

# Price Formation in the California Winegrape Economy\*

Dale Heien<sup>a</sup>

## Abstract

This paper presents a theory of price determination for winegrapes in California. As the California wine economy developed, winegrape contracts took on a role as one of the centerpieces of this transformation. The theory is presented and it is shown how two important factors, weather and financial uncertainty, served to shape the contracts. Hence, long term planting contracts for new vineyards, specifying the price, helped ameliorate the uncertainty to growers. Similarly, shorter contracts played a similar role for established vintners. The model deals with two types of growers: those with contracts made well before the year in question and those who will sign a contract in the Spring of the year of harvest. This paper hopes to illuminate these elements and their interaction. The model is then empirically estimated and tested. (JEL classification: K12, Q11)

## I. Introduction

The manner in which price determination takes place in agriculture markets often differs from the static paradigm of instantaneous adjustment of supply and demand. Transparent and well organized grain and livestock exchanges facilitate the equilibration of supply and demand, while price determination in some areas of agriculture occurs under conditions of asymmetric information, imperfect competition, and uncertainty. Although there is considerable literature on price determination for grains,<sup>1</sup> livestock<sup>2</sup> and, to some extent, vegetables,<sup>3</sup> comparatively little research has been done on fruit price formation.

This paper deals with price formation for winegrapes. In terms of cash receipts, grapes are the largest fruit crop in the U.S. with over three-fourths of these receipts coming from

\*My thanks to colleagues Rachael Goodhue and Richard Sexton, to the referees and Karl Storchmann, all of whom gave useful insights and comments.

<sup>a</sup>University of California Davis, Department of Agricultural and Resource Economics. Email: dale@primal.ucdavis.edu.

<sup>1</sup>See, for example, Williams and Wright (1991) for models of storable commodity price determination.

<sup>2</sup>See, for example, Brandt and Bessler (1981) and Chavas and Holt (1991).

<sup>3</sup>See, for example, Sexton and Zhang (1996) and Hammig and Mittelhammer (1980) and on celery by Shonkwiler and Pagoulatos (1980) and Taylor and Kilmer (1988).

winegrapes. Winegrapes are a high value crop with relatively steep entry costs. Since time is required to recoup large initial investments, price variation and future price levels are major concerns. Both of these concerns are often handled in contracts.

Prices in the California winegrape economy do not adjust instantaneously to supply and demand. This failure to adjust within any given crop year arises out of the interaction of two characteristics of the winegrape economy: (1) the widespread use of long-term contracts between growers and wineries and, (2) the impact of weather and disease on the grape crop level. The contracts, to some extent, lock in current and future prices while the weather and disease determine crush levels. Hence, there is considerable latitude for a disconnect between actual crush levels and prices paid since contract prices are often based on expected crush levels and may be locked in for several years.

This independence was demonstrated in 1997 in Napa county. The quantity crushed of Cabernet and Chardonnay increased 43 and 51 percent, respectively, while grower prices increased 11 and 13 percent. Slightly increased bearing acreage augmented by ideal weather produced a bumper crop. While demand was increasing, it is difficult to imagine a demand shift sufficient to warrant these increases in price, given the increase in quantity crushed. Wineries that were locked into long-term contracts, were not able to take advantage of the large crop by paying lower prices. This occurred because the prices were specified in long-term contracts long before it was realized that the crop would be relatively large.<sup>4</sup>

The purpose of this paper is: (1) to describe the price formation process for winegrapes and its unique characteristics; (2) to model this process analytically; and (3) to test several hypotheses regarding price determination. To achieve these goals the paper uses annual data on three winegrape varieties (Cabernet Sauvignon, Chardonnay, and Merlot) from three different areas (North Coast, Central Coast, and Central San Joaquin Valley).

