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Certification and Supply Response in the Organic Lettuce Market

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The impact of supply relationships and certification programs on the organic lettuce market is examined using an integrated partial adjustment and asymmetric supply reponse model. Costs associated with organic certification, production, and marketing have not restricted producers' abilities to respond to price signals. Organic growers allocate output between certified and noncertified markets in response to changing price premiums. Estimates of short-run supply elasticities indicate that organic lettuce growers are more responsive to price changes than producers of nonorganic lettuce. Long-run elasticity has increased since 1988, a change that coincides with the market entry of larger producers.

Key words: asymmetric adjustment costs, lettuce market, organic certification, partial adjustment, price premiums, supply response.

Introduction

Organic certification programs may be a source of asymmetry in the supply of organic produce as evidenced in the market for organic lettuce. Farmers' ability to adjust quantity of organic produce supplied to a desired output level depends on the costs of making adjustments in individual marketing and productive assets. The responsiveness of organic producers to changes in market conditions depends on establishing and maintaining individual marketing networks as well as the value of production assets required to attain and maintain organic certification. Increased capacity added in an expansionary period may constrain farmers to supply the same quantity in a contractionary period if there are asymmetric adjustment costs. Capacity expansion to bring more product to the market may be in the form of either production assets or marketing assets.

Marketing assets such as established transportation and information networks and a reliable market niche are particularly important for certified organic farmers who must rely on still evolving marketing channels for certified produce to coordinate supply and demand. Costs of adjusting harvested organic produce and marketing practices to changing market conditions are related to the value of individual marketing networks established by growers and the costs of maintaining them, as well as to the value of production assets acquired to produce organically. If the adjustment costs of switching back and forth between the certified and noncertified markets are great enough, we would expect to see asymmetry in supply for the organic market.

This article models supply in the market for organic romaine lettuce and tests for asymmetric behavior in output adjustment using a modified partial adjustment model and weekly farm level market data. Our approach is the first attempt to formally model the factors influencing marketing decisions and price patterns for organic produce utilizing

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a unique data set. The first section of the article provides a qualitative description of factors affecting the costs of output adjustments. The basic empirical model is then defined, followed by the development of model variables from market factors. Estimation results and calculated elasticities are followed by conclusions.

Cost Determinants of Supply Asymmetry

Profit-motivated farmers may find justifications for converting to certified organic production practices. The benefits compared to noncertified production include price premiums received for output and greater flexibility in marketing (certified producers may sell in both certified and noncertified markets). Adjustment costs for making the change are weighed against the benefits. In this section, we review the benefits and adjustment costs associated with this change and describe how they could contribute to asymmetry.

There are three categories of adjustment costs for certified organic farmers—transition and certification costs, distribution and information costs, and costs of maintaining a clientele or niche. While only transition and certification costs are unique to organic farmers, marketing costs are more limiting for certified than for noncertified farmers. The costs for marketing through certified channels may be substantially greater than for noncertified networks due to the immaturity of the existing organic market structure (Hall et al.).

Farmers entering the organic produce market face a sequential decision process. First they must decide whether to become certified, then they must decide how much to supply and where to market the output. Transition and certification costs relate to production decisions in the first step; distribution and information costs and costs of maintaining a market niche are associated with marketing in the second step. We review the adjustment costs associated with each in terms of their effects on possible asymmetry.

In California, "organic" agriculture is defined legally and practically in terms of restricted synthetic chemical use (California Health and Safety Code §26569.11–.17, California Certified Organic Farmers). The California Certified Organic Farmers (CCOF) offers a voluntary certification program. The CCOF program is based on use of approved materials and production practices, including soil management, recordkeeping, site inspections, and testing of fields and raw commodities (CCOF).

The main motivations for undertaking transition to certified organic farming historically have been lifestyle, ecological, and health concerns. In a survey of organic growers in 1988, Cook determined that newer entrants into the organic market tend to have large acreage and cite profit as a motivation for adoption of organic practices. For this group, yield, costs, and prices are important factors in the decision to become certified. We compare these factors for organic and nonorganic producers.

A review of the literature indicated that yield and cost differentials between organic and nonorganic production systems for lettuce are not as great as commonly believed. Stanhill compared organic to conventional yield for numerous studies in Europe and North America. The ratio of organic to conventional yield for an eight-year field experiment with lettuce was .76. Hall et al. found that both higher and lower yield estimates for organics have been observed for various crops. In a greenhouse trial comparing the effects of synthetic and organic nitrogen sources on lettuce, yield differences ranged from 26% higher to 68% lower for organic compared to nonorganic lettuce (Leclerc et al.). Since other management factors can improve the results in a field setting, there is no indication organically grown lettuce will necessarily have lower yields.

