0.684. Rayon is a substitute for cotton. The empirical results support the fact that alfalfa and cotton are rotating crops in California.

In recent years there has been an increase in Pima acreage relative to the traditional Upland variety in California. Upland cotton prices have a positive impact on acres planted to Upland. When Pima prices increase, the acres planted to Upland decrease. A similar situation applies to Pima acreage. That is, an increase in Upland prices causes a decrease in Pima acreage. Thus, the empirical results support that hypothesis that relative prices of Upland and Pima have a significant impact on the adoption of the two varieties.

Future research needs to focus on the collection of more data related to the consumption of California cotton and alfalfa, stocks and inventories, and interstate trade of alfalfa between California and Oregon and Nevada.

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ALFALFA HAY

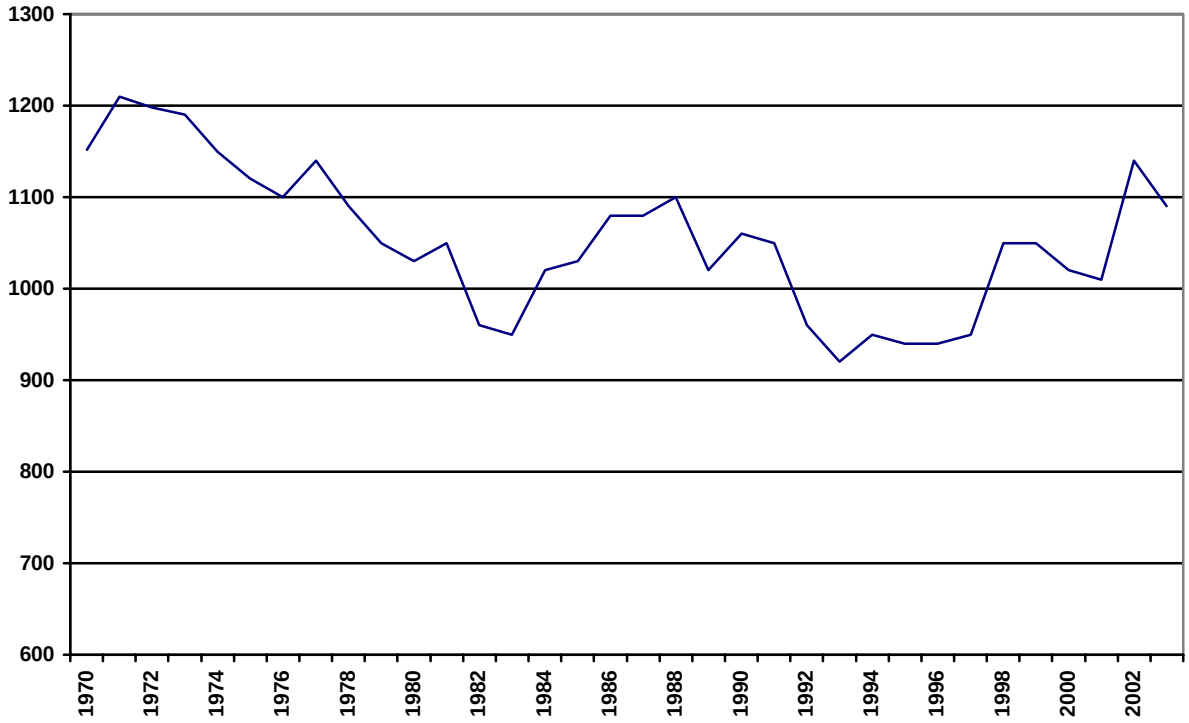

Figure 1A: Harvested Acreage for Alfalfa in California (Thousands of Acres).

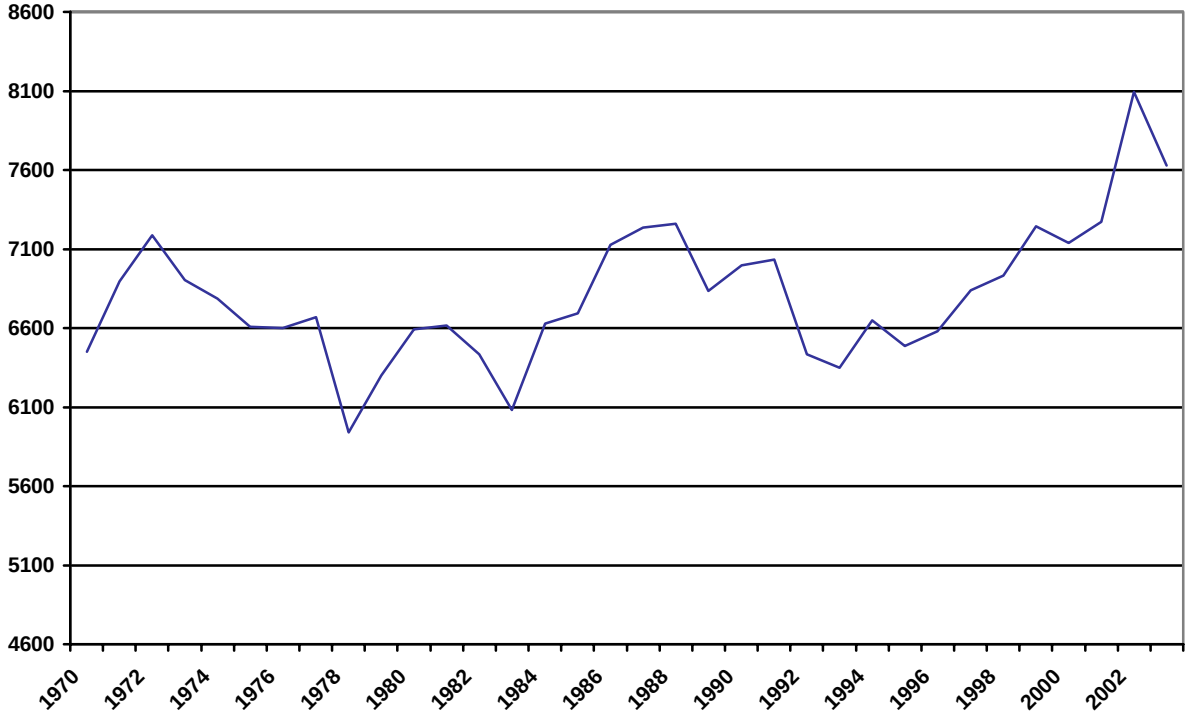

Figure 2A: Alfalfa production in California (Thousands of tons)

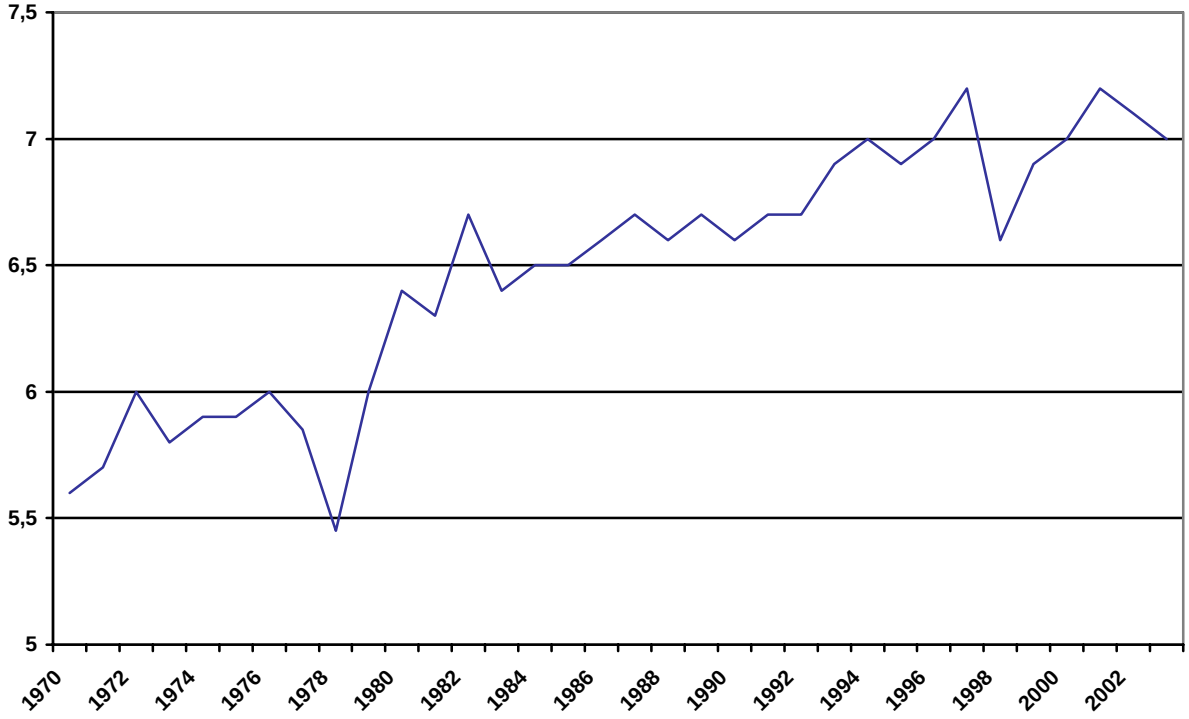

Figure 3A: Alfalfa Yield in California (tons)

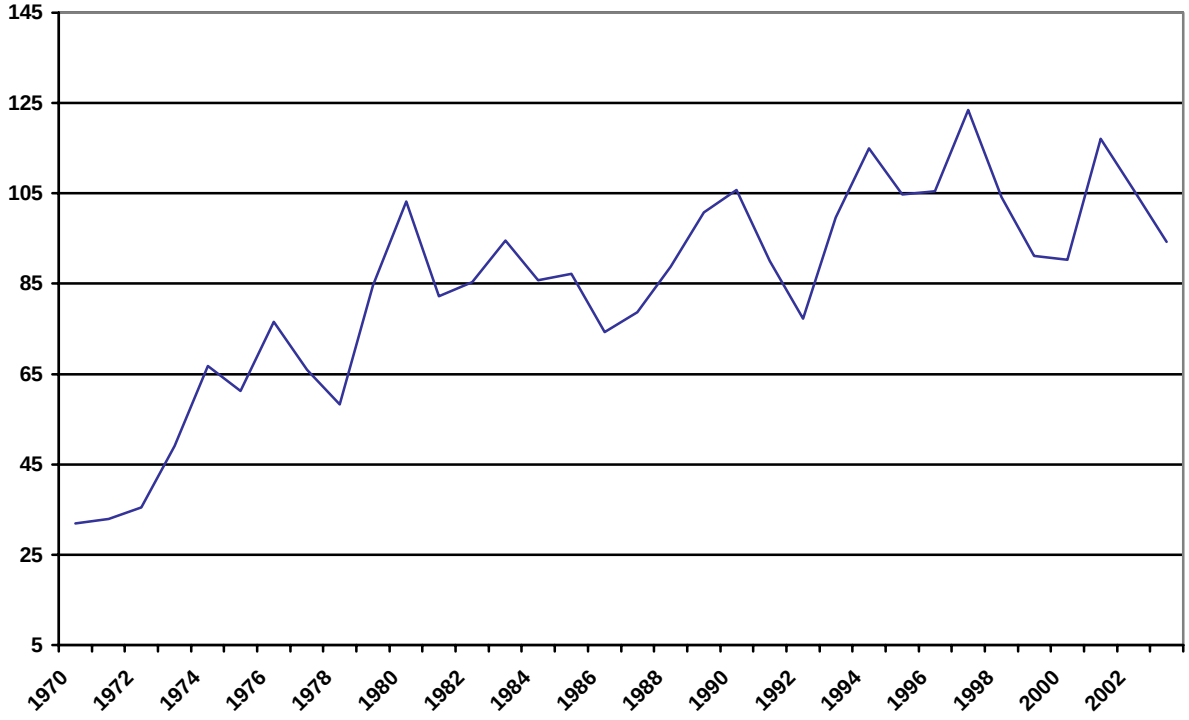

Figure 4A: Alfalfa Nominal Grower Price in California (12 month average)

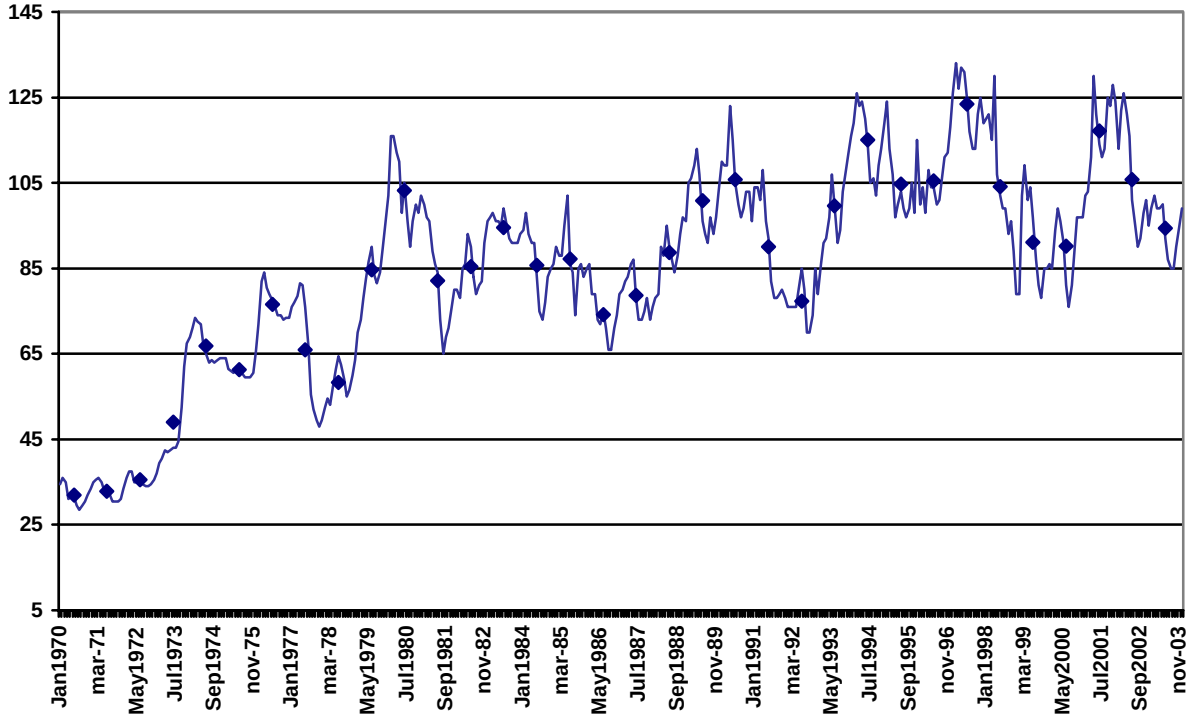

Figure 5A: Alfalfa Nominal Grower Price (Monthly- dollars per ton)

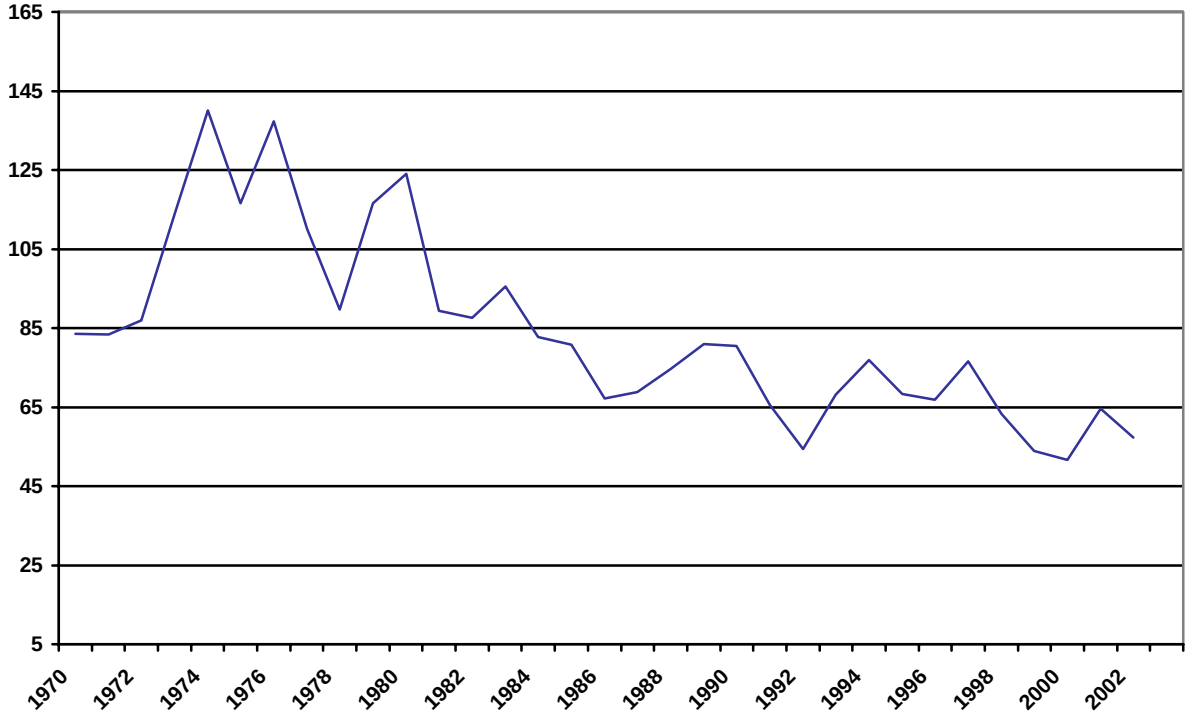

Figure 6A: Alfalfa Real Grower Price in California (12 month average, dollars per tons – base 1983/4)