## II. The Winegrape Market: Institutional Setting

In California there are roughly 12,000 grape growers and 600 wineries. There is no organized winegrape market. Although there are two grape brokerage houses most contracts are formed through personal contact between growers and wineries. A large proportion of these growers are under long-term contracts. A recent survey showed that fifty-one percent of growers had contracts of three years or greater while thirty-six percent had one year contracts.<sup>5</sup> As a result, the majority of growers are removed from the year to year price negotiation process due to the multiyear nature of their contracts. Data on prices paid the previous year is published in the *Grape Crush Report* each March. These prices play an important role as the escalator in many long-term contracts. Long-term contract base prices are often “moved” by the percentage change in the previous year’s crush district average

<sup>4</sup>Many of these were planting contracts which typically run ten years.

<sup>5</sup>See Goodhue, Heien, and Lee (1999). In addition to the fifty one percent, there are those with two-year contracts and others waiting to renew multiyear contracts.

price.<sup>6</sup> Arrangements such as these tend to make price behavior independent of current year market conditions.

The remaining growers are in reality spot market participants although they will eventually make a contract (oral or written) for the coming harvest. Growers in the spot market generally make contracts in late Spring or early Summer for that Fall's crop. At this point in time information on Spring weather (i.e. frost or excessive heat) and its impact on crop size is more clearly understood. Because of this weather variability long term contracts do not specify the amount to be crushed in terms of tons. Eighty percent of California grape contracts do not even specify a maximum tonnage (Goodhue, Heien, and Lee, 1999). Due to yield variability growers are reluctant to enter maximum tonnage contracts.

Wineries enter into long-term contracts and predict quantity on the basis of the expected yield with the understanding that some years will be short and others long. Wineries are in a better position to deal with this variability because it is easier for them to expand storage, e.g., new tanks can be added and aging wines can be marketed sooner or later. Growers desire long-term contracts to obtain bank financing, deal with future price uncertainty, and avoid unfamiliar marketing tools. Wineries, on the other hand, need contracts because they need to be assured of a steady supply of grapes at a known quality, without having to deal with the problems associated with growing grapes.

In most contracts it is either explicitly stated or implicitly assumed that all grapes produced on the stated acreage will be purchased by the winery.<sup>7</sup> Hence, with supply relatively inelastic in the short-run, one way to model price determination is via a price dependent demand curve. Such a model is useful when supply is inelastic and markets adjust rapidly to demand shifts through price changes. For winegrapes such is partially, but not wholly, the case. The important intervening factor is, of course, the presence of multi-year contracts.

Contracts usually make some mention of the acreage covered, but seldom specify an exact tonnage. This omission is due to the difficulty in forecasting the crop size as discussed above. For contracts over one year, the best estimate of tonnage will be based on (known) bearing acreage and some notion of expected yield. This implies that quantity demanded is based on expected harvest, i.e., bearing acreage times expected yield.<sup>8</sup> For those growers with long term contracts the quantity demanded is the expected crop level. For those selling in the spot market the actual quantity is the relevant quantity because at the time they enter into a contract the actual level is more accurately known. Hence, the weighted average crush district price will depend on both spot (one year contract) and long-term contract prices.

<sup>6</sup>The California winegrape economy is divided into 17 crush districts. Some districts are unique counties while other districts are comprised of several counties.

<sup>7</sup>The survey by the Agricultural Issues Center showed that only 22 percent of winegrape contracts stipulated a maximum tonnage (Goodhue, Heien, and Lee, 1999).

<sup>8</sup>Expected yields were estimated by regressing the yield on a time trend. While there are many economic factors affecting yields, these effects are of a long-run nature and are essentially exogenous in the short-run. Weather and disease induced effects on yields are current, but also exogenous to economic variables.

### III. Winegrape Price Formation: Model Formulation

This section uses the institutional setting described above to specify a grape price formation relationship. It is only one of several relations needed to construct a complete model of the winegrape sector. However, due to the above mentioned disconnect between supply and demand, excess demand relations provide an interesting vehicle to attempt to model the disequilibrium. The model assumes there are two distinct groups of growers: spot market operators, i.e., individuals with one year contracts, and longer term contract growers. Winegrape contracts typically run three to five years with planting contracts up to ten years. Renewal of these contracts is typical, so a hiatus forcing contract growers into the spot market is not typical. Hence, the price formation relation here will consider both scenarios and incorporate them in a single relation which determines market price.