Hall et al. noted the main cost of the transition period from conventional to organic systems is the substantial human capital investment of learning how to manage the farm agroecosystem without chemical inputs. Knoblauch, Brown, and Braster commented that the main difference between established conventional and organic systems tends to be lower purchased input costs, but higher economic costs in terms of labor and interest charges on land use for organic systems. Existing production systems for lettuce limit the cost differential due to input substitution. In California, chemicals for insect and fertility management account for 11% of variable costs for nonorganic lettuce production in Monterey County and 9% in Fresno County, while labor for hoeing and thinning weeds accounts for about 9% in both counties (Livingston). Harvest is by hand. The relative labor-intensity of lettuce cropping means that the cost differential between organic and nonorganic production depends primarily on the choice of inputs (managerial or physical) substituted for synthetic chemicals. The relative cost difference may be small, perhaps even favoring organic production.

If costs and yields are roughly the same for organic and nonorganic lettuce, profit-oriented farmers considering conversion to organic systems will focus on certification costs and price premiums as decision variables. Certification costs for CCOF include a $100 initial application fee, inspection and laboratory fees, an annual assessment of .5% of gross sales, and annual chapter dues varying from $10 to $500 (CCOF). Farmers also incur economic costs for required recordkeeping and soil management practices. After January 1992, a three-year phase-in will be required. This imposes an opportunity cost on farmers who are decertified for violation of CCOF standards equal to the difference between organic and conventional net revenues for the three-year period required to regain certification.

Certified organic produce commands a retail price premium that may range from 25% to 35% of noncertified produce prices in supermarkets and up to 50% in health food stores (Food Institute). This range was verified in a report from the *Small Farm News* referenced in Knoblauch, Brown, and Braster. At the producer level, premiums of up to 250% more for organic products were cited, with the highest premiums for produce (Knoblauch, Brown, and Braster).

Continued optimism regarding price premiums may be warranted. Results of consumer studies by van Ravenswaay and Hoehn; Jolly; Goldman and Clancy; Ott, Misra, and Huang; and other studies reported by Lynch indicate a willingness to pay a higher price for fresh produce described variously as "grown organically," "grown without sprays," or sold "with no pesticide residues." Acceptable retail price premiums ranged from 5% to 100% across the studies, depending on base price and risk perception.

Flexibility in marketing, price premiums, and recertification costs represent opportunity costs that discourage voluntary decertification. If yields and costs do not differ greatly between organic and nonorganic farmers, it is unlikely that certified growers would voluntarily decertify their farms. Acreage planted to organic crops would thus be likely to expand with price premium increases, but not necessarily to decline with price premium decreases. Transition and certification costs for organic producers represent the first category of adjustment costs that may induce supply asymmetry in organic produce markets.

Distribution and information costs relate to the difficulty with identifying a market and getting the product to it. The costs of maintaining a niche or loyal clientele are associated with guaranteeing market share. Both categories represent relatively high marketing adjustment costs for the certified farmer. These constitute another set of factors that contribute to asymmetry in marketing organic produce.

From week to week, organic farmers choose to market their produce in either certified or noncertified markets. Price premiums for certified produce are inducements for farmers to sell through organic outlets. Observed marketing behavior depends on costs associated with the distribution choice. If these costs are significant, farmers with established certified marketing channels would be less likely to switch to noncertified outlets on a weekly basis, even if price premiums are not consistent. Under these conditions, the market will display supply asymmetry in the face of fluctuating or declining price premiums for organic produce.

Limited distribution channels were cited as one of the three most important obstacles to market expansion by 56% of organic producers surveyed by Cook. Organic outlets may be more costly to identify and transportation costs may be higher since there are fewer outlets for certified produce. CCOF-certified growers market 33% of their output through wholesalers or brokers. Most of these (50 of 77 in 1988) were located in northern California.

Over 5% of CCOF-certified growers had difficulty in finding handlers for their product. Principal transportation problems cited were reluctance of truckers to pick up small loads, too much time spent transporting product, and lengthy distance to markets. Contract sales, self-trucking, and f.o.b. sales options may alleviate these problems. The cost of negotiating these arrangements may make growers reluctant to abandon identified organic markets in favor of conventional market outlets, even if price premiums fall in the short run.

Since it may be costly to establish a loyal clientele or market niche, maintenance of market share is a priority for certified organic farmers. The ability to create and maintain a loyal customer base reduces the risk growers may face due to unstable market demand. If these costs are high enough, the market may exhibit supply asymmetry as certified farmers seek to retain market share.

Fluctuations in the demand for organic produce and the development of organic certification guidelines suggest the appropriateness of the partial adjustment model developed by Griliches for analyzing supply response in the organic lettuce market. This model was motivated by two types of costs—the costs of being out of equilibrium and the costs of changing output in the short run. These cost factors apply to decisions about production and marketing strategies for organic produce.