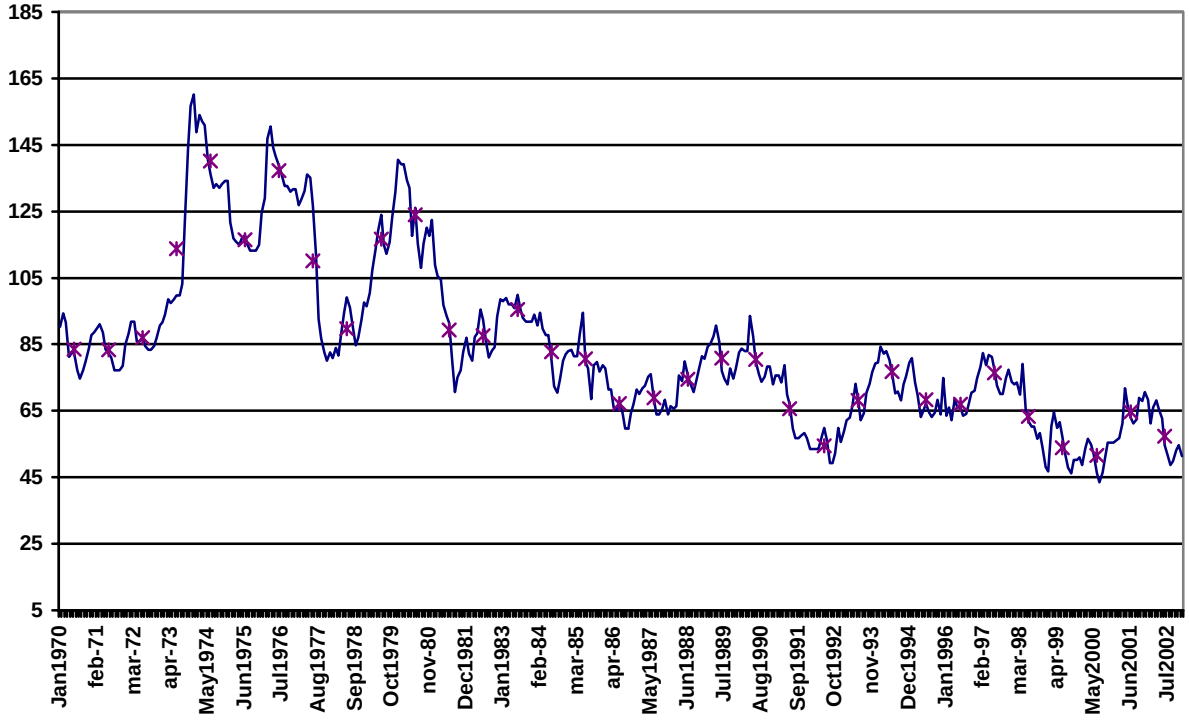

Figure 7A: Alfalfa Real Grower Price in California (monthly, dollars per tons– base 1983/4)

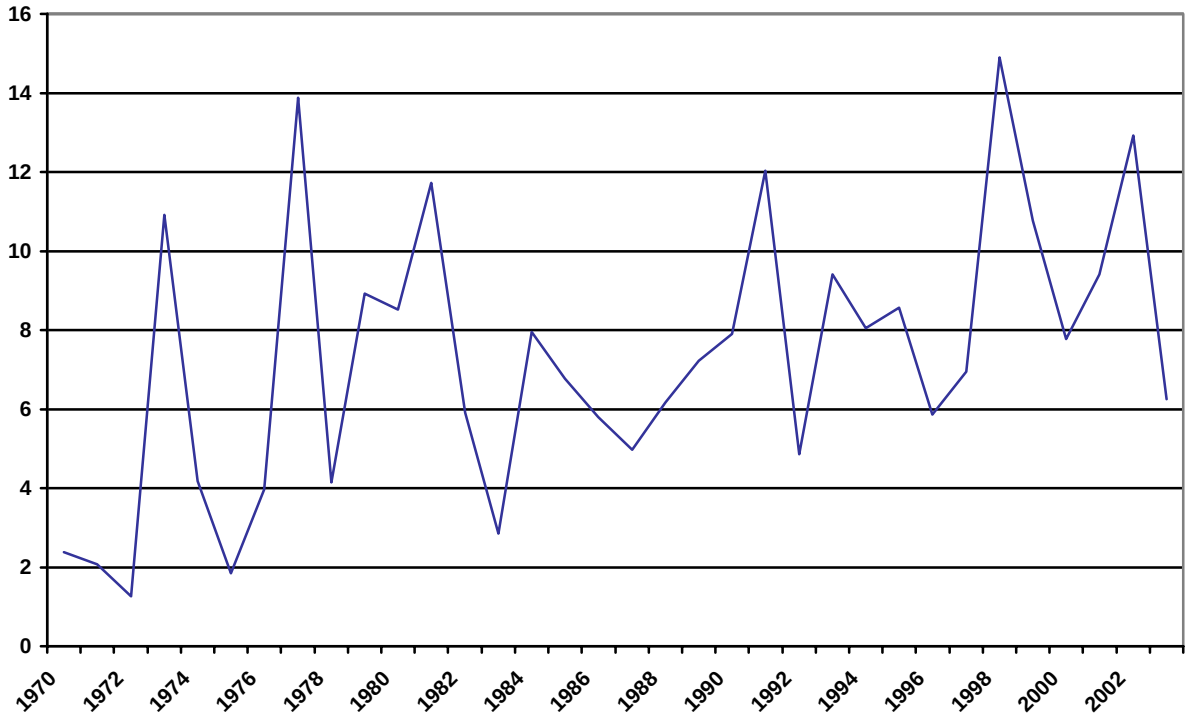

Figure 8A: Standard Deviation of Monthly Alfalfa Price (Nominal, $/month).

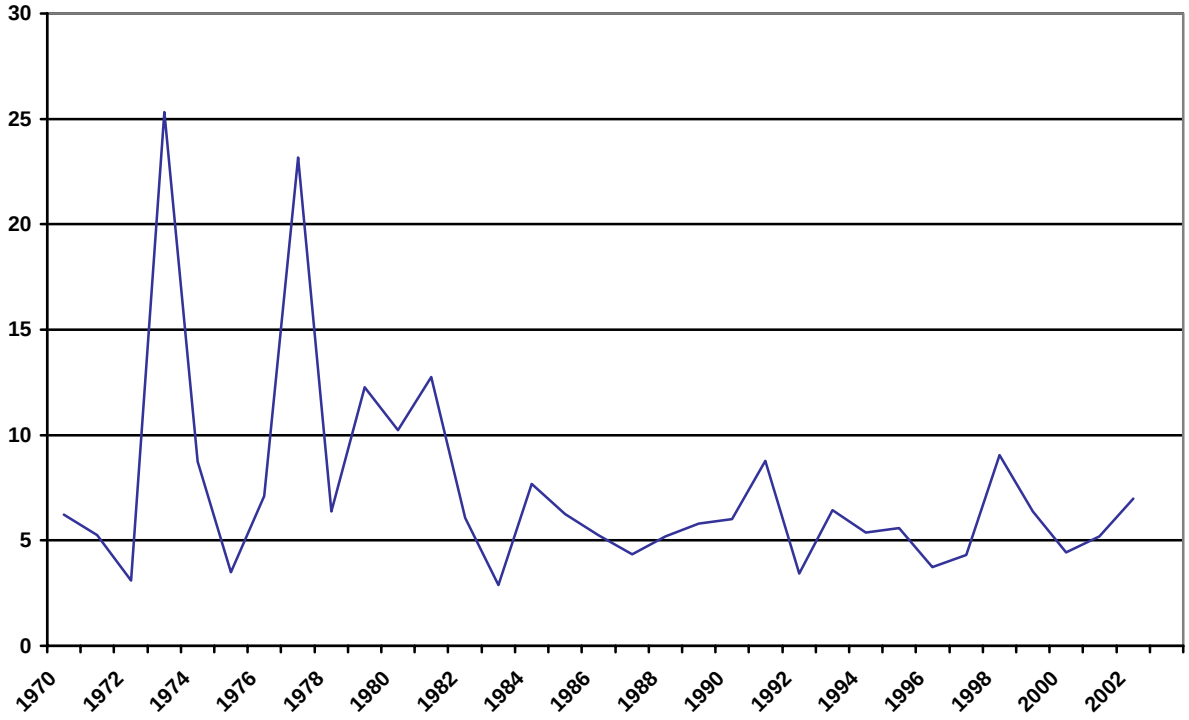

Figure 9A: Standard Deviation of Monthly Alfalfa Price (Real dollars per month, base 1983/4).

COTTON

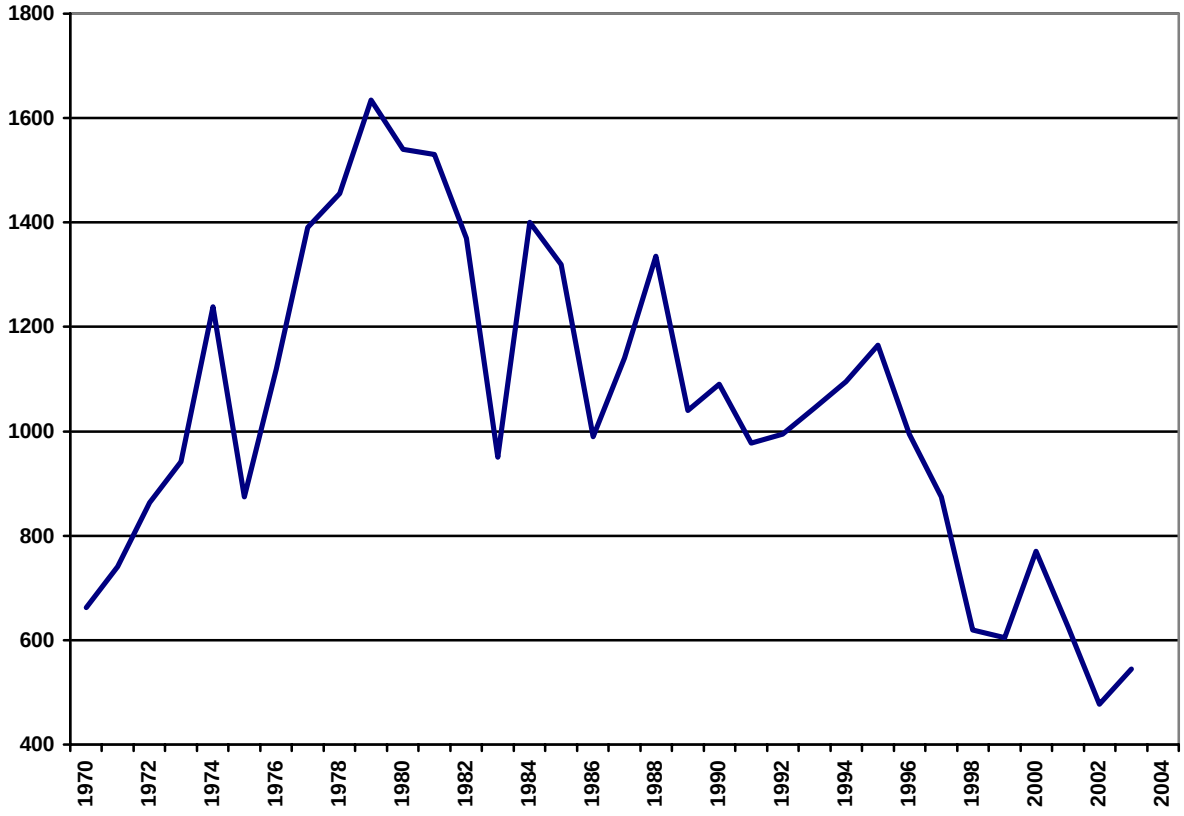

Figure 10A: Cotton Acreage in California (acres/ in thousands).

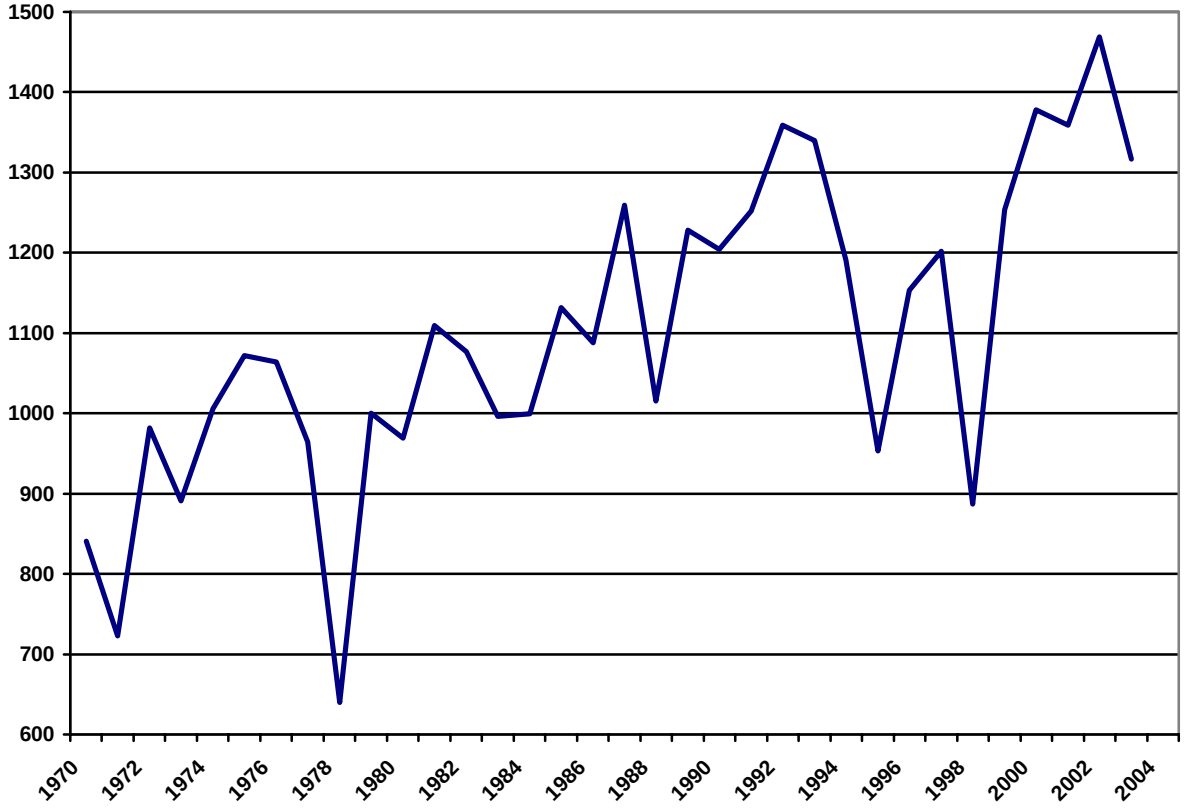

Figure 11A: Cotton Yield in California (pounds).

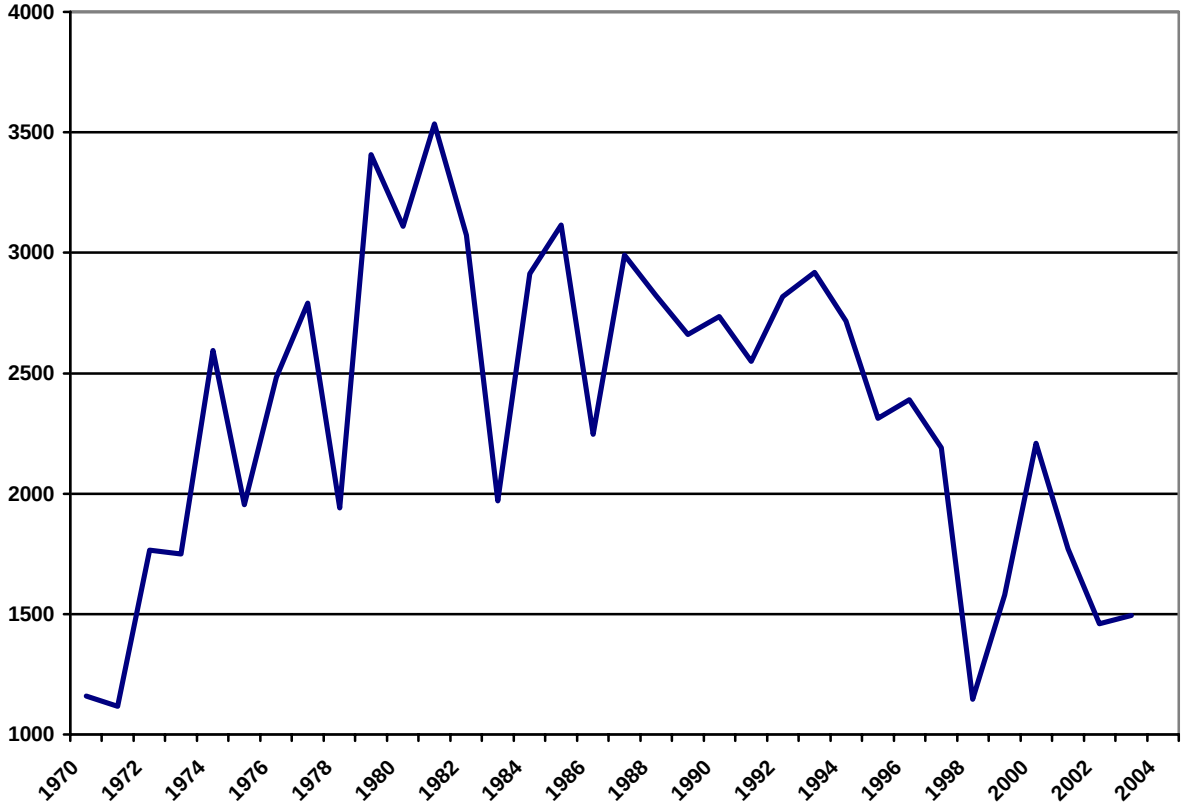

Figure 12A: Cotton Production in California (1000 bales).