Begin by considering the price formation relation for a grower who has a long-term contract. Often, there is a reference price, frequently last year's average return for that district (e.g. North Coast) and variety (Cabernet), which "moves" the price the grower receives. Such a relation can be specified as

$$cp_t = \beta_0 + \beta_1 dp_{t-1} + \beta_2 (S_{t-1} - S_{t-1}^*), \quad (1)$$

where  $cp$  is the contract price,  $dp$  is the crush district average price for that variety,  $S$  is the actual crush level and  $S^*$  is the expected crush level. The lagged district price reflects the use of last year's district price as an escalator for contract price movement as discussed above. The latter term reflects contract price re-negotiation considerations which occur in the year following the current crush year. If actual crush exceeds expected crush growers' revenues will be greater than expected under the contract.<sup>9</sup> This provides a bargaining chip for the winery, especially if the contract comes up for renewal the next year. Conversely, if actual crush falls short of expected crush, the growers will have an argument for higher contract prices.

Spot prices will be determined by the supply and demand for grapes not under contract. The price adjustment process for these spot market grapes is in the tradition of excess demand relationships.<sup>10</sup> When demand is based on expected crush there will be unfulfilled expectations when the actual crop differs from the expected one. In any given crop year, the spot market reduces this imbalance to some extent. Hence, the corrective mechanism must be specified for the spot market as well. Since we assume that crush levels are relatively inelastic and known to some extent at this time, the excess demand relation is given by

$$sp_t = \gamma_0 + \gamma_1 (D_t - S_t) + \gamma_2 (S_{t-1} - S_{t-1}^*), \quad (2)$$

<sup>9</sup>Unfulfilled demand expectations do not seem to have the same effect. This may be due to the fact that wine is often marketed longer than one year after crush. Also, marketing problems may be considered more in the domain of the winery, wholesalers and retailers rather than a shared problem between growers and wineries.

<sup>10</sup>See Baumol (1959, pp. 82–135) and Samuelson (1961, pp. 257–284).

where  $sp$  is the spot price and  $D$  is the expected demand for wine. Again, the term  $S_{t-1} - S_{t-1}^*$  is used as an indicator of market over/under-supply carried forward from last year. As such, this difference is a relevant part of this year's demand or supply. Last is the crush district average price equation,

$$dp_t = w \cdot cp_t + (1 - w)sp_t, \quad (3)$$

where it is assumed that the proportion of the crop going to the spot market,  $w$ , is fixed over time.<sup>11</sup> Aggregating over both classes of growers gives the crush district average price determination relationship. Substituting (1) and (2) into (3) gives

$$dp_t = \alpha_0 + \alpha_1 dp_{t-1} + \alpha_2 (S_{t-1} - S_{t-1}^*) + \alpha_3 \phi Y_t - \alpha_4 S_t \quad (4)$$

where

$$D_t = \phi Y_t$$

$$\alpha_1 = w\beta_1 > 0$$

$$\alpha_2 = w\beta_2 + (1 - w)\gamma_2 < 0$$

$$\alpha_3 = (1 - w)\gamma_1 > 0$$

$Y$  is real Personal Consumption Expenditures which represents demand effects and  $\phi$  is a constant which converts dollars to tons.

#### IV. Empirical Estimation and Results

Annual data on winegrape prices and crush tonnage for the three main grape growing regions of California was obtained from the *Grape Crush Report* (California Department of Food and Agriculture, 1981a–2005a). The period covered was 1980–2004. The regions with crush districts in parenthesis are: North Coast (Lake, Mendocino, Napa and Sonoma counties); Central Coast (Alameda, Contra Costa, Monterey, San Luis Obispo, Santa Barbara, Santa Clara and Santa Cruz counties); and Central San Joaquin Valley (Merced, Sacramento, San Joaquin, Stanislaus, and Yolo counties). Annual data on bearing acreage was obtained from corresponding issues of *California Grape Acreage* (California Department of Food and Agriculture, 1981b–2005b).