Empirical Model

An integrated model of partial adjustment and supply irreversibility was adapted to the organic lettuce market. The empirical model is based on four equations. In this section, the general form of each equation is presented and brief interpretations of the parameters are provided. In the next section, key features of the organic lettuce market are described and incorporated into the specification of the estimated econometric model.

Long-run desired output, Q_t^*, is defined as a function of price, P_t, and other exogenous factors influencing supply, Z_t:

$$Q_t^* = \beta_0 + \beta_1 P_t + \beta_2 Z_t. \tag{1}$$

In the partial adjustment model, adjustment costs act to constrain the rate at which producers alter the supply of organic produce. Over time, producers also adapt desired or target output levels, Q_t^{adj}. The rate at which the output adjusts over time is given by

$$Q_t - Q_{t-1} = \delta_1(Q_t^{adj} - Q_{t-1}). \tag{2}$$

The rate of adjustment is measured by the parameter δ_1, which lies between zero and one. If δ_1 is zero, the costs of adjustment are so severe that output cannot be changed. If δ_1 is one, actual output can be instantaneously changed to the desired output.

Asymmetric adjustment costs constrain producers' ability to reduce production or marketing capacity. In an expansionary period, producers want to increase output, so that long-run desired output exceeds the maximum output in previous periods, $Q_t^* > Q_t^{max}$. Define a dummy variable, D_t, that equals zero in expansionary periods. In contractionary periods, long-run desired output is below the previous maximum output and the dummy variable equals one.

The model for asymmetric adjustment costs defined by Burton is

$$Q_t^{adj} - Q_t^{max} = (1 - \delta_2 D_t)(Q_t^* - Q_t^{max}), \tag{3}$$

where Q_t^{max}, Q_t^*, and D_t are as previously defined. The parameter δ_2 measures whether asymmetry is present in the supply function. If asymmetric adjustment costs are absent, then δ_2 is zero. Long-run desired output and adjusted desired output are equal at each point in time. By contrast, if δ_2 is one, asymmetric adjustment costs prevent output from falling below the previous maximum level.

The output adjustment process is based on average or expected output taking into account the impacts of weather on available supply. Organic lettuce is produced in a few centralized regions, with limited marketing periods from each location subject to similar weather. Farmers are able to adjust expected output decisions to account for normal weather effects. The geographic concentration of growers reinforces the argument of LaFrance and Burt that the dynamic supply model be modified to account for weather in farmers' planning decisions. To purge the effects of weather from the adjustment process, let $\tilde{Q}_t$ be output net of weather effects denoted by W_t so that $\tilde{Q}_t = Q_t - \gamma W_t$. The partial adjustment equation becomes

$$\tilde{Q}_t - \tilde{Q}_{t-1} = \delta_1(Q_t^{adj} - \tilde{Q}_{t-1}). \tag{4}$$

The dynamic model for estimation was obtained by combining equations (1), (3), and (4) to yield

$$Q_t = \delta_1\beta_0 + \delta_1\beta_1 P_t + \delta_1\beta_2 Z_t + \gamma W_t + (1 - \delta_1)(Q_{t-1} - \gamma W_{t-1}) + \delta_1\delta_2 D_t(Q_t^{max} - \beta_0 - \beta_1 P_t - \beta_2 Z_t) + \epsilon_t. \tag{5}$$

Description of Organic Lettuce Supply

Supply characteristics for certified organic produce are difficult to quantify because the market is not as well-defined as the noncertified market and data on acreage planted and harvested are not readily available. In California, Cook reported survey results indicating that an estimated 30,000 acres are farmed organically by 900 growers. Wholesale returns for all organic crops were estimated at $50 million. Franco projected wholesale returns at over $300 million by 1992, if current sales trends continue. Of organic farmers reporting specific commodities, Cook found that 24% produce leafy greens, including lettuces.

In the absence of farm level surveys, data from the Organic Market News and Information Service (OMNIS), published by the Committee for Sustainable Agriculture, were used. This database gives weekly farm prices and quantities of organic produce sold based on responses from wholesalers in California, Oregon, and Washington.

The OMNIS wholesalers represent a large share of the organic market. Cook's survey indicated that 40% of all CCOF-certified growers use wholesalers and brokers as their main organic outlet. Among farmers with larger acreage, the percentages wholesaled are about the same—41% for farms from 10 to 50 acres and 38% for farms larger than 50 acres. Thus, the data may be taken as representative of the organic lettuce industry.

Conventionally grown lettuce from different parts of California is marketed year round. Four types of lettuce—romaine, green leaf, butter (Boston), and red—are consistently listed in the OMNIS reports on a weekly basis. Romaine lettuce was selected for analysis based on availability and familiarity to consumers. *The Packer*'s 1990 Fresh Trends survey of 2,000 households determined that 77% found romaine lettuce available in stores, while 27% had purchased it in the previous 12 months (King and Zind).