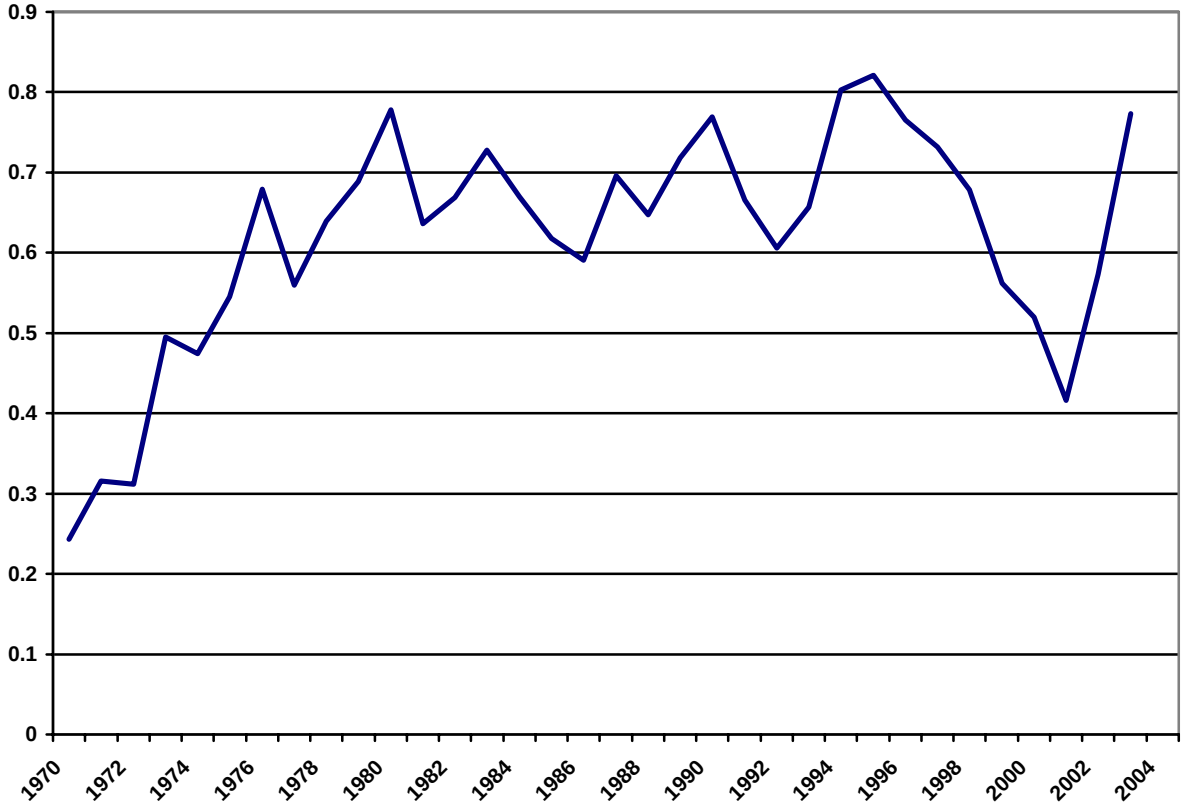

Figure 13A: Nominal Producers' Price in California for Cotton ($/lb).

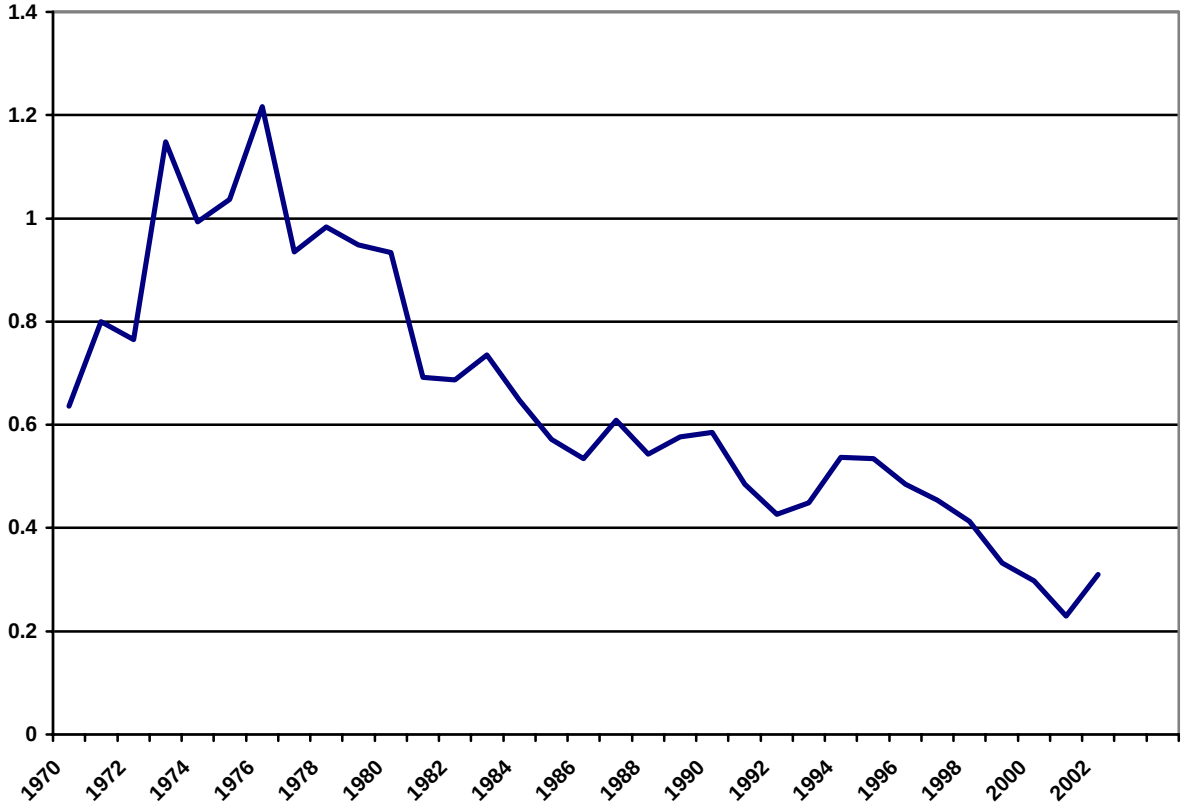

Figure 14A: Real Producers' Price in California for Cotton ($/lb).

RICE

National vs. State Model

California is one of the major producers of rice in the US. The other most important states are Arkansas, Louisiana, Mississippi, Missouri and Texas. The market in California appears to be fully integrated with the southern states, as suggested by an empirical check of the law of one price. This conclusion is hardly surprising, given that rice is a storable and easily transportable commodity. Figure 1 illustrates the law of one price between California and Arkansas.

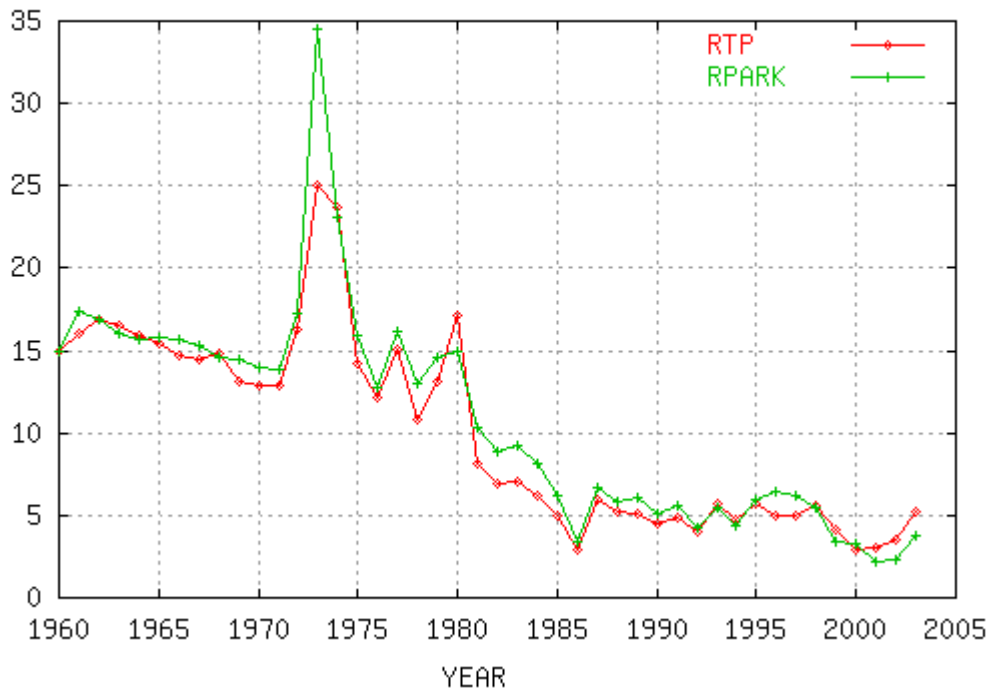

Figure 1: ***Rice grower price (real) in California (RTP) and Arkansas (RPARK)***

(in real dollars per cwt.)

A simple ordinary least squares regression of California rice price on Arkansas price gives an R^2 of 0.939 and an estimated slope coefficient between 0.80 and 0.94 (with a 95% confidence level). Moreover, a simple cointegration test suggests the absence of unit roots in the disturbances. Thus, California price and Arkansas rice prices move together over the long run. Market integration suggests

that a US level model can be useful to describe California rice production. In this study, however, we present both national and state models.

The US Market

We estimated two models for the US rice industry. The first one is based on a longer time series, but does not account for policy distortions or trade. The second model considers the influence of policy and trade but data limitations constrain the length of the available time series.

A simplified model

A simplified production model is

$$\ln Q_t = \beta_0 + \beta_1 \ln P_{t-1} + \beta_2 \ln P_{t-2} + \beta_3 t + \beta_4 \ln Q_{t-1} + \beta_5 D_t + \varepsilon_t \tag{1}$$

where Q is the quantity of rice production in tons, P_t is rice price per ton , t is a time trend and D is a binary variable identifying the years 1977 and 1983 (outliers).

Prior to reporting the estimated production function for rice, a brief discussion of some aberrations of the rice market will be explained. Around 1976-77 there was a price collapse that caused producers to rotate to other crops or not plant rice at all. This lead to decreases in rice production. In the early eighties rice prices collapsed again and this caused many growers to forfeit their crop to the government because the price was below the value of the government loan. This was not only the case with rice, but other program crops such as wheat and corn. In an attempt to reduce acreage and sell off the rice that the government had claimed, the government implemented the 50/92 plan. Subsides were directly linked to production. Thus, if a grower did not produce he was not paid. The 50/92 program allowed the grower to produce on 50% of his acreage and receive 92% of the subsidies that he would receive if he had produced on 100% of his land. This reduced production allowed the government to reduce the stocks of commodities that they had to claim in 1981-82. The 50/92 program ran until about 1988. Since then subsidies have been decoupled from production to prevent problems like this from happening again. The 50/92 program was popular in the south, especially in Texas where their

production was lower and they had low fixed costs of land, but in California it was only widely used for a few years. Policy variables are incorporated into some of the models below.

The estimated partial adjustment production model for rice, for the time period 1972-2004, is:

$$\ln \hat{Q}_t = \underset{(0.68)}{2.32} + \underset{(0.07)}{0.23} \ln P_{t-1} - \underset{(0.08)}{0.07} \ln P_{t-2} + \underset{(0.00)}{0.02} t + \underset{(0.16)}{0.41} \ln Q_{t-1} - \underset{(0.07)}{0.26} D_t \qquad (2)$$

with R^2 = 0.896 and n = 33. The Durbin *h* test did not indicate problems with autocorrelation. The coefficient on lagged production is positive and significant. This indicates that there is some adjustment each year in the production of rice. By removing the lags, i.e., by assuming $Q_t = Q_{t-1}$, the long-run price elasticity of production is 0.27 which is inelastic and significant, but indicates that rice producers do respond to price changes. The estimated coefficient on the time trend variable is 0.02 and significant indicating a positive trend over time. The estimated coefficient on the dummy variable is negative (coefficient = -0.26) and significant for the outlier years as expected.

Figure 2 describes the fit of the regression (in logarithmic scale--the original series is in 000 cwt).

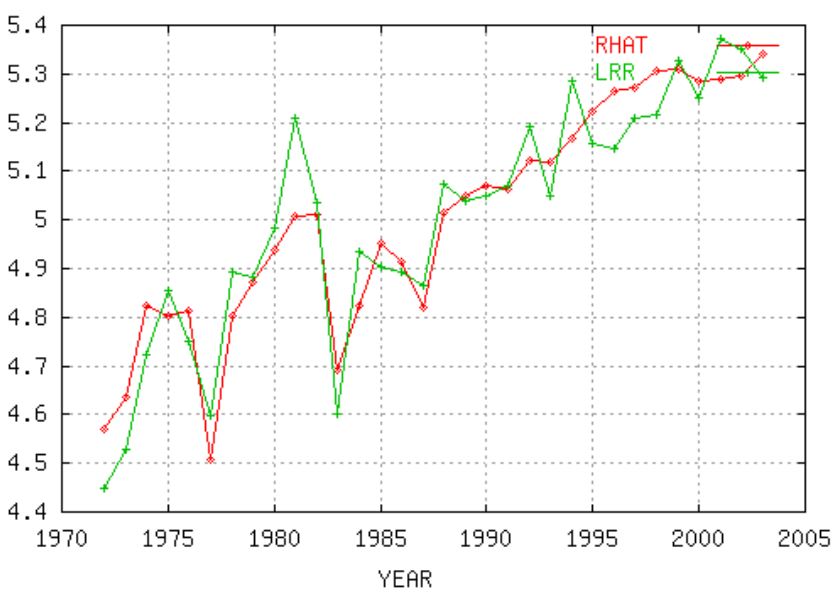

Figure 2: ***US rice production actual (LRR) and estimated (RHAT)***

(logarithmic scale)

Domestic Demand for Rice

The US domestic demand equation for rice is:

$$\ln PC_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln PCINC_t + \beta_3 \ln CPI_t + \varepsilon_t \tag{3}$$

where PC represents domestic consumption in pounds per capita, P denotes rice price per cwt, $PCINC$ represents per capita income in dollars per capita, and CPI is the consumer price index.

The estimated domestic demand function for rice, corrected for first-order autocorrelation, is:

$$\ln P\hat{C}_t = \underset{(1.16)}{-4.51} - \underset{(0.05)}{0.08} \ln P_t + \underset{(0.25)}{0.74} \ln PCINC_t - \underset{(0.29)}{1.47} \ln CPI_t \tag{4}$$

with R^2 = 0.93 and n = 34. The results of the simple model suggest that rice consumption is price inelastic (estimated own-price elasticity of -0.08), however, it is not significantly different from zero (p-value = 0.09). Domestic consumption of rice is positively related to income with a statistically significant (p-value = 0.0000) estimated income elasticity of 1.56. The estimated autocorrelation coefficient was 0.57 with an asymptotic t-ratio of 4.07 and after the correlation the Durbin-Watson statistic did not indicate any problems with autocorrelation.

The single equation estimates may be inefficient, given that errors may be correlated across equations. To overcome this problem we estimated a seemingly unrelated regression (SUR) production-consumption system for rice based on the simplified model specification. The results are:

$$\ln \hat{Q}_t = \underset{(0.07)}{11.21} + \underset{(0.03)}{0.14} \ln EP_t + \underset{(0.002)}{0.02} t - \underset{(0.07)}{0.19} D_t \qquad \text{(production equation)} \tag{5}$$

$$\ln P\hat{C}_t = \underset{(2.85)}{1.15} - \underset{(0.05)}{0.03} \ln P_t + \underset{(0.61)}{0.36} \ln PCINC_t - \underset{(0.61)}{0.32} CPI_t + \underset{(0.002)}{0.02} t \qquad \text{(demand equation)} \tag{6}$$

where EP represents the expected price of rice (price lagged one time period). The individual equation R^2s are high (0.93 and 0.89; respectively). The estimated own-price elasticity of production is

0.14 and but not significant. The own-price elasticity of demand for rice is -0.03, but it is not significant either. The income elasticity of demand for domestic rice is 0.36 and is also not significant. The explanatory variables were highly collinear which accounts for some of the estimated coefficients being insignificant.