The *Grape Crush Report* contains data on price received, quantity crushed and other information on every load of grapes crushed in California. For each Crush District a quantity weighted average price (i.e. a “unit value” index) is created. These unit value indices, technically called Average Grower Returns, were aggregated into unit value indices for each of the three regions given above. These are the prices given by (4) and are the dependent variable for the model to be estimated. This price data does not distinguish between contract grapes and those sold in the spot market.

<sup>11</sup>Data does not exist on  $w$  (the proportion of the crush coming from spot market growers).

In California all loads of grapes to be crushed are required to be weighed at a state designated weigh station. The weight of the grapes, the price of the grapes, the buyer and seller, and various other data called Brix Factors are collected. These Brix Factors include incentives and penalties, weight loss in late harvest grapes, limits for acceptable grapes, and various other information. This data is not a sample. It covers all grapes crushed in California (for example 1,400 loads of Cabernet in Napa county). Each and every “weighed in load” appears in the crush report. Since the law requires that all grapes to be crushed must be weighed by state officials all loads will be counted. Hence, much useful information is available on each crop. However, the information does not link to any grower information such as education, age, acres, etc.

The varieties selected are Cabernet Sauvignon, Chardonnay and Merlot. Hence, nine regressions are estimated to test the theory of price determination presented above. All of these grapes are prominent wine varieties and do not constitute blending grapes. Also, none of these varieties are suitable for the concentrate market. The expected crop is obtained by multiplying actual bearing acreage by the expected yield. The expected yield is obtained by regressing the actual yield on time. Yields have increased gradually over time due to improved rootstock, better equipment and closer row spacing. The estimated yield from the regression is then taken as the expected yield. Table 1 gives the regression coefficients for these yield functions.<sup>12</sup> The regression residuals will capture the unexpected effects. The yield regressions (Table 1) generally show the time trend to be significant. The coefficient of variation ( $\sigma/\mu$ ) averaged .195, somewhat large for time series data indicating considerable variation in yields.

*Table 1*  
**Yield Regression**  
**(Dependent variable: yield (tons per acre)<sup>1</sup>)**

<i>Region</i>	<i>Cabernet Sauvignon</i>			<i>Merlot</i>			<i>Chardonnay</i>		
	<i>N</i>	<i>C</i>	<i>C SJ</i>	<i>N</i>	<i>C</i>	<i>C SJ</i>	<i>N</i>	<i>C</i>	<i>C SJ</i>
Time	0.044	0.151	0.387	0.052	0.119	0.513	0.105	0.149	0.375
<i>t</i> -ratio	(1.50)	(4.94)	(6.52)	(1.24)	(2.64)	(5.01)	(3.81)	(4.41)	(6.59)
Adj. <i>R</i> <sup>2</sup>	0.072	0.594	0.722	0.033	0.272	0.602	0.457	0.059	0.726
DW	2.23	1.15	1.16	2.13	1.06	1.58	1.75	1.51	2.08
Regression standard deviation	0.60	0.62	1.21	0.84	0.84	2.07	0.56	0.69	1.15
Mean dependent variable	3.66	3.67	7.34	4.32	3.81	7.24	4.21	3.61	7.15
Coef. of variation	0.16	0.17	0.16	0.19	0.22	0.29	0.13	0.19	0.16

<sup>1</sup>Crush divided by bearing acreage.

<sup>12</sup>The yield regressions were estimated in both the linear and log-linear form. Based on the MacKinnon-White-Davidson test the linear form was chosen.