Weekly quantity and price data from 19 September 1985 through 30 December 1989 were used. High and low prices paid to growers were averaged to represent the overall market price. Since organic farmers have the option of selling their produce through either certified or noncertified channels, the ratio of organic to conventional prices was constructed to reflect this choice. As farm prices for noncertified romaine lettuce are not available, conventional wholesale prices, measured as the average of high and low weekly prices for romaine lettuce at the San Francisco and Los Angeles terminals, were collected from U.S. Department of Agriculture (USDA) Agricultural Marketing Service reports.

A flexible method for trend measurement in weekly data was proposed by Hahn, based on previous work with monthly trend analysis by Doran and Quilkey. This method relies on the harmonic motion mapped by sine and cosine waves. This approach was adopted and both elements were incorporated into the supply specification.

Regional concentration for lettuce production has an influence on susceptibility of the market to weather, disease, and pest problems in particular geographic locations. The regional specialization is even more pronounced in the production of organic lettuce, because less acreage and fewer growers supply the market. Wholesalers contacted said they obtain their supply from the Central Coast (areas around Watsonville, Santa Cruz, Salinas, Monterey, and Oxnard), the Imperial Valley (El Centro), and the Southern San Joaquin Valley (Bakersfield), with some quantities purchased locally during the summer months.

Bakersfield was mentioned by most wholesalers as the primary source from mid- to late November through mid-March to mid-April. Watsonville provides the majority of lettuce for many wholesalers from late March to early April through late October to mid-November. This information was taken into account in attempting to construct relevant weather variables.

Temperature is a significant factor in plant growth, particularly as it relates to seed germination and disease and pest problems. Since Watsonville and Bakersfield were mentioned most frequently by wholesalers and since these areas have significant acreage in CCOF-certified lettuce production, weather data were taken from stations at these sites. Daily maximum and minimum temperature data were collected from National Oceanic and Atmospheric Administration documents. Cooling degree days (65°F base) were calculated and summed for the seven-day periods preceding the dates of the weekly OMNIS reports.

The weekly cumulative degree days were then dummied with the appropriate months by location to reflect their importance in the overall market at given times of the year. For Bakersfield, the weather variable assumes nonnegative values in the months from November through March and zero values the rest of the year. For Watsonville, an analogous weather variable has nonnegative values from April through October and zeroes the rest of the year.

Tests for supply asymmetry traditionally have used ordinary least squares, neglecting potential misspecification biases associated with the simultaneous determination of price and quantity. Lettuce growers are able to adjust the frequency and intensity of lettuce harvested taking advantage of a readily available, seasonal labor force. Organic producers have additional flexibility in adjusting harvesting and marketing in response to relative price movements in both organic and conventional markets. The quantity-dependent specification for the organic lettuce market is appropriate given these potential adjustments in quantity harvested and marketed by organic producers.

Following Thurman, a Wu–Hausman test was applied to the quantity-dependent specification in equation (1) to test the endogeneity of the organic–conventional lettuce price ratio. If the price ratio for romaine lettuce is predetermined, the ordinary least squares estimate yields best linear unbiased estimates, denoted by $\hat{b}$. If the price ratio of romaine lettuce is endogenous in the supply specification, instrumental variable estimates, denoted by $\tilde{b}$, are consistent, while ordinary least squares estimates are biased and inconsistent.

A test statistic for the endogeneity of the lettuce price ratio is

$$T = (\hat{b} - \tilde{b})[\hat{V}(q)]^{-1}(\hat{b} - \tilde{b}), \tag{6}$$

where $\hat{V}(q)$ is a consistent estimate of the variance–covariance matrix under the null hypothesis and T is asymptotically distributed χ_1^2. Instrumental variable estimates were obtained using two-stage least squares. The Wu–Hausman test resulted in a test statistic of .11, well below the χ_1^2 test value of 3.84. The test fails to reject the null hypothesis that the price ratio of organic to conventional lettuce is predetermined, indicating that ordinary least squares estimation provides unbiased and consistent estimates. The quantity-dependent specification is an appropriate model to develop and test for irreversibility.

Results from the Asymmetric Supply Model

The estimated model for supply irreversibility in organic lettuce is

$$\begin{aligned} (7)\quad Q_t = {} & \delta_1\beta_0 + \delta_1\beta_1\frac{ORGPR_t}{CONVPR_t} + \delta_1\beta_2 SINE_t + \delta_1\beta_3 COSINE_t + \gamma_1 SUMBCDD_t \\ & + \gamma_2 SUMWCDD_t + (1 - \delta_1)(Q_{t-1} - \gamma_1 SUMBCDD_{t-1} - \gamma_2 SUMWCDD_{t-1}) \\ & + \delta_1\delta_2 D_t\left(Q_t^{\max} - \beta_0 - \beta_1\frac{ORGPR_t}{CONVPR_t} - \beta_2 SINE_t - \beta_3 COSINE_t\right) + \epsilon_t. \end{aligned}$$