An Alternative Model

An alternative model considers policy and exports. However, due to the short time series (1986-2003), the model must be parsimonious. For a comprehensive and disaggregated treatment of the influence of commodity programs on the rice acreage response to market prices, see McDonald and Sumner.[1]

The least squares estimated production equation is:

$$\ln \hat{Q}_t = \underset{(0.236)}{10.843} + \underset{(0.067)}{0.176} \ln P_{t-1} + \underset{(0.001)}{0.003} PSE_t + \underset{(0.033)}{0.034} t \tag{7}$$

with R^2 = 0.87 and n = 18. The policy variable, PSE_t, is the OECD percentage producer support estimate for the U.S. that is a comprehensive or aggregate measure of total policy support. The other explanatory variables are as defined above. The estimated policy coefficient is positive with a value of 0.003 and almost significant (p-value = 0.079). The estimated expected price elasticity of production is 0.176 and is significant (p-value = 0.02). The estimated coefficient on the time trend indicates that production has been increasing over time.

Overall the results suggest that public support has a significant and positive effect on production. The fit of the regression is depicted in Figure 3.

[1] McDonald and Sumner incorporate detailed rice commodity programs into their approach. Their approach is based on an econometric estimation of a marginal cost curve, some assumptions about the distribution of parameters of their cost function combined with a simulation methodology. Their main policy results indicate that models that do not take into account all the programs' rules produce smaller structural parameters. They cite previous studies that find the acreage elasticites for rice vary from 0.09 to 0.34 which their results indicate are too small.

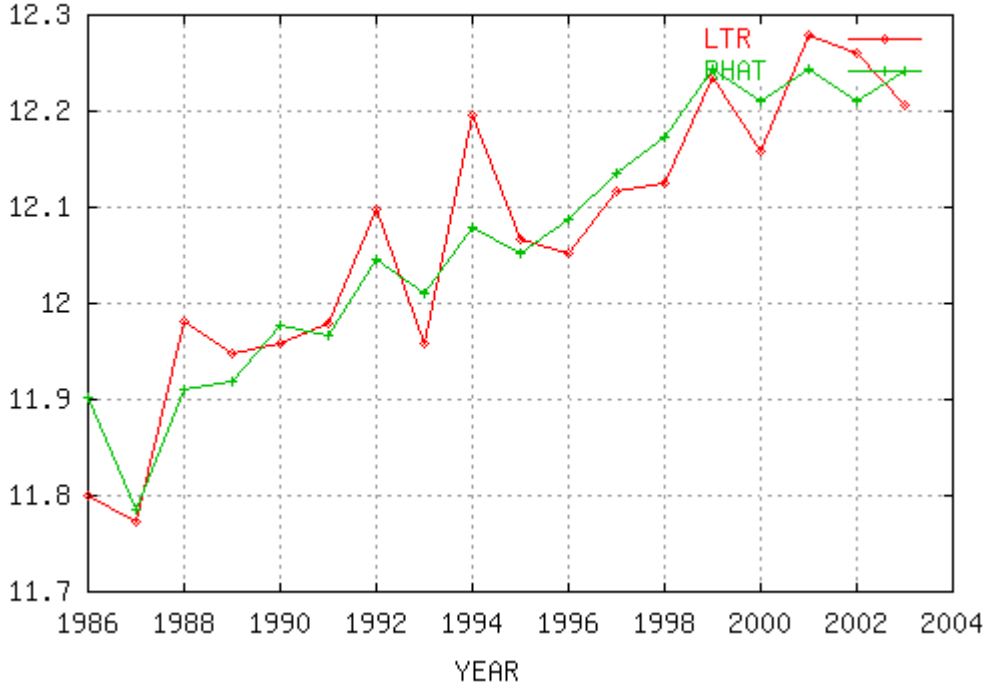

Figure 3: ***US rice production actual (LTR) and estimated (RHAT)***

(in billions of lbs)

Export Demand for Rice

The estimated export equation for rice is:

$$\ln \hat{E}X_t = 31.81 - 0.49 \ln P_{us,t} + 0.91 \ln P_{Thai,t} - 1.99 \ln Inc_{Japan,t} + 0.04t \qquad (8)$$
$$(6.52)(0.19) \qquad (0.31) \qquad (0.62) \qquad (0.01)$$

with R^2 = 0.78, n = 18, and where EX_t represents US exports of rice in 000 cwt, P_{US} represents the grower price for US rice in $/cwt, P_{Thai} denotes the price for rice in Thailand (the major competitor in the world market) and Inc_{Japan} represents per capita income in Japan (the major importer of US rice). The estimated results indicate that US exports decrease with US price increases (US price elasticity of exports is -0.49), increase with increases in Thailand rice prices, and have been increasing over time, conditioned on the other variables. The negative sign on per capita income in Japan was not expected.

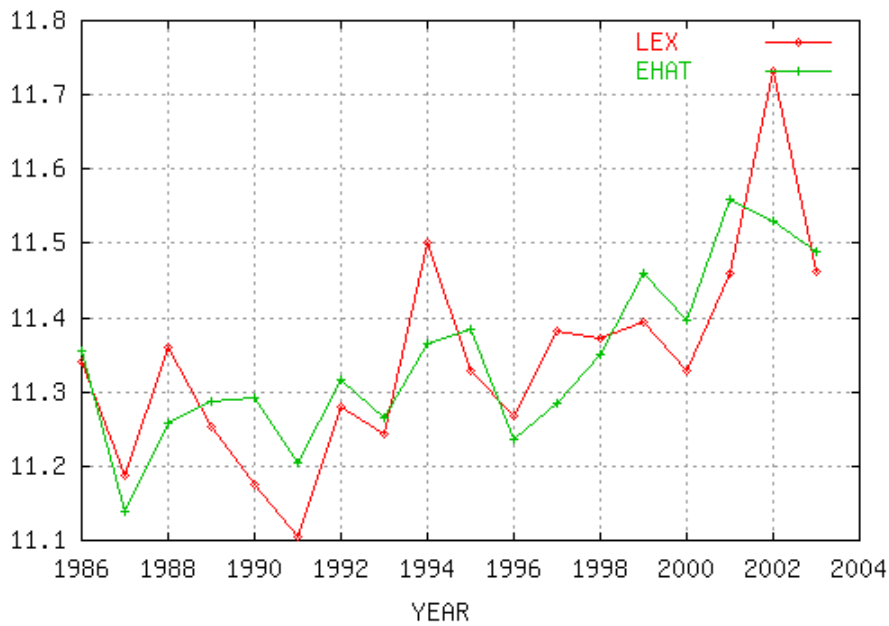

Figure 4: ***US rice export actual (LEX) and estimated (EHAT)***

In order to account for price endogeneity, correlated errors across equations, and to obtain more efficient estimates, we estimated a system of two equations for US rice, under the market clearing assumption. Lagged price was used as the instrumental variable for current price to account for endogeneity of prices. The system was estimated by iterative three stage least squares (3SLS). The estimators have the same asymptotic properties as maximum likelihood estimators. That is, they are consistent, asymptotically normally distributed and efficient. Iterative 3SLS converge to the same value as MLE, but are not equivalent because of a Jacobian term in the likelihood function. The first equation is a production function and the second equation is a demand function. The system results are:

$$\ln \hat{Q}_t = \underset{(1.74)}{8.92} + \underset{(0.39)}{0.45} \ln P_{US,t} + \underset{(0.14)}{0.27} \ln P_{Thai,t} + \underset{(0.01)}{0.01} PSE_t + \underset{(0.02)}{0.06} t \tag{9}$$

$$\ln \hat{Q}_t = \underset{(3.77)}{2.68} - \underset{(0.17)}{0.36} \ln P_{US,t} + \underset{(0.25)}{0.39} \ln P_{Thai,t} + \underset{(0.21)}{0.33} Inc_t + \underset{(0.49)}{0.34} Inc_{Japan,t} \tag{10}$$

The fit of the system is depicted graphically in Figure 5 (the R^2 for the first equation is 0.718 and for the second is 0.888).

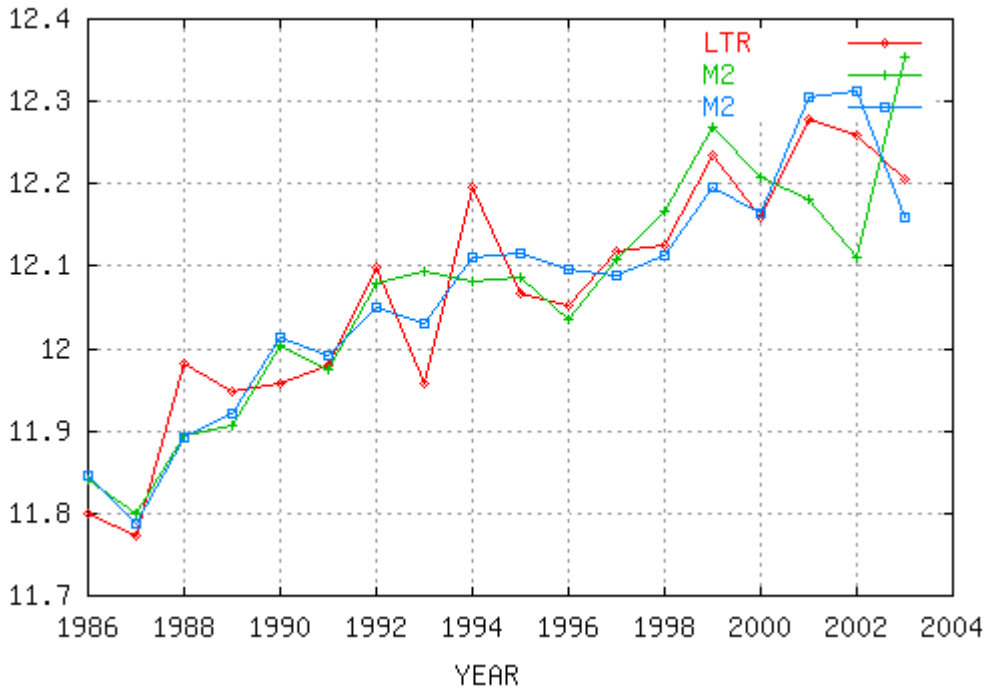

Figure 5: ***Estimation of supply and demand for US rice, under market equilibrium assumption***

The estimated US price expectation (the lag price) elasticity of supply is 0.45 which is also inelastic but is not significant. The estimated coefficient of Thailand price of rice is 0.27 with a t-ratio of about two. The index for price support is positive but not significant. There is also a positive (0.06) and significant time trend in the supply of rice. According to the estimated price coefficient (-0.36), the elasticity of demand of US rice implies that an increase of 1% in price results in a decrease of 0.36% change in the quantity demanded. As the price of Thailand rice increases, the demand for US rice increases, but again the estimated coefficient is not significant. The income elasticity is 0.33 and the estimated coefficient of Japanese income is 0.34 as expected. Both coefficients are not significant, however.

California Market

The estimated production function of California rice is:

$$\ln \hat{Q}_t = 7.56 + 0.48 \ln P_{t-1} + 0.11 Pay_t - 0.005 Loan_t + 0.04t + 1.21 D_t - 1.23 D_t * Pay_t \quad (11)$$
$$(0.72)\ (0.16) \qquad (0.05) \qquad (0.04) \qquad (0.01)\ \ (0.52)\ \ (0.48)$$

with R^2 = 0.816, n = 21, and where Q denotes California production, P denotes grower price, Pay represents direct payments, $Loans$ are the interest rate on marketing loans and D is a dummy variable identifying the years 1996 and after to account for policy changes.

The estimated own-price elasticity is 0.48 (and significant) which is higher than the corresponding estimated value for US production. Producers respond positively to increases in direct payments and to policy changes occurring after 1996. There is also a positive time trend. Interest rates on marketing loans did not have a significant impact on California production. Figure 6 depicts the fit of the California production model.

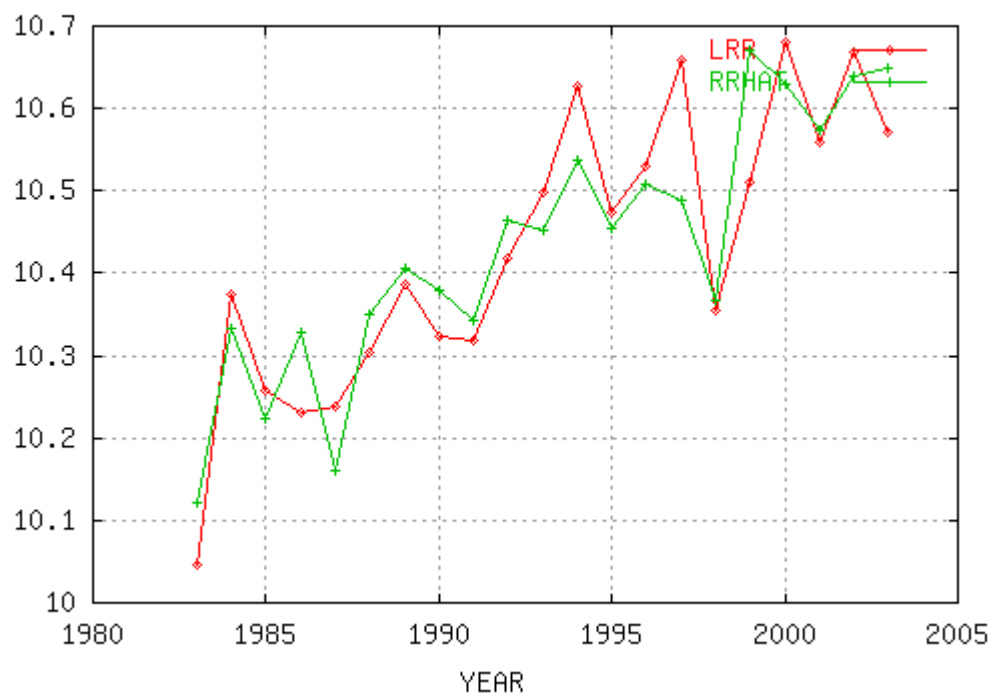

Figure 6: ***California rice production actual (LRR) and estimated (RRHAT)***

Conclusions

Rice producers in California and throughout the United States respond positively to increases in rice prices. The short-run price elasticity of production, based on a partial adjustment model, for the US was estimated to be 0.23. When policy variables were included in the production equation the price elasticity dropped to 0.18 (see eq. 7). Rice producers respond positively to support programs. The production equation was an aggregated one. For a disaggregated approach that estimates how rice producers respond to different support programs, see McDonald and Sumner.

The estimated own-price elasticity of demand for rice was found to be inelastic (-0.140) for a SUR system. The income elasticity for rice was estimated to be 0.74 in a single-equation demand function (eq. 4).

US rice producers export less when the US price increases (estimated elasticity =-0.49). They export more when the Thailand rice price increases (estimated Thailand price elasticity of 0.91) since Thailand is a major competitor in the world market.

References

McDonald, J. and D. Sumner, "The Influence of Commodity Programs on Acreage Response to Market Price: with an Illustration Concerning Rice Policy in the United States", *American Journal of Agricultural Economics*, 85(4): 2003: 857-871.

TOMATOES

Background

The United States is the world's second leading producer of tomatoes, after China. Fresh and processed tomatoes combined accounted for almost $2 billion in cash receipts during the early 2000s. Mexico and Canada are important suppliers of fresh market tomatoes to the United States and Canada is the leading importer of U.S. fresh and processed tomatoes.

The characteristics of tomato consumption are changing. Fresh tomatoes consumption increased by 15% between the early '90s and early 2000s, while the use of processed products declined 9%. Currently, the per capita consumption is 18 pounds per person of fresh tomatoes, and 68 pounds for processed tomatoes (fresh-weight basis).

The U.S. fresh and processing tomato industries consist of separate markets. According to ERS (website) four basic characteristics distinguish the two industries. Tomato varieties are bred specifically to serve the requirements of either the fresh or the processing markets. Processing requires varieties that contain a higher percentage of soluble solids (averaging 5-9 percent) to efficiently make tomato paste, for example.

- Most tomatoes grown for processing are produced under contract between growers and processing firms. Fresh tomatoes are largely produced and sold on the open market.
- Processing tomatoes are machine-harvested while all fresh-market tomatoes are hand-picked.
- Fresh-market tomato prices are higher and more variable than processing tomatoes due to larger production costs and greater market uncertainty

Policy

Tomato production is not covered by price or income support. However, tomato producers may benefit from general, non crop specific-programs such as federal crop insurance, disaster assistance,

and western irrigation subsidies. The only federal marketing order in force for tomatoes covers the majority of fresh-market tomatoes produced in Florida between October and June.

With respect to imports, the United Stated negotiated a voluntary price restraint on fresh tomato imports from Mexico starting in 1996. Mexico agreed to set a floor price of $0.21 per pound of tomatoes exported to the United States The effect of the policy was to reduce Mexican exports to the U.S. and there were sizeable fresh tomato diversions (to other importing countries) and diversions into processing; see Baylis and Perloff for more details of this policy.