The statistics in Table 2 which present the price determination relationships are of much greater interest. All coefficients have the correct sign with the exception of  $\alpha_3$  for Central Coast Merlot which has a  $t$ -ratio of .33. The overall  $F$ -statistic is significant in all nine cases. The lagged price coefficients'  $t$ -ratios exceed 2.0 in all regressions except one. Table 3 provides a summary of the statistics generated by the model. The top row labeled "All Variables" gives the average  $t$ -statistics for all four variables by variety and by region. The next four rows give the average  $t$ -statistic first by variety and then by region for each of the four slope coefficients. Since there is a lagged dependent variable the Durbin-Watson statistic is biased toward 2.0. Hence the "Durbin  $h$ " statistic was used to test for autocorrelation.<sup>13</sup> Table 4 gives the short and long run elasticities of price with respect to expenditure and crop yield (expected crush).

Table 2  
Price Determination Relations  
(Dependent variable: price<sup>1</sup>)

Region	Cabernet Sauvignon			Merlot			Chardonnay		
	N Coast	C Coast	C SJ	N Coast	C Coast	C SJ	N Coast	C Coast	C SJ
Lagged endogenous	0.881 (5.51)	0.715 (4.64)	0.506 (2.16)	0.836 (4.64)	0.597 (2.84)	0.501 (2.52)	0.884 (3.77)	0.671 (2.95)	0.415 (1.47)
Real personal consumption expenditures	0.125 (2.58)	0.109 (2.88)	0.208 (2.20)	0.093 (1.32)	0.121 (1.49)	0.171 (3.13)	0.078 (1.17)	0.13 (1.71)	0.073 (1.14)
$(S_{t-1} - S_{t-1}^*)$	-0.0082 (-3.13)	-0.013 (-2.51)	-0.0058 (-0.91)	-0.0215 (-2.02)	-0.061 (-1.35)	-0.0082 (-0.82)	-0.0041 (-1.75)	-0.0059 (-1.36)	-0.0006 (-0.16)
$S$	-0.0064 (-2.54)	-0.0042 (-1.16)	-0.0059 (-1.59)	-0.0034 (-1.20)	0.003 (0.33)	-0.0027 (-1.71)	-0.0013 (-0.56)	-0.0024 (-0.96)	-0.0007 (-0.46)
Adj. $R^2$	0.96	0.95	0.77	0.97	0.94	0.95	0.68	0.74	0.41
Durbin's $h$	0.90	0.43	1.52	2.13	1.17	2.44	5.59	2.93	3.55

<sup>1</sup>Crush divided by bearing acreage.

Table 3  
Average  $t$ -statistics and Adjusted  $R^2$  by Region and Variety

	By variety			By region		
	Cabernet	Merlot	Chardonnay	N Coast	C Coast	C SJ
All variables	2.65	1.95	1.46	2.52	2.01	1.61
Lagged price	4.64	3.33	2.73	4.64	3.47	2.05
Real personal consumption expenditures	2.55	1.98	1.34	1.69	2.03	2.16
$(S_{t-1} - S_{t-1}^*)$	-2.18	-1.40	-1.09	-2.30	-1.74	-0.63
$S$	-1.76	-1.08	-0.66	-1.43	-0.81	-1.25
Adj. $R^2$	0.89	0.95	0.61	0.87	0.88	0.71

<sup>13</sup>For cases when the Durbin  $h$  requires the square root of a negative number the Breusch-Godfrey LM is the appropriate test. This was the case for Chardonnay in the Central San Joaquin. The LM Chi-squared statistic is 3.55 for this case.