Table 1. Estimates for Partial Adjustment and Asymmetric Models of Organic Romaine Lettuce Supply

Coefficient	Partial Adjustment	Asymmetric (***n*** = 2)
β_0	92.39	92.44*
	(1.55)	(11.54)
β_1	94.81*	94.86*
	(2.10)	(10.98)
β_2	−43.69*	−22.77
	(−1.81)	(−.98)
β_3	83.27*	91.25*
	(3.64)	(4.20)
γ_1	4.95	5.03
	(1.41)	(1.53)
γ_2	−2.55*	−2.51*
	(−1.74)	(−1.73)
δ_1	.41*	.41*
	(7.14)	(7.27)
δ_2		.11
		(1.31)
R^2	.57	.58
G	1.69	1.26

Notes: The partial adjustment model is equation (7) with $\delta_2 = 0$. The asymmetric model is equation (7) with $\delta_2 \neq 0$. Figures in parentheses are asymptotic t-statistics. Significance at the $\alpha = .10$ level is represented by an asterisk. G is derived from the Godfrey autocorrelation test and is distributed as an F-statistic. Critical value for the test statistic is $F_{1,196} = 2.71$.

The quantity of romaine lettuce sold weekly in boxes of 24 is denoted by Q_t, $ORGPR_t$ is the organic farm level price in period t, and $CONVPR_t$ is the average weekly conventional wholesale price in period t. Seasonal effects are captured by the weekly harmonic terms $SINE_t$ and $COSINE_t$, indexed to the week ending 31 December 1985. The regional impact of weather in the supply of organic lettuce is represented by $SUMBCDD_t$ and $SUMWCDD_t$, the weekly cumulative cooling degree days in Bakersfield and Watsonville, respectively, dummied by the relevant months.

The traditional partial adjustment model, in which δ_2 in equation (7) is constrained to equal zero, is first estimated. The estimation procedure for the asymmetric response model is iterative, beginning with the estimates of the traditional partial adjustment model. The dummy variable, D_t, relating desired long-run output to maximum previous output, is formulated using the parameter estimates from the traditional partial adjustment model in which $\delta_2 = 0$. The asymmetric model in equation (7) is then estimated using the generated dummy variable. The new parameter values are used to recalculate the dummy variable. This process continues until the dummy variable is unchanged between iterations.

Burton defined Q_t^{max} as the maximum output in the preceding ***n*** marketing periods. This decision rule is consistent with a model in which information used for marketing decisions is updated continually over a fixed time horizon as earlier maximum price ceases to influence current decisions. Operationally this method is designed to overcome situations when the estimation of asymmetric supply models is infeasible, such as when the maximum output occurs at an early point in the sample period under consideration. The smaller this window, the shorter the duration of the influence of previous market results on current output decisions. The log-likelihood function was examined for various window sizes and the maximum value was attained for a window of two weeks (***n*** = 2).

The model of organic lettuce marketing decisions was tested for specification error. Tests for autocorrelation in the traditional partial adjustment model and the asymmetric model are presented. The autocorrelation test developed by Godfrey, which is valid in the presence of a lagged dependent variable, was applied to (7). The F-tests for the significance of the coefficient on the lagged residuals for the partial adjustment model (δ_2

= 0) and for the asymmetric model ($\delta_2 \neq 0$) indicate no evidence of autocorrelation at the .05 significance level.

Maximum likelihood estimates for the traditional partial adjustment model and asymmetric model using nonlinear least squares in SHAZAM (White) are presented in table 1. The estimated parameters from the models have similar values and signs for both the partial adjustment and the asymmetric response models. The coefficient on the price ratio variable, β_1, which reflects the choices available to certified organic farmers in allocating produce between the organic or conventional markets, is highly significant. This indicates that higher organic prices relative to conventional prices increase the quantity marketed to organic outlets. The trend variables, *SINE* and *COSINE*, are first-order harmonic terms which account for seasonality in the supply of produce and estimated coefficients, β_2 and β_3, are both significant at the .10 level of significance.

The estimated coefficient for the weather variable in Watsonville, γ_2, is significant. In conjunction with the information about the timing of production from each location, the results indicate that cumulative cooling degree days in Watsonville have a greater effect on quantity marketed to organic wholesalers than cooling degree days in Bakersfield. Watsonville has a more constant and lower average temperature than Bakersfield, so that temperature fluctuations measured by cooling degree days may have a more obvious result on organic output available to the market in the former location.

This result may instead be a phenomenon of the timing dummy incorporated into the weather variables. There is a single large grower of organic lettuce in Bakersfield. With relatively lower and consistent distribution and market maintenance costs, this grower may control a major share of the market from November through March, reducing market output variability during this period.