California Production

California is the second leading producer of fresh tomatoes in the US, after Florida. Figures 1-3 compares fresh tomatoes planted acreage, production and nominal price for US, Florida and California.

California accounts for about 95 percent of the area harvested for processing tomatoes in the United States—up from 79 percent in 1980 and 87 percent in 1990. The other major producers are Texas, Utah, Illinois, Virginia, and Delaware and Florida. In Figure 1, total U.S. fresh tomato acreage has declined over the period 1960 to 2002, but acreage in California and Florida has remained steady. The declined in acreage has come from the states of Texas, Utah, Illinois, Virginia, and Delaware (Lucier). Figures 4-6 illustrates the trends for California and US planted acreage, production and nominal prices for processed tomatoes.

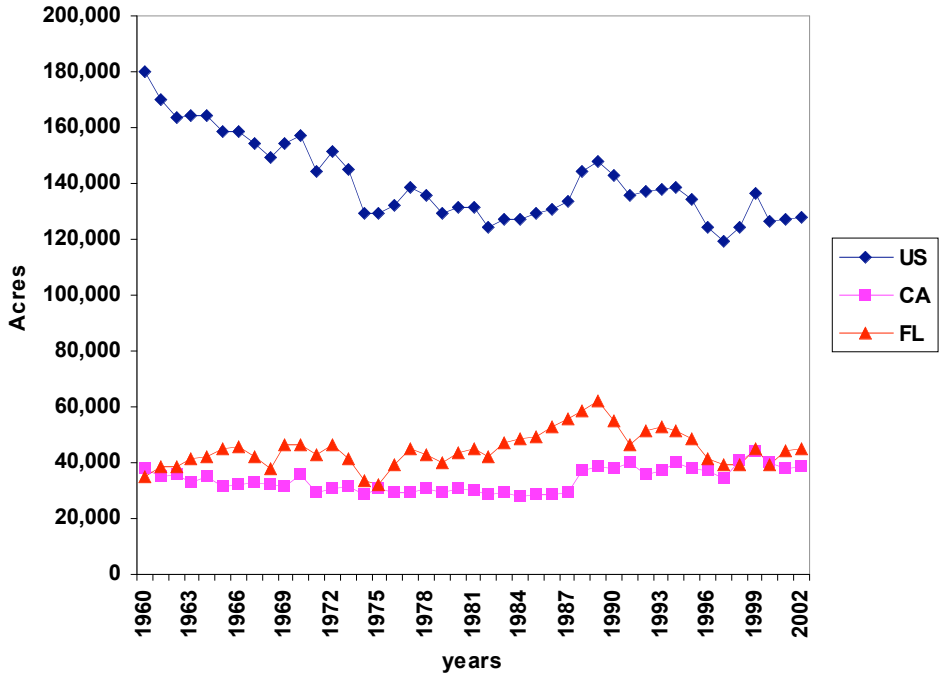

Figure 1: ***Fresh tomato acreage 1960-2002 – (source ERS)***

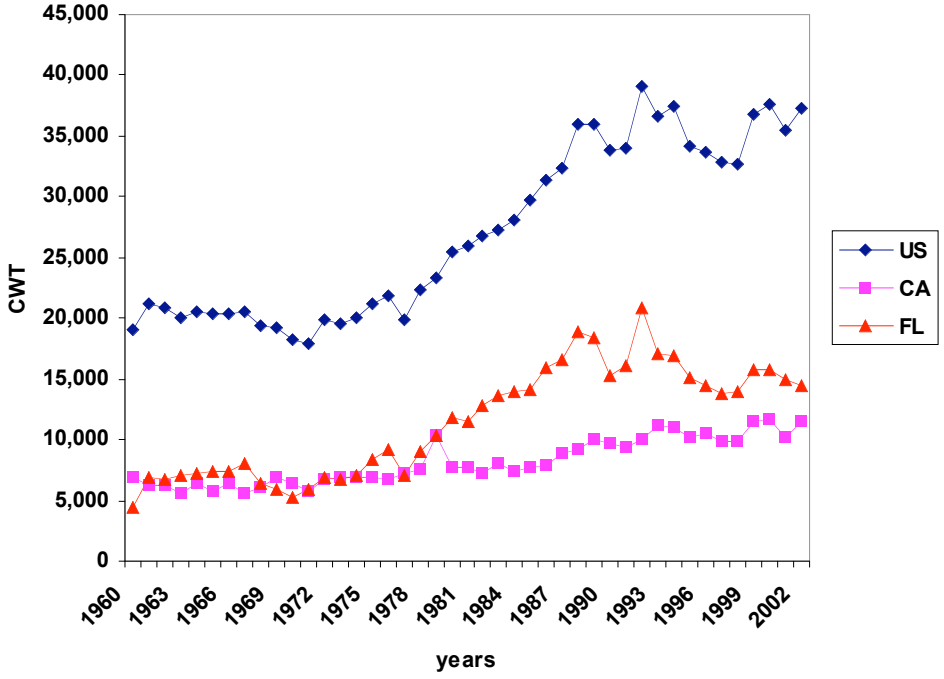

Figure 2: ***Fresh tomato production 1960-2002 – (source ERS)***

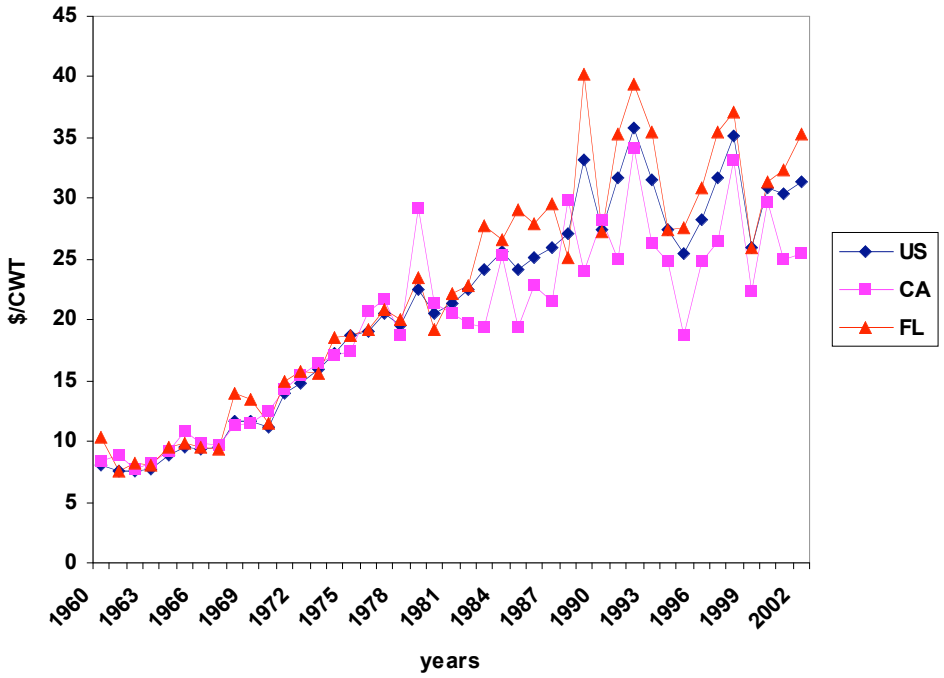

Figure 3a: ***Fresh tomato nominal prices 1960-2002 –(source ERS)***

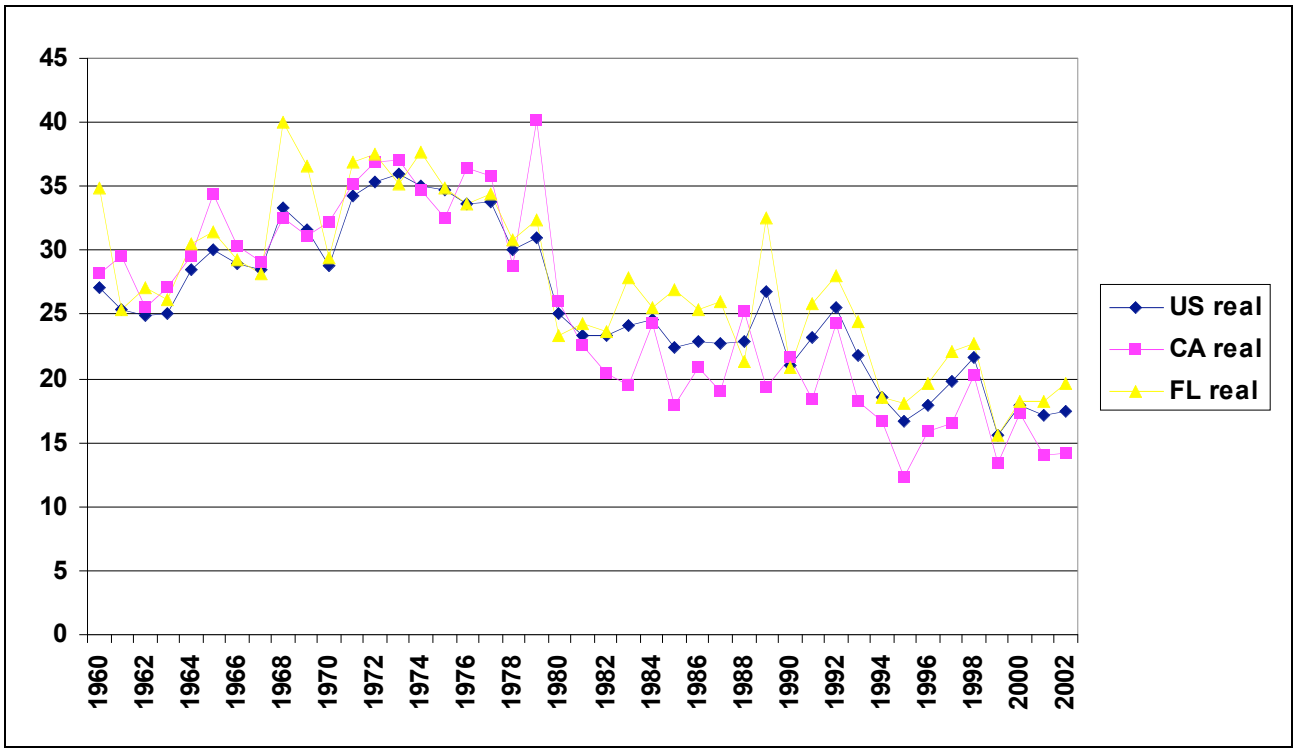

Figure 3b*: Fresh tomato real price 1960-2002 (base 1983-84)*

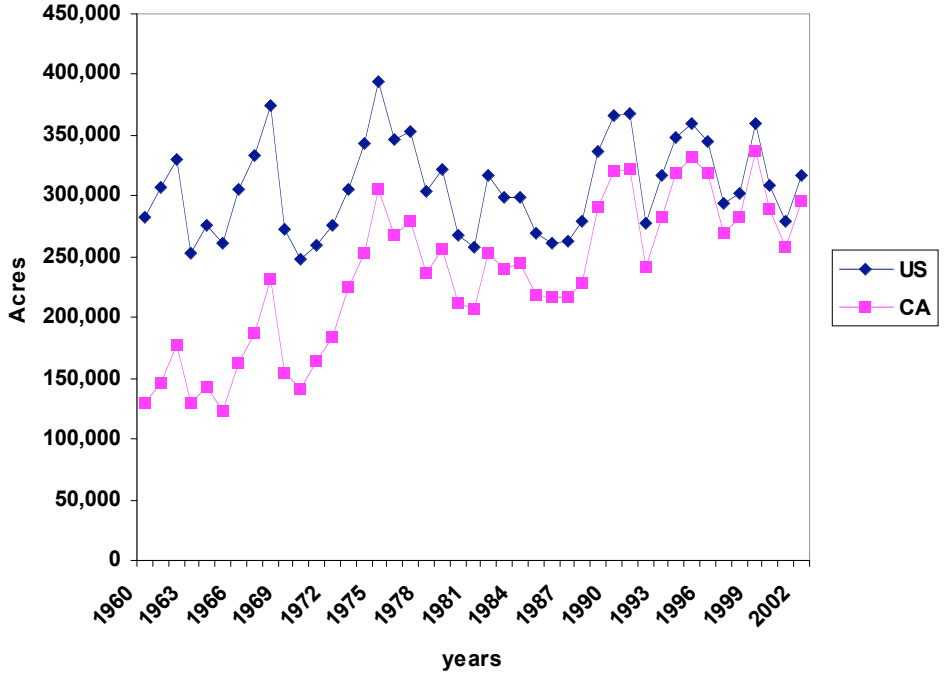

Figure 4: ***Processing tomato acreage 1960-2002 – (source ERS)***

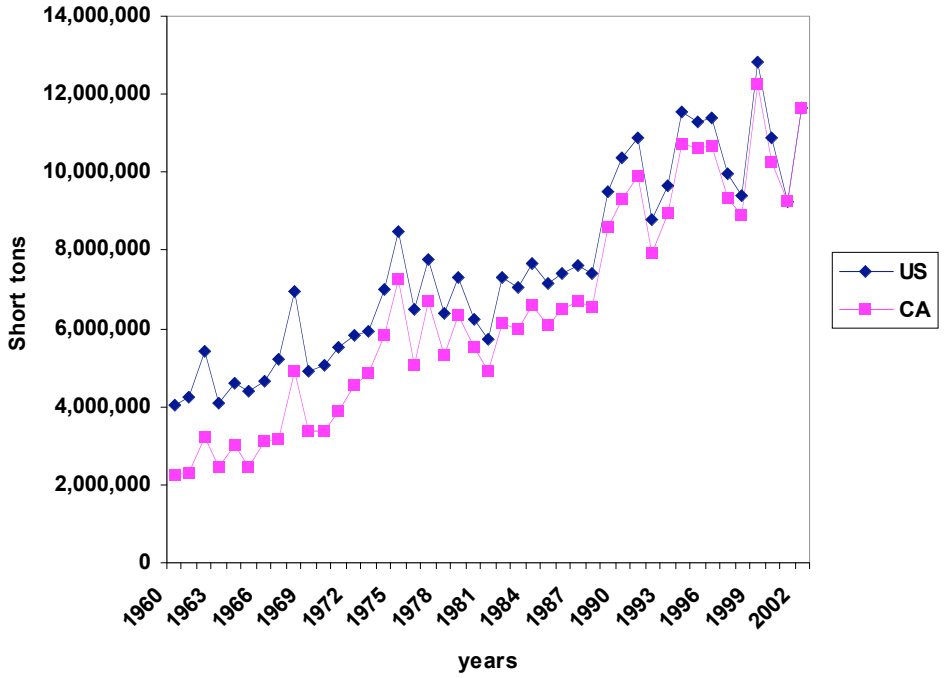

Figure 5: ***Processing tomato production 1960-2002 – (source ERS)***

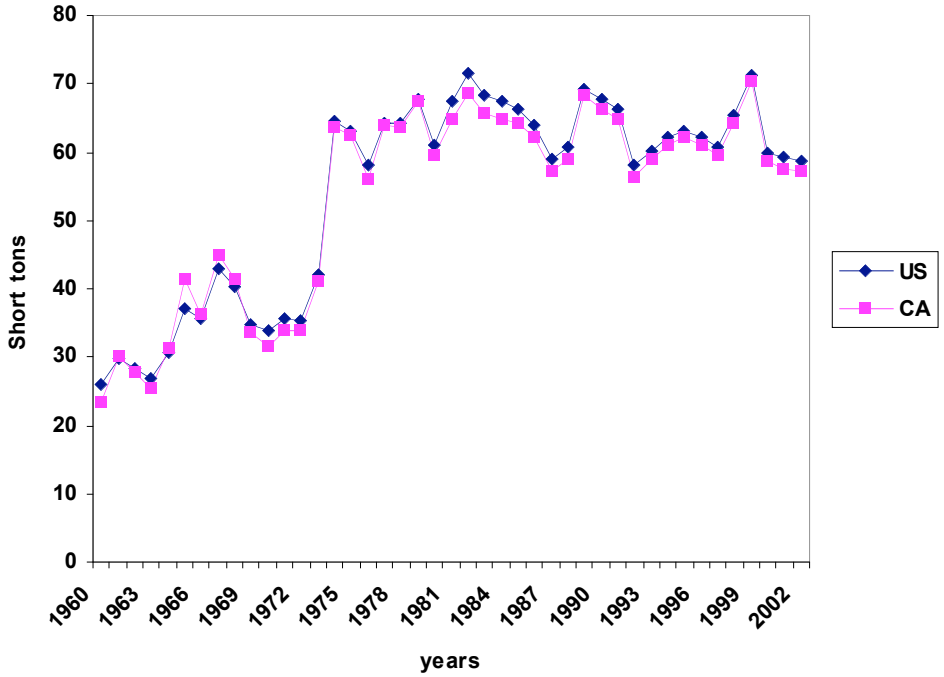

Figure 6: ***Processing tomato nominal prices 1960-2002 ($/ton) – (source ERS)***

Processing Tomatoes

Tomato growing is based on grower-processor contract agreements. The majority of production is traded this way with the spot market playing a marginal role. Most initial processing is by firms that manufacture tomato paste, a raw ingredient. Tomato paste is storable up to 18 months. Downstream firms transform the paste in final consumer products. According to the Food Institute, at the end of the process, raw material (tomatoes and fees) account for 39%-45% of total production cost.