*Table 4*  
**Long and Short Run Elasticities: All Regressions**

	<i>N Coast</i>	<i>C Coast</i>	<i>C SJ</i>
<i>Cabernet Sauvignon</i>			
Expenditure			
Short-run	0.41	0.57	1.59
Long-run	3.43	2.01	3.22
Crop yield			
Short-run	-0.31	-0.14	-0.38
Long-run	-2.61	-0.49	-0.75
<i>Merlot</i>			
Expenditure			
Short-run	0.29	0.51	1.15
Long-run	1.71	1.24	2.50
Crop yield			
Short-run	-0.21	-0.48	-0.46
Long-run	-1.98	-1.44	-0.78
<i>Chardonnay</i>			
Expenditure			
Short-run	0.24	0.48	0.45
Long-run	2.05	1.45	0.78
Crop yield			
Short-run	-0.09	-0.12	-0.05
Long-run	-0.75	-1.03	-0.08

Elasticity of price ( $dp$ ) with respect to PC expenditure ( $Y$ ): SR & LR elasticities. Elasticity of price ( $dp$ ) with respect to crop yield ( $S$ ): SR & LR elasticities.  $dp$  is crush district price defined by (3); long run is when all variables in (4) are at current time period  $t$ .

## IV. Conclusion

This paper sets out a model of price determination for winegrapes. Grapes are harvested once a year and the crop level is difficult to forecast before late Spring or early Summer. For reasons discussed above, long-term contracts frequently arise between wineries and growers. These contracts specify forward prices or the mechanism by which they are to be computed. The price model given here incorporates the price determination process for growers with contracts as well as the process for spot market growers. The combined market price determination process gives current price as a function of the last year's price, the current excess demand and the lagged excess supply. Lagged price represents the fact that many contracts call for annual updating of the current price based on last year's district average price. Excess demand is specified as the difference between current demand (represented by real personal consumption expenditures) and the current crush. Excess supply, the difference between last year's actual crush and last year's expected crush, is termed a contract renegotiation mechanism.

Table 2 reports the effect of lagged prices. It shows that for any given variety the biggest effect is in the relation for the North Coast with the Central Coast always second and Central San Joaquin smallest. This larger lagged effect for the North Coast reflects the



greater use of escalator price contracts by North Coast growers. Evidence from the winegrape contract survey showed that contracts with a reference price were most prevalent in the Coastal regions, further verifying the model results. Reference price contracts use the previous year's crush district average price as a basis for a price adjustment in the current year. The AIC survey (Goodhue, Heien, and Lee, 1999, p. 3) showed the following percentages of contracts with reference prices: North Coast – 50%; Central Coast – 41%; and Central Valley – 34%.

This more frequent escalator price usage might also be due to a more competitive environment. Napa county, a North Coast crush district, has over 300 of the states 600 wineries. Also, a strong lagged effect will mean that current demand or supply shocks will play a smaller role than relations with smaller lagged price coefficients. The short run elasticity of price with respect to real income is inelastic in seven of the nine regressions. However, the long run elasticities are substantially greater than one in all cases except one.

In terms of significance, the demand effects and price renegotiation effects are generally second to the lagged price effects with the current supply effect generally last. The effect of current supply is due to two factors. First, while it is likely of considerable impact for spot market prices, it is true that there are fewer spot market growers.

Second, the results also confirmed the hypothesis that contracts have more price inertia in areas where there is more competition and hence a greater desire to have good grower-winery relations by smoothing price realizations. This was confirmed by the fact that the coefficient on the lagged dependent variable in the three areas declined monotonically by level of concentration, percentage of contracts with price specification, and by grape price over the three areas considered. As the point estimates declined there was an accompanying decline in the *t*-ratios.

The results show that specification of price determination relations for the winegrape sector should include knowledge of the impact of contracts and their provisions as opposed to static instantaneous market clearing models. In areas where there is more competition and higher valued grapes, these contractual provisions are more significant. Lastly, inertia in price determination was found to have a greater effect in the areas where there is less buyer concentration. The inertia reflects the fact that prices adjust more slowly in these regions because contracts which state prices in advance of knowledge of crop levels are more prevalent.

An alternative rationale for this model is to envision a market with two price regimes. The first is a competitive market with spot participants whose prices are determined solely by the equilibration of supply and demand. The second is a market with long-term contracts with prices set equal to last year's market average. The final market price will be a weighted average of the two, the weights depending on the relative sizes of each class of growers. Such a model is a (stable) first order difference equation.