The estimated rate of adjustment parameter, δ_1, is significant in each model and is equal to .41 in both the partial adjustment and the asymmetric models. The magnitude of this parameter in both models indicates that adjustment costs in the organic lettuce market do not severely restrict expansion of output. The magnitude of δ_1 implies that actual output can be changed to adjusted desired output, albeit at a moderate rate.

These results suggest that the supply of organic lettuce has adjusted to price changes over time. Adoption of organic cropping systems, management practices, and alternative input choices do not prevent farmers from expanding production as prices for organic lettuce increase relative to prices for conventional lettuce. There are other institutional factors (the three-year transition period) and production asset factors (land quality and human capital endowments) not explicitly modeled that could cause some stickiness in price responsiveness. Nevertheless, our results suggest that the expectation of price premiums is enough to encourage market entry by growers, even if the premiums are not consistently available on a week-to-week basis.

Asymmetric adjustment costs are negligible as measured by the estimated δ_2 parameter of .11, which is not statistically significant. The estimated model suggests output response in the organic lettuce market is not asymmetric since producers who have attained certification do not face additional costs when reducing output. Certified producers retain flexibility and can adjust marketing allocations between the organic and conventional markets in response to shifts in price premiums. This implies that certification and marketing costs do not constrain supply decisions for organic lettuce growers. The certification system does not add impediments to supply response flexibility which would not be faced by conventional growers.

Elasticity Estimates for Organic Lettuce Producers

The asymmetric model distinguishes between short-run supply response when producers desire to reduce output and periods when price signals induce producers to expand output. Supply elasticities are presented to evaluate the impact of asymmetry in output response. In contractionary periods, the elasticity derived from equation (5) is

$$\frac{\partial Q_t}{\partial P_t}\frac{P_t}{Q_t} = \delta_1\beta_1(1 - \delta_2 D_t)\frac{P_t}{Q_t},$$

where D_t is the previously defined dummy variable. In periods when producers expand output, the supply response is given by

$$\frac{\partial Q_t}{\partial P_t}\frac{P_t}{Q_t} = \delta_1\beta_1\frac{P_t}{Q_t}. \tag{9}$$

The short-run supply elasticity from the partial adjustment model does not distinguish between expansionary periods and contractionary periods. Long-run supply elasticity also is calculated from equation (5) for both the asymmetric and partial adjustment models, with δ_2 constrained to zero for the latter. In the long run, Q_t and Q_{t-1} converge to equilibrium quantity Q_t^* for both models and D_t is zero for the asymmetric model.

The estimated elasticity of supply under market conditions inducing growers to reduce production, η_{Reduce}, and the elasticity of supply under conditions encouraging expansion, η_{Expand}, are represented by equations (8) and (9), respectively, evaluated at the mean price and quantity values. Supply elasticities for the short run and the long run are presented in table 2 for the partial adjustment and asymmetric models.

Confidence intervals for the elasticities are derived using Geweke's Bayesian technique following steps outlined by Hayes, Wahl, and Williams. The technique is implemented using information that is available from the estimated model: the estimates of the parameter vector, denoted by $\hat{\beta}$, and the variance–covariance matrix, denoted by $\hat{V}$. Random draws are made from a multivariate normal distribution with variance–covariance matrix $\hat{V}$ and mean $\hat{\beta}$ to create a new parameter vector, $\hat{\hat{\beta}}$. For each draw of $\hat{\hat{\beta}}$ (here set at 1,000), the elasticities are calculated. An empirical distribution for the elasticities is then obtained using the complete set of random draws. To form the $(1 - \alpha)$ confidence interval, the empirical distribution of the elasticities is ranked from highest to lowest and $\alpha/2$ values from each tail of the distribution are dropped. The 95% confidence intervals are presented in table 2.

The short-run elasticity from the partial adjustment model is .23. The short-run elasticities from the asymmetric adjustment model are similar to the values from the partial adjustment model. The impact elasticity is .21 for contractionary periods and .23 for expansionary periods. The 95% confidence intervals for all the short-run elasticities indicate that these estimates differ significantly from zero. The estimated elasticities suggest that suppliers exhibit only marginally different responses in periods of price increases and decreases. This implies a negligible degree of asymmetry in the supply function for organic lettuce. The slightly higher estimated elasticities based on the asymmetric model imply that organic lettuce growers are more selective in choosing markets and dates for sale in response to price changes than would be predicted under the traditional partial adjustment model.

It is instructive to compare elasticity estimates for organic produce with elasticities for conventional produce. In absence of elasticities for conventional lettuce calculated on a weekly basis, available elasticities from other studies represent the best available data. Due to differences in a range of factors including model specification, estimation techniques, alternative variables, and frequency of observations, these comparisons are not offered as statistical tests for differences between the organic and conventional markets.