According to the ERS, there was a radical structural change in the processing industry in the late 1980's and early 1990's. A period of relatively high prices in the late 1980s triggered new investments. This finally resulted in excess supply and decreasing prices. As a consequence, many processors went bankrupt and the whole industry was restructured. The current structure is the result of such adjustments.

Estimation

A brief industry description highlights two key points prior to the estimations.

Price expectations. The majority of production is sold under contract. This has two implications: i) producers know (with good approximation) prices when planning production, so we do not need to model expectations; rather we assume perfect information, ii) the actual contract price is unobservable, being industry private information. It is reasonable to assume that the spot market price is correlated with contract price according to the additive error formula:

$$\text{spot price} = \text{contract price} + \text{error} .$$

We use the spot price as a proxy for the real contract price. However, since the measurement error is likely to be correlated with the error terms in the production equations (for example in case of unexpected shortage, we expect higher spot prices) we use an instrumental variable (IV) approach. The instrument is the previous year's spot price, which is correlated with the current spot price, but uncorrelated with random shocks in current production.

Structural change. The industry underwent structural changes from the late '80s until the early '90s. Much of the change is likely due to continued expansion in food-service demand, especially for pizza, taco, and other Italian and Mexican foods (Lucier). Increased immigration and changes in America's tastes and preferences have contributed to rising per capita tomato use (Lucier, *et al)*. Commercial varieties were developed to expedite packing, shipping, and retailing in the processing market. Mechanical harvesting and bulk handling systems replaced hand harvest of processing tomatoes in the California in the 1960's as the new varieties were introduced. Increases in yields are due to the development of higher yielding hybrid varieties and improved cultural practices such as increases in use of transplanting (Plummer). The hypothesis of structural change was tested on both the supply and demand side.

Acreage

The acreage equation is based on a partial adjustment model:

$$\ln A_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln A_{t-1} + \beta_3 t + \varepsilon_t \tag{1}$$

where A_t represents acreage at time t in actual acres, P_t represents the spot price of processing tomatoes in \$/cwt, and t is a time trend.

The OLS estimated acreage function for the years 1960-2002 is:

$$\begin{aligned} \ln \hat{A}_t &= 5.67 + 0.47 \ln P_t + 0.32 \ln A_{t-1} + 0.03t \\ &\quad (1.38)\ (0.12) \qquad (0.13) \qquad (0.01) \end{aligned} \tag{2}$$

with $R^2 = 0.815$, n = 42 and where the numbers in parentheses are standard errors.

The instrumental variable estimated acreage equation is:

$$\begin{aligned} \ln \hat{A}_t &= 5.67 + 0.41 \ln P_t + 0.36 \ln A_{t-1} + 0.02t \\ &\quad (1.39)\ (0.18) \qquad (0.14) \qquad (0.01) \end{aligned} \tag{3}$$

with $R^2 = 0.814$ and n = 42.

Figures 7 and 8 compare the fits of the two regressions.

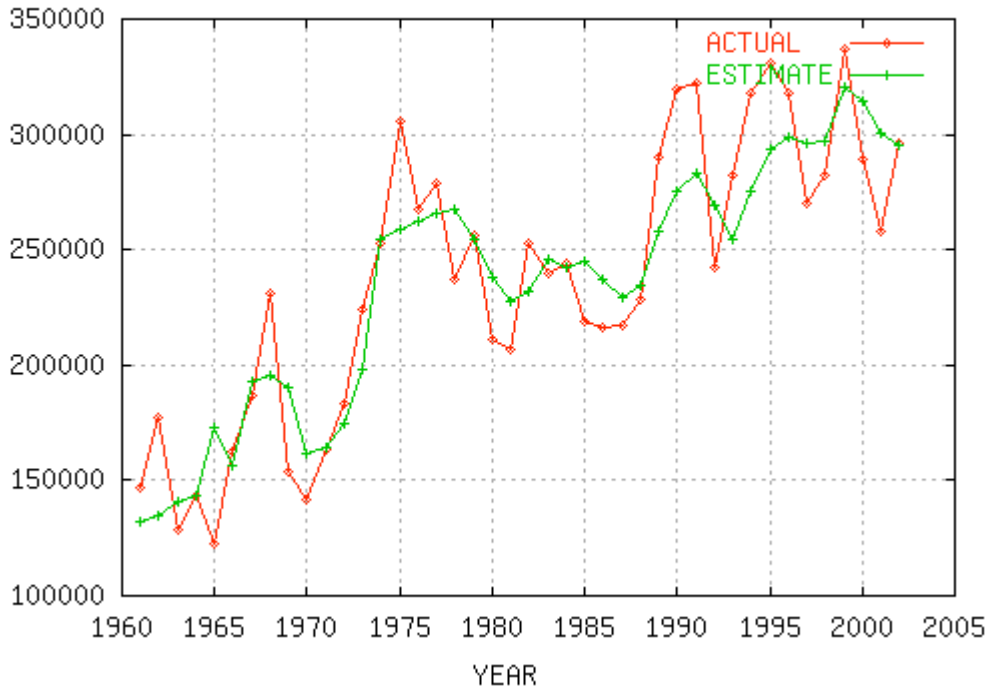

Figure 7: ***OLS estimation of processing tomato acreage (in acres).***

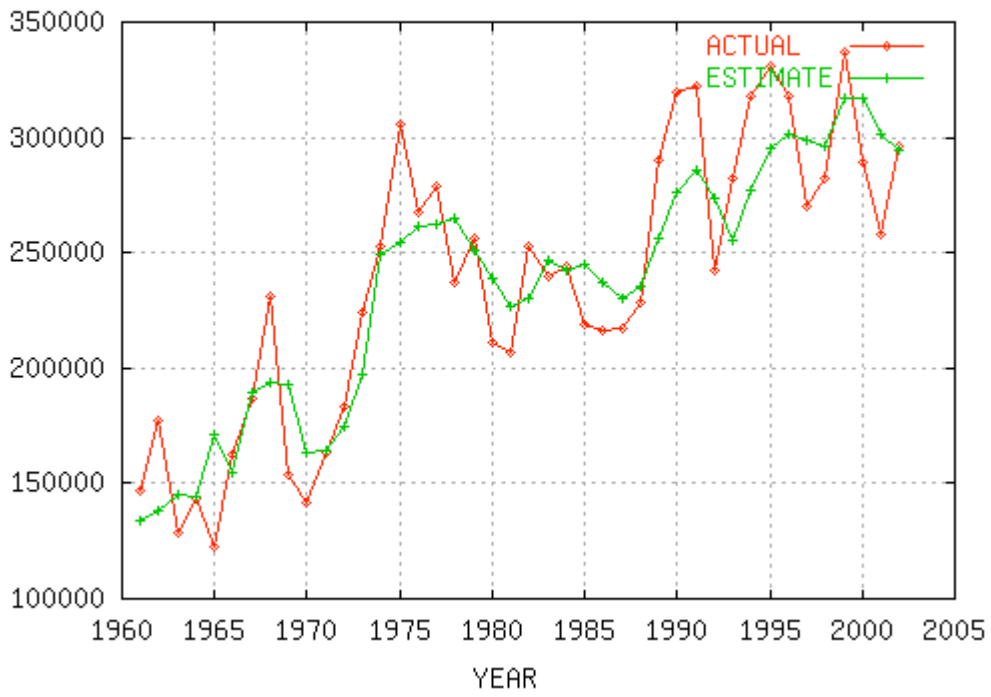

Figure 8: ***IV estimation of processing tomato acreage (in acres).***

The two estimation procedures –OLS and IV- give similar results. According to the partial adjustment model, the IV estimate of the short-run elasticity of acreage with respect to a change in price is 0.41 compared to the OLS estimate of 0.47. The estimate of the long-run price elasticity is 0.64. The coefficients on lagged acreage and the time trend are both positive. All the coefficients are statistically significant from zero.

Structural change

The Chow test confirmed the possibility of a structural break in the late '80s. The estimation of the model for the two periods (before and after 1988) gave the following results:

Dep. Variable: Tomato Acreage	Before 1988		After 1988	
Variable	estimate	std. dev.	estimate	std. dev.
Constant	5.62	1.73	2.20	3.21
Price	0.51	0.15	1.09	0.36
Lag Acreage	0.32	0.16	0.40	0.19
Time Trend	0.02	0.01	0.03	0.01

Table 1. Chow test results for processing tomato acreage function.

By observing the results prior to 1988 and past 1988, almost all of the coefficients are significantly different from zero. Most of the estimated coefficients differ little in magnitudes between the two periods. However, the short-run elasticity of acreage with respect to price is 0.51 before 1988 and 1.09 after 1988. Producers are much more responsive to prices after 1988 regarding their acreage. What explains this difference? Producers are, apparently, more responsive to price changes with the increased use of contracts and other structural changes mentioned above.

Figure 9 depicts the fit of the estimated structural-break model.

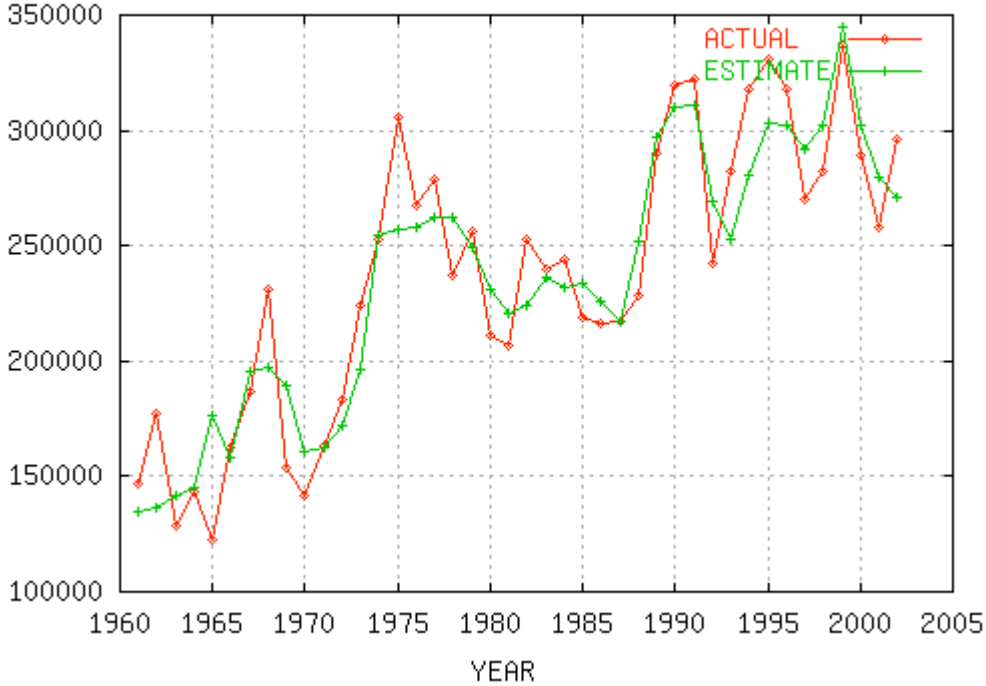

Figure 9: ***Structural break model for processing tomato acreage (in acres)***

Production

The partial adjustment model for processed tomato production is

$$\ln Q_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln Q_{t-1} + \beta_3 t + \varepsilon_t \tag{4}$$

where Q_t denotes production at time t in tons, P_t represents real price of processing tomatoes in \$/cwt, and t is a time trend. The OLS estimated production function is

$$\ln \hat{Q}_t = \underset{(1.98)}{11.00} + \underset{(0.13)}{0.45} \ln P_t + \underset{(0.14)}{0.10} \ln Q_{t-1} + \underset{(0.01)}{0.04} t \tag{5}$$

with $R^2 = 0.92$ and n = 42.

The same model, estimated by using lagged prices as instrumental variables, gave comparable results:

$$\ln \hat{Q}_t = \underset{(1.99)}{11.03} + \underset{(0.19)}{0.55} \ln P_t + \underset{(0.15)}{0.07} \ln Q_{t-1} + \underset{(0.01)}{0.05} t \tag{6}$$

with $R^2 = 0.91$ and n = 42. The OLS estimate of the own-price elasticity is 0.45 compared to that of 0.55 for the instrumental variables estimate. Both coefficients are significant. Coefficients of lagged acreage are both positive but not significant. And both coefficients on the time trends are positive and significant.

Figures 10 and 11 compare the fit of the two estimations.

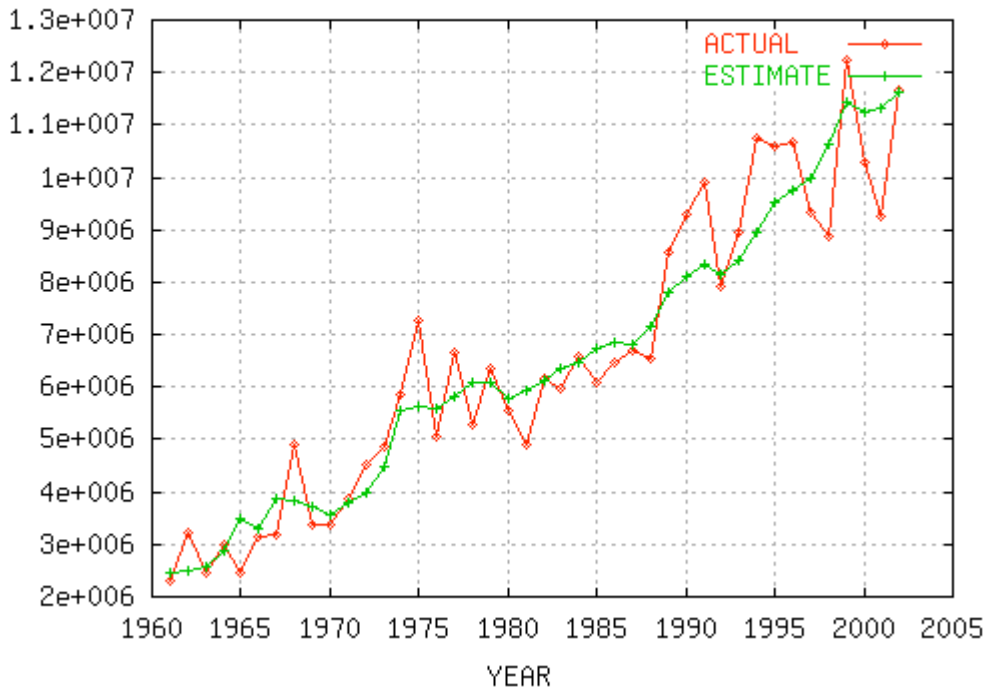

Figure 10: ***Production estimation for processing tomato (OLS) in tons.***

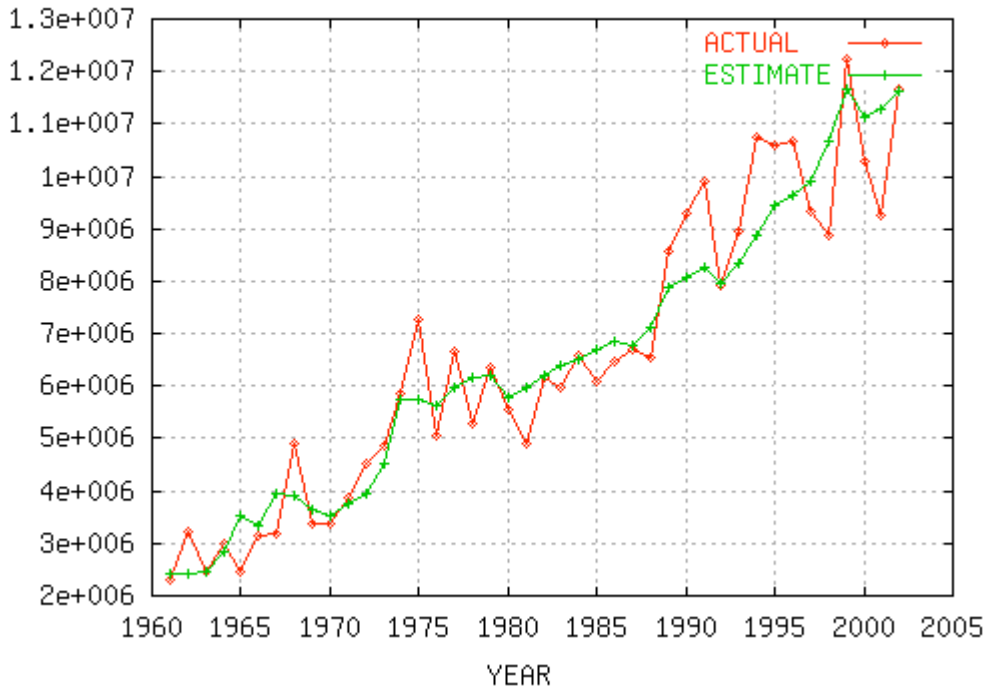

Figure 11: ***Production estimation for processing tomato (IV)in tons.***

Although a Chow test did not reject the null hypothesis of no structural change[1], we present the estimates for the two-period model, to provide a comparison with the acreage model.