A second explanation is risk incidence, which is very similar to the efficiency wage theory. Prices based on expected crop reduce income risk to the grower. This occurs because,

presumably, wineries are less risk averse than growers. They are less risk averse because: a) they are bigger; b) perishability of crop is less a problem for wineries; c) wineries are more diversified than growers; d) wineries have better bank connections; e) growers face uncertainty due to weather, disease, and labor availability. Also, it is costly to search a heterogeneous market when a product is perishable. Custom crushing has shifted this balance somewhat since growers can have their crop crushed, vinted, and marketed at the facility.

There are several explanations which are consistent with multiperiod profit maximization. Wineries pay a premium in the form of a known price over time to insure future supply from these growers. This is analogous to an employee who values security of employment. Contracts also provide a mechanism for better viticultural practices. Also, consumers, and hence wineries, want this higher quality in the wine they drink and make.

The results indicate that in markets with fewer buyers, supply and demand adjust faster than in markets with many buyers. This seeming contradiction is resolved when one considers the dynamics of the market. Wine is not a homogeneous product. Reputation, product differentiation, and quality are extremely important. Hence, in order to insure an adequate supply of grapes over time, wineries must be far-sighted in their relations with growers. Financial market models are also adaptable since disequilibrium is often a financial phenomenon. Taylor (1980) has presented a model of "Over-lapping Contracts" which for macro models generates cyclical patterns similar to those found in GNP. Since winegrapes have cyclical patterns due to planting lags, this model might be useful in understanding agricultural markets also.

## References

- Goodhue, R., Heien, D., and Lee, H. (1999). Contract use in the California winegrape economy. *Agricultural Issues Center Issues Brief*, 11, December 1999.
- Baumol, W.J. (1959). *Economic dynamics*. 2nd ed., London: Macmillian Co.
- Brandt, J.A. and Bessler, D.A. (1981). Composite forecasting: an application with U.S. hog prices. *American Journal of Agricultural Economics*, 63, 135–140.
- California Department of Food and Agriculture (1981a–2005a). *Final Grape Crush Report*. Sacramento.
- California Department of Food and Agriculture (1981b–2005b). *California Grape Acreage*. Sacramento.
- Chavas, J.P. and Holt, M.T. (1991). On nonlinear dynamics: the case of the pork cycle. *American Journal of Agricultural Economics*, 73, 819–828.
- Hammig, M.D. and Mittelhammer, R.C. (1980). An imperfectly competitive market model of the U.S. lettuce industry. *Western Journal of Agricultural Economics*, 5, 1–12.
- Heien, D.M. (1977). Price determination processes for agricultural subsector models. *American Journal of Agricultural Economics*, 59, 126–132.
- MacKinnon, J., White, H., and Davidson, R. (1983). Tests for model specification in the presence of alternative hypothesis; some further results. *Journal of Econometrics*, 21, 53–70.

- Samuelson, P.J. (1961). *Foundations of Economic Analysis*. Cambridge, Mass.: Harvard University Press.
- Sexton, R. and Zhang, M. (1996). A model of price determination for fresh produce with application to California iceberg lettuce. *American Journal of Agricultural Economics*, 78, 924–934.
- Shonkwiler, J.S. and Pagoulatos, E. (1980). A model of weekly price discovery for Florida celery. *Southern Journal of Agricultural Economics*, 12, 113–118.
- Taylor, J.B. (1980). Aggregate dynamics and staggered contracts. *Journal of Political Economy*, 88, 1–23.
- Taylor, T.G. and Kilmer, R.L. (1988). An analysis of market structure and pricing in the Florida celery industry. *Southern Journal of Agricultural Economics*, 20, 35–43.
- Williams J. and Wright, B. (1991). *Storage and Commodity Markets*. Cambridge, U.K.: Cambridge University Press.