Using a quarterly model of the conventional lettuce market, Hammig and Mittelhammer suggested that acreage planted is more responsive to price than acreage harvested. This is due to the combined effects of a fixed number of acres available for harvest and short-term changes in the intensity of harvest. The short-run elasticity of acreage harvested with respect to price was .006 derived from the quarterly model. This indicates that price plays a relatively minor role in supply decisions for conventional lettuce, perhaps due to established supply contracts that lock in suppliers to specific outlets in the noncertified market.

The short-run elasticities of supply for organic lettuce for the partial adjustment and

Table 2. Short-Run and Long-Run Elasticities for the Partial Adjustment and Asymmetric Models

	Partial Adjustment		Asymmetric (n = 2)	
Situation	Elasticity	Confidence Interval	Elasticity	Confidence Interval
Short Run				
η_{Reduce}	**.230**	.033 .444	**.209**	.138 .284
η_{Expand}	**.230**	.033 .444	**.233**	.163 .308
Long Run	**.561**	.076 1.046	**.562**	.463 .665

Notes: Formulas for long-run supply elasticity [derived from equation (5)], the short-run supply elasticity in contractionary periods [equation (8)], and the short-run supply elasticity for expansionary periods [equation (9)] are provided in the text. The elasticities are evaluated at the mean price and quantity values. The 95% confidence intervals are reported.

asymmetric models were much larger than for conventional lettuce. Organic suppliers have the option to market their produce through organic or conventional outlets. Decisions are adjusted based on observed and expected price differentials between the two markets. The enhanced marketing flexibility of organic certification appears to outweigh any production and marketing adjustment costs that may be higher for certified compared to noncertified produce in terms of increasing supply elasticity.

The long-run supply elasticity of organic lettuce developed from these models is larger than for conventional lettuce. The long-run elasticities from the partial adjustment and the asymmetric adjustment models are essentially identical at .56. Both estimates are significantly different from zero. Buxton's recent study of supply response in selected vegetable markets yielded an estimated long-run supply elasticity of .36 for conventional lettuce.

An important policy issue is to examine changes in elasticities for organic produce as the market matures over time. Hall et al. noted that early adopters of organic farming methods were motivated by nonpecuniary rewards, where profit was not the primary motivation. Early adopters also operated smaller, more diversified farms. For these growers, an inelastic supply response to output price changes would be expected.

Cook's survey showed that more recent entrants into the organic market have larger farms and are concerned about profits. These growers are more responsive to price signals and premiums for organic produce and have greater flexibility in adjusting marketing allocations between certified and noncertified channels. If this is the case, supply behavior should display greater elasticity in the period following entry of this grower segment.

To examine this contention more rigorously, we calculated the short- and long-run elasticities for the sample divided into two periods—pre-1989 (1985–88) and 1989. Equation (7) was estimated for the two separate time periods and elasticities were calculated from equations (8) and (9) to obtain long- and short-run elasticities under contractionary and expansionary conditions. Self-reported indicators of oversupply and undersupply among wholesalers in the OMNIS data set both declined after 1989, indicating a market approaching equilibrium. Table 3 presents the comparison of pre-1989 and 1989 elasticity estimates for the partial adjustment and asymmetric models.

The short-run and long-run elasticities implied by both the partial adjustment and the asymmetric response models are greater during the 1989 period. The short-run elasticities for this period are much larger than those for the pre-1989 period. For the asymmetric model, the pre-1989 elasticity under contractionary conditions is .09 compared to .63 for 1989. Under expansionary conditions, the pre-1989 elasticity calculation is .34 while the

Table 3. Short-Run and Long-Run Elasticities for the Partial Adjustment and Asymmetric Models: Pre-1989 and 1989

	Partial Adjustment				Asymmetric (n = 2)			
	Pre-1989		1989		Pre-1989		1989	
Situation	Elasticity	Confidence Interval	Elasticity	Confidence Interval	Elasticity	Confidence Interval	Elasticity	Confidence Interval
Short Run								
η_{Reduce}	**.182**	−.148 .496	**.685**	.084 1.458	**.088**	−.023 .227	**.628**	.294 .995
η_{Expand}	**.182**	−.148 .496	**.685**	.084 1.458	**.340**	−.096 .806	**.689**	.348 1.067
Long Run	**.439**	−.321 1.199	**1.416**	.194 2.637	**.472**	−.142 1.086	**1.411**	1.233 1.582

Note: Refer to notes to table 2, in their entirety.

1989 value is .69. The pre-1989 elasticities are close in magnitude to those for the entire sample. A similar pattern is apparent in the elasticities from the partial adjustment model. A comparison of elasticities across time periods indicates that short-run supply of organic lettuce has become more responsive to price changes in the 1989 period. This could be due to competitive pressure from newer entrants, more interest in profit-maximizing behavior of newer entrants, or more experience among existing farmers in producing and marketing organic lettuce, among other explanations.