Dep. Variable Production in tons	Before 1988		After 1988	
Variable	estimate	std. dev.	estimate	std. dev.
Constant	12.11	2.52	4.89	5.29
Price	0.51	0.17	1.04	0.47
Lag Acreage	0.01	0.19	0.35	0.25
Time Trend	0.05	0.01	0.04	0.01

Table 2. Chow test results for processing tomato production function

[1] The test has a p-value of 0.117.

With respect to the production model, the two-period approach suggests that production after 1988 became more elastic. An estimated price elasticity of 0.51 before 1988 versus an estimate of 1.04 after 1988. Both coefficients are significant. Figure 12 illustrates the fit of the estimation.

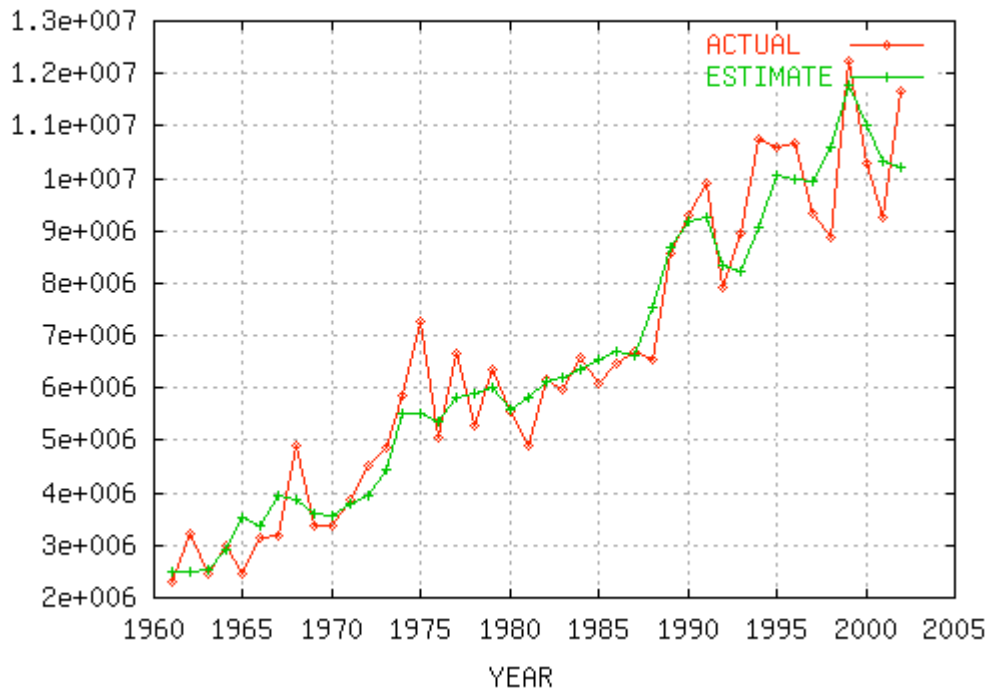

Figure 12: ***Structural break model for processing tomato production in tons.***

Demand

In this section two demand models for processing tomatoes are presented. The first one describes the demand for processing tomatoes at the farm level and the second one illustrates the final demand (at the consumer level) for tomato products.

Demand for processing tomatoes

The demand for processing tomatoes is a function of farmer prices and the price index for tomato paste. The data refer to 21 time periods (from 1982 to 2002). The model describes the industry demand under the assumptions of price taking behavior and market equilibrium. Industry expectations

are modeled using lagged prices. The regression model has been estimated with a moving average process of order one. The derived demand equation for processed tomatoes is:

$$\ln Q_t = \beta_0 + \beta_1 \ln PF_{t-1} + \beta_2 PR_{t-1} + \beta_3 t \tag{7}$$

where Q_t represents the quantity demanded of California processing tomatoes , PF_{t-1} denotes the grower price, lagged one time period, PR_{t-1} is the price of tomato paste, lagged one time period, and t is a time trend.

The estimated demand equation is

$$\ln \hat{Q}_t = \underset{(0.06)}{15.67} - \underset{(0.05)}{0.18} \ln PF_{t-1} + \underset{(0.04)}{0.16} \ln PR_{t-1} + \underset{(0.02)}{0.03} t \tag{8}$$

where $R^2 = 0.815$ and n = 21. Based on the estimates, the demand for California processing tomatoes is inelastic (a statistically significant own-price estimated elasticity of -0.18). The coefficient of tomato paste price is 0.16 and significant. As the price of tomato paste increases the demand for processing tomatoes increases. This is as expected since the demand for processing tomatoes is a derived demand.

Figure 13 shows the fit of the regression.

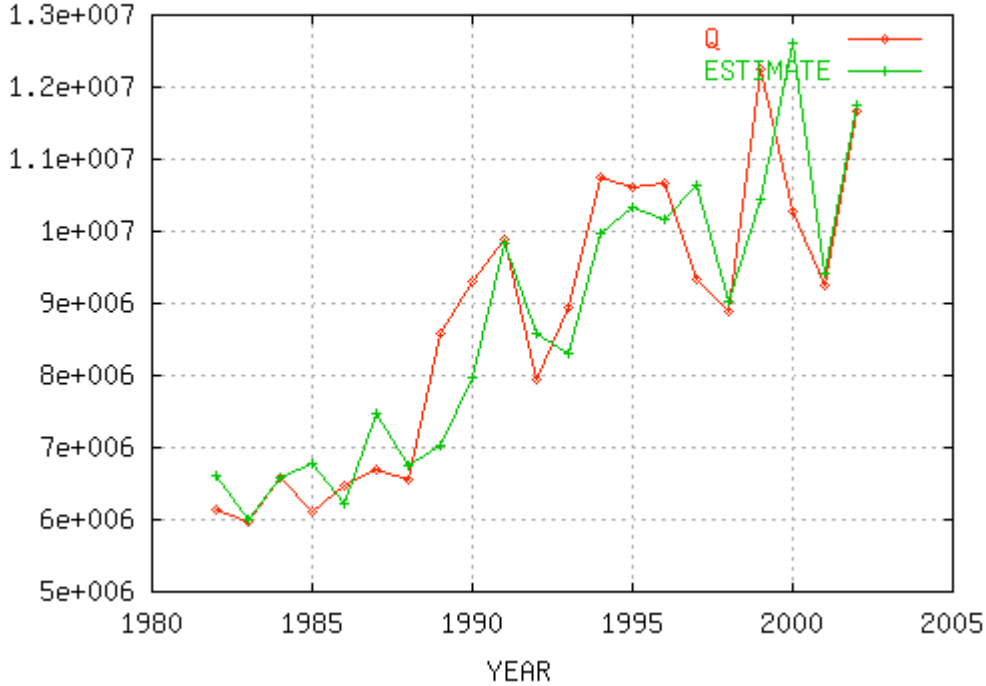

Figure 13: ***Demand for California processing tomatoes (million tons).***

Demand for tomato products

The demand for tomato products was estimated based on quarterly US retail sales data from 1993 to 2004 (Food Institute). Since the data exhibit a strong seasonal pattern, the estimation model is:

$$\ln Q_t = \beta_0 + \beta_1 \ln PT_t + \beta_2 EF_t + \beta_3 PF_t + \beta_4 D_{1t} + \beta_5 D_{2t} + \beta_6 D_{3t} + v_t \tag{9}$$

where PT_t represents the price of tomato products, EF_t denotes the expenditure for food, PF_t represents the price index for food, and D_1, D_2, and D_3 are seasonal dummy variables for the first, second and third quarters.

The model was estimated with a moving average of order four error term (consistent with seasonality). The results are

$$\ln \hat{Q}_t = \underset{(0.52)}{14.84} - \underset{(0.08)}{0.26} \ln PT_t - \underset{(0.19)}{1.64} EF_t + \underset{(0.22)}{0.86} PF_t + \underset{(0.01)}{0.05} D_{1t} - \underset{(0.01)}{0.33} D_{2t} - \underset{(0.01)}{0.29} D_{3t} \tag{10}$$

where $R^2 = 0.99$ n = 48. The demand for tomato products is inelastic (a significant own-price elasticity estimate of -0.26) and on average is higher during the first and the fourth quarters (since fresh tomatoes are less available). The sign of the food expenditure elasticity is negative which is not as expected.

Figure 14 illustrates the fit of the regression.

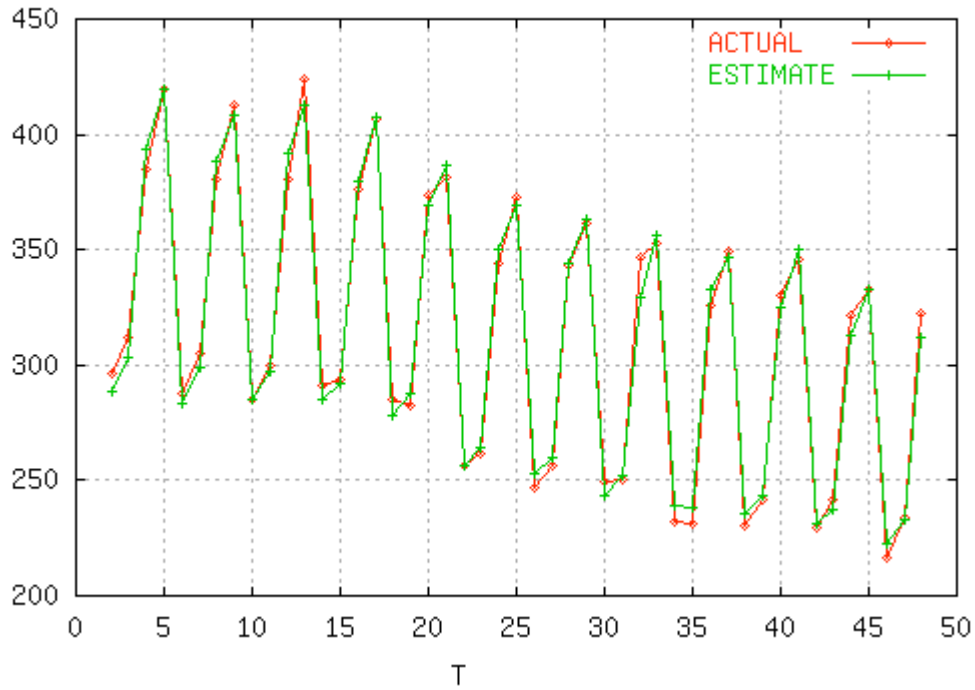

Figure 14: ***Consumers' demand for processing tomato products (1st quarter 1993-4th quarter 2004)***

Fresh Tomatoes

Per capita consumption of fresh tomatoes has been increasing since the '80s (Figure 15). Higher demand triggered a structural adjustment in the industry. Figure 1 shows that, initially, the main acreage adjustment was in Florida, while California increased acreage sharply in the late '80s.

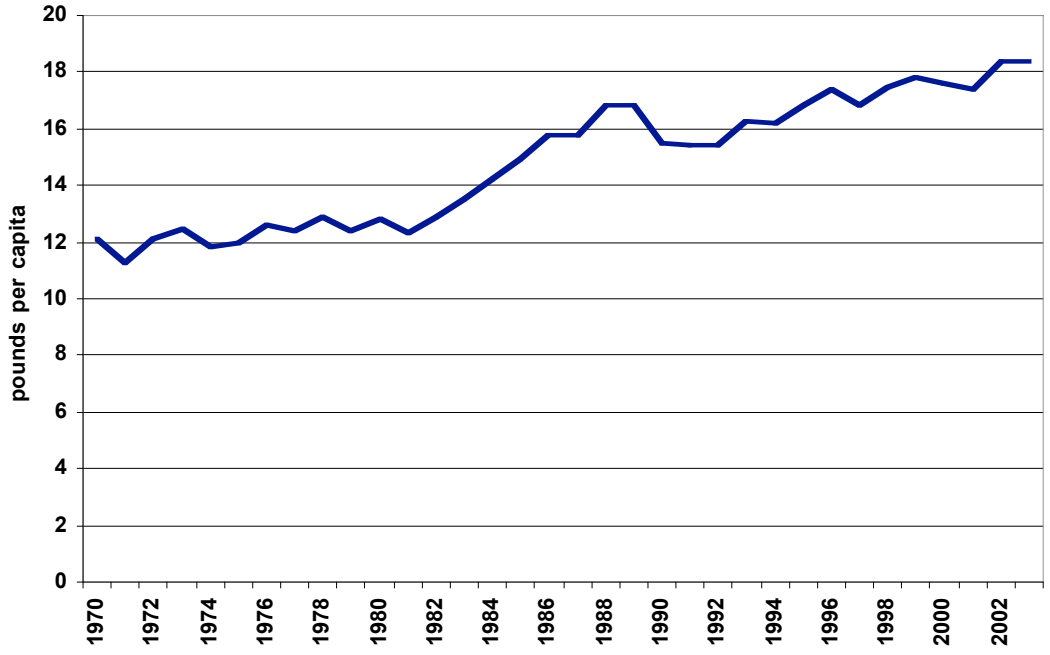

Figure 15: ***US per capita consumption of fresh tomatoes***

Given this trend in the industry the estimations allowed for a structural break. The two periods are 1960-1987 and 1988-2002.

Acreage for Fresh Tomatoes

The acreage model was estimated assuming a partial adjustment process. Price expectations have been modeled using the previous year's price for the period 1960-1987 and a two-year lagged price before the period 1988-2002. This was done because after the structural change, the prices exhibits an alternate pattern, so that the current price is negatively correlated with the previous year, but

positively correlated with two periods before. Finally we tested the influence of the processing industry on the fresh tomato acreage, by using the price of processing tomato as a regressor.

What accounts for the structural break in 1987 in fresh tomato acreage? Much of the increase in California acreage can be explained as a response to changes in consumption patterns, according to the USDA. In terms of consumption, tomatoes are the Nation's fourth most popular fresh-market vegetable behind potatoes, lettuce, and onions. Fresh-market tomato consumption has been on the rise due to the enduring popularity of salads, salad bars, and sandwiches such as the BLT (bacon-lettuce-tomato) and subs. Perhaps of greater importance has been the introduction of improved tomato varieties, consumer interest in a wider range of tomatoes (such as hothouse and grape tomatoes), a surge of immigrants with vegetable-intensive diets, and expanding national emphasis on health and nutrition. After remaining flat during the 1960s and 1970s at 12.2 pounds, fresh use increased 19 percent during the 1980s, 13 percent during the 1990s, and has continued to trend higher in the current decade. Although Americans consume three-fourths of their tomatoes in processed form (sauces, catsup, juice), fresh-market use exceeded 5 billion pounds for the first time in 2002 when per capita use also reached a new high at 18.3 pounds. Because of the expansion of the domestic greenhouse/hydroponic tomato industry since the mid-1990s, it is likely per capita use is at least 1 pound higher than currently reported by USDA (the Department does not currently enumerate domestic greenhouse vegetable production). One medium, fresh tomato (about 5.2 ounces) has 35 calories and provides 40 percent of the U.S. Recommended Daily Amount of vitamin C and 20 percent of the vitamin A. University research shows that tomatoes may protect against some cancers.

he partial adjustment acreage function for fresh tomatoes is:

$$\ln A_t = \beta_0 + \beta_1 \ln EP_t + \beta_2 \ln PP_t + \beta_3 t + \beta_4 \ln A_{t-1} + \varepsilon_t \tag{11}$$

where A represents fresh tomato acreage in acres, EP denotes the price expectation in \$/ton (equal to the previous year price for the period 1960-1987 and to the price of two years before for the period 1988-2002), PP denotes the price of processing tomatoes, and t is a time trend.

The estimated fresh tomato acreage function for the period 1960-1987 is:

$$\ln \hat{A}_t = \underset{(0.96)}{17.43} + \underset{(0.05)}{0.00} \ln EP_t - \underset{(0.05)}{0.16} \ln PP_t - \underset{(0.00)}{0.02} t - \underset{(0.07)}{0.67} \ln A_{t-1} \tag{12}$$

where $R^2 = 0.828$ and n = 27. The estimated coefficient on expected price of fresh tomatoes is positive but insignificant. The results indicate a declining trend in acreage, with disinvestments from the industry regardless of any price expectation. The negative coefficient on lagged acreage (-0.67) and is highly significant and reflects rotation practices.

In the second period (1988-2002), the results of the estimation of fresh tomato acreage function are

$$\ln \hat{A}_t = \underset{(1.24)}{6.81} + \underset{(0.07)}{0.23} \ln EP_t + \underset{(0.10)}{0.48} \ln PP_t + \underset{(0.00)}{0.02} t - \underset{(0.12)}{0.04} \ln A_{t-1} \tag{13}$$

where $R^2 = 0.840$ and n = 15. The estimation suggests a structural change in the second period. The trend is increasing, the coefficient on price expectation is positive and significant (0.23) and the sign on the coefficient of processing tomato price indicates complementarities (0.48).

Figure 16 illustrates the fit of the model for the period 1960-2002.

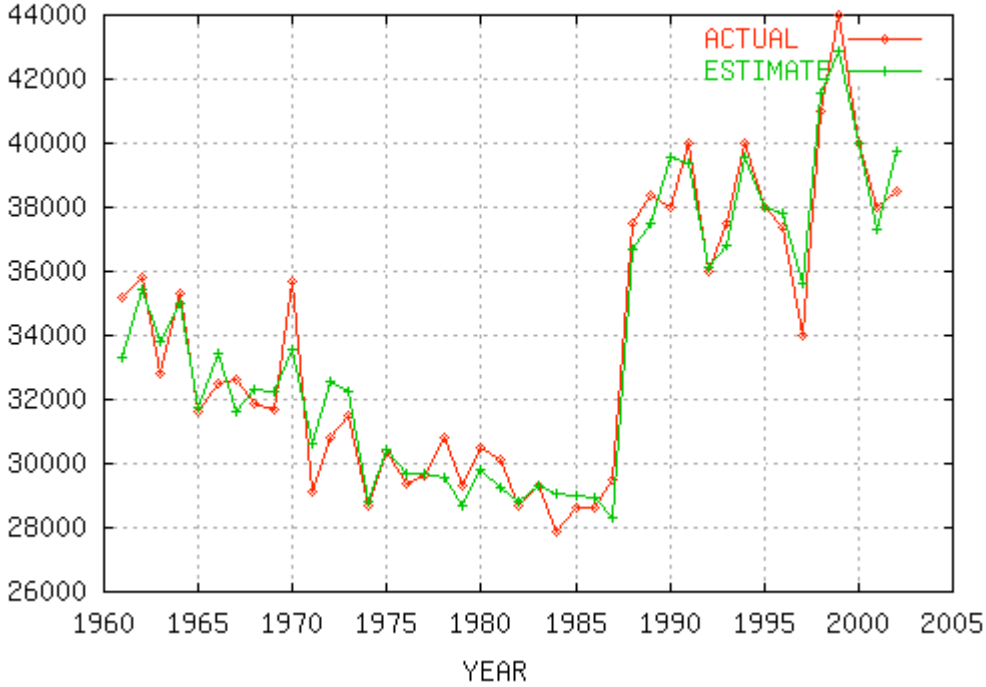

Figure 16: ***California fresh tomato acreage (in acres).***

Production

The partial adjustment model for fresh tomato production is:

$$\ln Q_t = \beta_0 + \beta_1 \ln EP_t + \beta_2 \ln PP_t + \beta_3 t + \beta_4 t^2 + \beta_5 W_t + \beta_6 \ln Q_{t-1} + D_{t,79} + \varepsilon_t \tag{14}$$

where Q represents annual production in tons, EP denotes the price expectation in \$/ton, PP denotes the price of processing tomatoes[2], also in \$/ton, t is a time trend, W_t represents the water availability (measured by the four river index) and D is a dummy variable identifying the year 1979 which had an exceptional yield. Note that in this equation the time trend including the quadratic trend, captures the effects of technological change. The model was estimated separately for the two time periods, assuming a moving average error process which is consistent with a partial adjustment specification. The results are as follows:

[2] For production, slightly better results can be obtained by using cotton as a competing crop. However, since cotton performs poorly in explaining acreage, we kept processing tomatoes in the estimation for consistency with the acreage equation.

Period 1960-1987:

$$\ln \hat{Q}_t = 10.04 + 0.22 \ln EP_t - 0.04 PP_t - 0.01t + 0.00t^2 + 0.00W_t + 0.11 \ln Q_{t-1} + 0.37 D_{t,79} \tag{15}$$
$$(1.51)(0.12) \quad (0.04) \quad (0.01) \quad (0.00) \quad (0.00) \quad (0.14) \quad (0.07)$$

where $R^2 = 0.932$ and n = 27.

Period 1988-2002:

$$\ln \hat{Q}_t = 6.82 + 0.27 \ln EP_t - 0.05 PP_t - 0.02t + 0.00t^2 + 0.00W_t + 0.33 \ln Q_{t-1} \tag{16}$$
$$(5.21)\ (0.11) \quad (0.31) \quad (0.09) \quad (0.00) \quad (0.01) \quad (0.47)$$

where $R^2 = 0.789$ and n = 15. Based on the estimations, the short run elasticity of fresh tomato production with respect to price expectations was 0.22 before 1987 and 0.27 after 1987. There is no statistical evidence of change in the values of elasticities after the structural break. Given the partial adjustment model, the estimation of long run elasticity is 0.247 (before 1988) and 0.403 (from 1988 on). The trend term coefficients were not significant nor were the coefficienets on the lagged production terms. Figure 17 describes the fit of the regression.

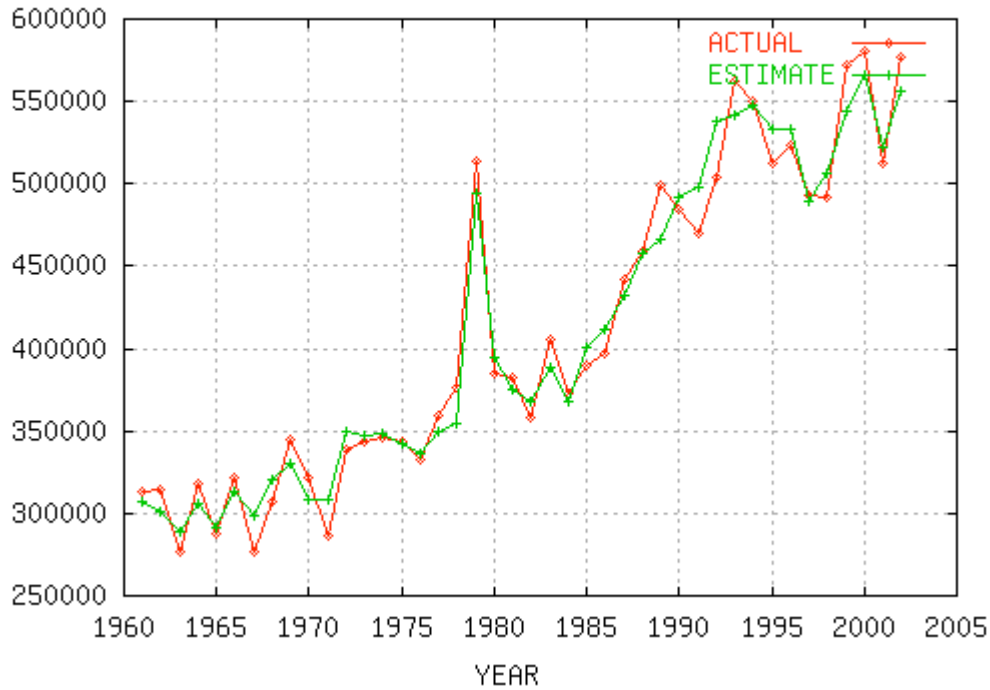

Figure 17: ***California fresh tomato production (in tons).***

Demand

The US demand for fresh tomatoes has been modeled using the Almost Ideal Demand System. The system estimates simultaneously the demand for four of the major vegetables: tomatoes, lettuce, carrots and cabbage. The approach assumes that consumers are price takers and that consumers of the four goods have preferences that are weakly separable. The assumption of weak separability permits the demand for a commodity to be written as a function of its own price, the price of substitutes and complements, and group expenditure.

The almost ideal demand system is

$$w_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(\frac{x_i}{P_t^*}) + \varepsilon_{it} \tag{17}$$

where w_i represents the ith budget share of commodity i, p_j denotes the jth price of the jth good, x_t is group expenditure for the particular set of commodities (fresh tomatoes, carrots, lettuce, and cabbage), and P_t^* is a translog deflator and is given by

$$\ln P_t^* = \alpha_0 + \sum_k \alpha_k \ln p_k + (1/2)\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j .$$

Adding-up restrictions require that $\sum \alpha_i = 1$, $\sum_i \gamma_{ij} = 0$, and $\sum_i \beta_i = 0$. Homogeneity requires $\sum_j \gamma_{ij} = 0$, and symmetry requires $\gamma_{ij} = \gamma_{ji}$. These conditions hold globally, that is, at every data point.

The demand functions for tomatoes, lettuce and carrots were estimated by maximum likelihood estimation methods, and the results were recovered for the cabbage equation from adding up. The estimated elasticities of demand with respect to prices and income have been calculated from the regression coefficients. The income elasticity is given by

$$\eta_i = 1 + \beta_i / w_i$$

and the price elasticities are given by

$$\varepsilon_{ij} = -\delta_{ij} + [\gamma_{ij} - \beta_i(\alpha_j + \sum_k \gamma_{ik} \ln p_k)] / w_i$$

where $\delta_{ij} = 1$ if $i = j$, zero otherwise.

. The data are for the time period, 1981-2004 and prices are retail prices. The almost ideal demand system was estimated with a first-order autoregressive process ($\hat{\rho} = 0.77$ with an associated asymptotic standard error of 0.08). The estimated elasticities for the fresh vegetable subsystem are given in Table 1.

Table 1: Estimated elasticities calculated using the AIDS estimation.

	Estimated AIDS Elasticities			
	Tomato	Carrots	Lettuce	Cabbage
Tomato	**-0.32*** (0.10)**	-0.03 (0.09)	-0.07 (0.05)	-0.002 (0.02)
Carrots	-1.51* (0.78)	**-0.53* (0.21)**	-0.48 (0.37)	-0.33 (0.45)
Lettuce	-0.19*** (0.05)	-0.09 (0.13)	**-0.71*** (0.20)**	-0.16 (0.72)
Cabbage	-0.01 (0.04)	-0.17 (0.25)	-0.98 (0.88)	**0.12 (0.55)**
Income	0.89*** (0.14)	1.44*** (0.24)	0.96*** (0.30)	1.06** (0.41)

a) ***: Significant at the .01 level. **Significant at the .05 level. *Significant at the .10 level.
b) Reported standard errors are bootstrap standard errors computed using a subroutine in SAS written by Dr. Barry Goodwin.

The own price elasticity of tomatoes is estimated to be -0.32, which is highly statistically significant. Therefore demand for fresh tomatoes is relatively inelastic with respect to changes in retail prices. The own-price elasticity of carrots is -0.53 and for lettuce it is -0.71. The estimate of the own-price elasticity of cabbage is positive at 0.12, which is counterintuitive. This finding, however, is not statistically significant. The estimated second-stage expenditure elasticities are all positive and range in values from 0.89 to 1.44. In all cases the expenditure elasticities are statistically significant. All of the cross prices elasticities are negative indicating that the four fresh vegetables are complements. Only the complementarities between tomato quantity with carrot and lettuce prices are statistically significant.

Conclusions

Models for both fresh and processed tomatoes were developed and estimated. An almost ideal demand subsystem was estimated for four fresh vegetables that included tomatoes, carrots, lettuce, and cabbage. The second-stage own-price elasticities were all inelastic except for cabbage which was unexpectedly positive. The conditional expenditure or income elasticites varied from 0.89 for fresh tomatoes to 1.44 for carrots. All of the cross-price elasticities were negative indicating that the four fresh vegetables are

gross complements. A plausible explanation for this is that the four commodities are used in salads, especially given that no significant complementarities were found with respect to fresh cabbage.

Ordinary least squares and instrumental variable techniques were used to obtain estimated partial adjustment acreage functions of processing tomatoes. The estimated short-run own-price elasticity estimates were between 0.47 and 0.41. Chow tests confirmed a possible structural break in the acreage function for processed tomatoes around 1988. One possible explanation of the break is the increase use of contracts around this time period.

Estimated own-price elasticities for processed tomatoes in the production function varied between 0.45 and 0.55. Producers respond to prices increases in a positive manner, in accordance with theory.

With respect to demand for processing tomatoes, the own-price elasticity was estimated to be -0.18 and the cross-price estimated elasticity of tomato paste on processing tomatoes was 0.16. Thus, as the price tomato paste increases the derived demand for processed tomatoes increases, as expected.

For the second period the estimated own-price elasticity in the acreage equation was 0.23 indicating that producers respond positively to increases in prices. The short-run elasticity of fresh tomato production with respect to price was 0.22 prior to 1987 and 0.27 after 1987. Thus, through out the sampling period, the own-price elasticity in the fresh tomato production function was found to be inelastic.

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SUMMARY AND FUTURE RESEARCH

This research project developed acreage, yield, production, and demand models for seven California commodities. Both single and system-of-equations models were developed and estimated. The primary findings are: (1) Domestic own-price and income elasticities of demand for California commodities are predominantly inelastic implying that shocks on the supply side will have large impacts on prices and subsequently on revenues. (2) On the supply side producers are responsive to prices. (3) Estimated supply and demand elasticities are important to policy makers in order to measure welfare gains and losses due to various changes in economic conditions. (4) An almost ideal demand subsystem for four fresh vegetables were estimated. Fresh tomatoes, carrots, lettuce, and cabbage were found to have conditional inelastic own-price elasticities (with the exception of cabbage). All had positive conditional expenditure elasticities. In addition, all four fresh vegetables were gross complements. This result is plausible given that the four vegetables are used in salads. And (5) Better data on prices, acreage, demand, production, yields, and other information would enable better analysis of economic conditions facing California producers and consumers. This report has undated the data on acres, prices and yields in a consistent manner. However, additional updating should be continued in the future.

Estimated own-price, cross-price and income elasticities were obtained for the demand and supply functions for six of the top twenty California commodities according to value of production in 2001 (see, Johnston and McCalla, p. 73). The six commodities are: almonds, walnuts, cotton, alfalfa, rice, and processing tomatoes. The report also includes fresh tomatoes. Fresh tomato per capita consumption is increasing relative to

the consumption of processing tomatoes. Future work will include grapes-wine, table, and raisins, citrus fruits, and other commodities.

Future research will examine in more depth the problems of heterogeneity and aggregation. Aggregation across consumers, unless strong conditions hold, results in aggregation biases. These can affect the elasticity estimates. There are different approaches to the problem. The distributional approach incorporates distributional changes in consumer income over time as well as distributional changes in consumer attributes. Future work will also address in more depth the issues involved with the export markets, the role of inventories and stocks, and welfare measures of consumers and producers due to various changes. The role of exports are becoming more important as trade barriers are broken down. Domestic producers find themselves players in global competitive markets.

All of the commodities studied in this report require irrigated water and have exhibited expanded acreage. Processing tomatoes production, for example, has grown to about 300,000 acres currently with 64% grown in the San Joaquin Valley. Acreage of almonds in California rose steadily over the years 1970-2001. In 2001 there were over 500 thousands acres in production. Walnut acreage is about 200,000 acres in California in 2001. Alfalfa hay acreage in California averaged about a million acres per year during the past 30 years. In 2002 there were about 700,000 acres planted to cotton in California. A summary of the harvested acres and the total value of production for the commodities examined in this report is given in Table 1.

Table 1. Harvested Acres and Total Value of Production in 2003

	Harvested Acres	Total Value of Production (in $1000)
Almonds	550,000 (bearing acres)	1,600,144
Walnuts	213,000 (bearing acres)	374,900
Cotton	694,000	753,355
Alfalfa	1,090,000	709,590
Rice	507,000	405,974
Tomatoes		
Processing	274,000	529,214
Fresh	34,000	366,180

Source: California Department of Food and Agriculture.

A concise summary of the models and estimated supply and demand elasticities for each commodity are given Tables 2 and 3 below.

Table 2. Estimated Supply and Demand Elasticities for California Commodities

I. Single-Equation Models [a]

Commodities:	**Supply Response (Own-Price)**		**Domestic Demand**	
	Short-Run	**Long-Run**	**Own-Price**	**Income**
Almonds	0.12	12.0	-0.48	0.86
Walnuts	0.02	0.08	-0.26	1.21 (0.43) [b]
Alfalfa	0.35-0.66 [c]	1.06	-0.11	1.74 [d]
Cotton	0.53	0.73	-0.68	NA
Rice	0.23	0.27	-0.08	0.74
Tomatoes				
Fresh	0.27 [e]	0.40	-0.25	0.89
Processing	0.41	0.69	-0.18	0.86

[a] The supply-response elasticities were taken from the estimated acreage equation. Various models were estimated and the reported elasticities represent, in the authors' judgment, the most reasonable estimates based on model specifications and efficient econometric estimators.

b. The value in parenthesis represents the income elasticity post 1983 after structural changes had occurred in the industry.

c. The elasticity varied between 0.35 and 0.66 based on different specifications.

d. The demand for alfalfa hay is a derived demand. The figure reported is the elasticity based on the number of cows in the dairy industry.

e. Post 1988.

Table 3. Estimated Supply and Demand Elasticities for California Commodities

II. System of Equations Models

Commodities	Supply Response (Own-Price)		Domestic Demand	
	Short-Run	**Long-Run** [a]	**Own-Price**	**Income**
Almonds	0.24	0.67	-0.69	1.43
Walnuts	0.15	0.19	-0.48	1.01
Cotton	0.46	15.33	-0.95	-0.05
Rice	0.45	0.72	-0.36	0.33
Tomatoes [b]				
Fresh	NA	NA	-0.25 [c]	0.89
Processing	NA	NA	NA	NA

[a] Based on killing off the lags in a single equation in the system.
[b] The fresh tomato elasticities are based on an AIDS model. NA indicates that a system for these commodities was not estimated.
[c] Based on an almost ideal demand fresh vegetables subsystem.