The long-run elasticities are also higher in the 1989 period for both the partial adjustment and asymmetric models than in the pre-1989 period. This result indicates that as the organic produce market matured, long-run supply response shifted from inelastic to elastic. Based on the confidence intervals presented in table 3, both short-run and long-run supply elasticities in the pre-1989 period are characterized by greater variability. Certified organic producers may be gaining more expertise in production and marketing, reducing the adjustment costs. The flexibility in marketing choices available to organic growers may contribute to this responsiveness to price signals.

Conclusions

This article represents an initial attempt to model supply relationships in the market for organic romaine lettuce. Based on estimation results of partial adjustment and asymmetric adjustment models, costs of organic certification, production, and marketing do not severely restrict producers' ability to respond to price signals. Organic producers have the option of selling in a certified market, which improves marketing flexibility, and more recent market entrants may have size advantages which reduce marketing adjustment costs. Rate of adjustment to changing prices is not instantaneous, but there is no evidence of asymmetry in supply.

Flexibility in response to changing prices is improved because organic farmers may on a weekly basis select among market alternatives. The choice of market appears to be influenced by other factors in addition to prices in the two markets, including seasonal weekly cooling degree days and a flexible time trend. Further investigation is needed to develop a more descriptive supply function.

There is evidence that organic lettuce growers will simply shift between certified and noncertified markets in response to reduced price premiums for organics, rather than reduce plantings or voluntarily decertify their farms. Recertification imposes costs that are not offset by yield and cost advantages in nonorganic production systems, providing an incentive for farmers to use marketing choices rather than changes in production to control quantity supplied to the certified market. Consumers may find organic lettuce supply is reliable even in the face of falling prices, although it may not be marketed through certified organic channels.

In the long run, the supply of organic lettuce should increase as long as the possibility for price premiums exists. Estimates of short-run supply elasticities under contractionary and expansionary conditions indicate that organic lettuce growers are more responsive to price changes than nonorganic producers. From 1985 through 1988, long-run supply response was inelastic, perhaps reflecting the alternative motivations of market participants. Long-run supply response estimated for data from 1989 was elastic, possibly due to the influence of larger, profit-maximizing growers with more sophisticated marketing skills and more efficient production methods.

It may be several years before the organic lettuce market reaches equilibrium due to continued fluctuations in demand and a still immature marketing system for certified produce. Whether price premiums can be sustained in the long run is an open question. Consumer studies have shown concern for environmental protection in agricultural production, which may result in an equilibrium price that is greater for certified than noncertified produce. Further investigation in this area is warranted in light of the elasticity results from this research.

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Appendix

Derivation of Equation (5)

Substituting equation (1) into equation (3) yields

(A1) $$Q_t^{adj} = (1 - \delta_2 D_t)[\beta_0 + \beta_1 P_t + \beta_2 Z_t] + \delta_2 D_t Q_t^{max}.$$

Note that the term Q_t^{max} is eliminated from both sides of this equation.

The resulting equation for Q_t^{adj} is substituted into equation (4) in the text:

(A2) $$\tilde{Q}_t - \tilde{Q}_{t-1} = \delta_1(1 - \delta_2 D_t)[\beta_0 + \beta_1 P_t + \beta_2 Z_t] + \delta_1\delta_2 D_t Q_t^{max} - \delta_1 \tilde{Q}_{t-1}.$$

Recall that $\tilde{Q}_t$ is defined as output net of weather effects W_t, so that $\tilde{Q}_t = Q_t - \gamma W_t$. This adjustment process implies that

(A3) $$\tilde{Q}_t - \tilde{Q}_{t-1} = Q_t - Q_{t-1} - \gamma W_t + \gamma W_{t-1}.$$

Substituting this term into equation (A2) yields

(A4) $$Q_t - Q_{t-1} - \gamma W_t + \gamma W_{t-1} = \delta_1(1 - \delta_2 D_t)[\beta_0 + \beta_1 P_t + \beta_2 Z_t] + \delta_1\delta_2 D_t Q_t^{max} - \delta_1 \tilde{Q}_{t-1}$$

or

(A5) $$Q_t = \delta_1(\beta_0 + \beta_1 P_t + \beta_2 Z_t) + \gamma W_t + Q_{t-1} - \gamma W_{t-1} - \delta_1(Q_{t-1} - \gamma W_{t-1}) + \delta_1\delta_2 D_t[Q_t^{max} - (\beta_0 + \beta_1 P_t + \beta_2 Z_t)].$$

Equation (A5) is rearranged and an error term is added to create equation (5) in the text:

$$Q_t = \delta_1\beta_0 + \delta_1\beta_1 P_t + \delta_1\beta_2 Z_t + \gamma W_t + (1 - \delta_1)(Q_{t-1} - \gamma W_{t-1}) + \delta_1\delta_2 D_t(Q_t^{max} - \beta_0 - \beta_1 P_t - \beta_2 Z_t) + \epsilon_t.$$