An Imperfectly Competitive Market Model of the U.S. Lettuce Industry

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An econometric model was specified to represent the U.S. lettuce industry. Cursory examination of the industry structure suggests that imperfect competition may prevail in the lettuce market. Therefore, relations were specified that allowed for the possibility of imperfectly competitive behavior to affect market equilibrium outcomes. Specifically, a supply price equation was specified to account for the influence of market power of large growers, particularly during seasons of geographically concentrated production. Results do not contradict the hypothesis that imperfect competition exists in the lettuce market.

The perfectly competitive model provides the basic analytical framework for the vast majority of research directed at agricultural commodity markets although analysts often recognize many deviations from the competitive norm within those markets. The assumptions of the competitive model are well known and, even though they may not be strictly representative of a given market, they often serve as useful approximations. However, in some agricultural commodity markets the competitive model is not appropriate. The lettuce market exemplifies a case where the tenets of perfect competition do not comfortably apply.

This paper presents part of a larger U.S.D.A. study to develop quarterly market models for a selected set of fresh salad vegetables. Though the market structures for most fresh vegetables are in general terms similar, the lettuce market displays some unique characteristics. The bulk of the crop is produced in California; Monterey County in the spring and summer and Imperial County in the fall and winter [U.S. Department of Agriculture]. A relatively small number of large producers control a significant portion of the total supply of lettuce. In California, eight producers have at times supplied nearly one-half of that State's production.[1]

Given a situation where a small number of producers control a large proportion of total production, the opportunity for the extraction of above-normal profits may exist. This paper presents an attempt to construct a simulation model of the U.S. lettuce market with notions of an imperfectly competitive market structure as its base. The model is then used to assess the impact on the lettuce market of a relative increase in wages paid to hired farm labor.

Model Structure

The market for lettuce is completely for fresh use. Neither long-term storage nor significant processing of lettuce takes place. Imports of lettuce are negligible; however, significant quantities are exported — mostly to Canada — each year. The econometric model developed for this study consists of

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[1]These figures were obtained from 4/1/74 to 3/31/75 based on unpublished data from the State of California Iceberg Lettuce Research Board.

five estimated relationships and two identities. Acreage planted, acreage harvested, supply price, domestic demand and export demand were estimated directly. Total domestic supply and yield were determined by identities.

Acreage Planted

In the process of producing lettuce, the first decision a producer must make relates to the acreage that he plants in a given season. Generally a minimum of ten weeks pass between planting and a decision concerning the harvest. Therefore the acreage planted decision must be based on information available well in advance of the time when actual quantities produced and consumed, and prices, are known to producers.

The key factors affecting acreage planted are hypothesized to include the expected price, the risk of error in determining that price expectation, the variable costs of producing the crop, and existing investment in fixed assets used in the production of lettuce. The acreage planted equation was specified as:

$$(1) \qquad AP_t = a_0 + a_1PE_t + a_2R_t + a_3CP_t + a_4AP_{t-4} + a_5Dsp + a_6Dsum + a_7\,Dfall + v_t,$$

where AP_t is the number of acres planted for production of lettuce in quarter t; PE_t is the expected price of lettuce per cwt.; R_t is the risk associated with price expectations; CP_t is the index of prices paid by farmers for items used in production, 1967 = 100; Dsp, Dsum, and Dfall are dummy variable intercept shifters for the spring, summer, and fall quarters, respectively; and v_t is the disturbance.

The expected price variable is defined as a three-year geometrically declining weighted average of past observed prices as

$$(2) \qquad PE_t = \sum_{i=1}^{3} w^i\, P_{t-4i}$$

where w = .54369.[2] This specification for price expectation is motivated, in part, by Nerlove's adaptive expectations hypothesis, where expectations are adjusted by weighted differences between actual and expected outcomes on price. When this type of expectations hypothesis is properly transformed to eliminate unobservable variables, an infinite series of geometrically declining weighted past prices results. Expectations variables used in the model presented here are also based on geometrically declining weighted lagged prices. However, the lags are finite. It is hypothesized that producers cease to rely on past experience in forming current expectations after an appropriate time span. Experimentation with various lag lengths has shown that the three-year lag provides the best empirical results.

The risk associated with price expectations is represented by the square root of a weighted average of squared deviations between actual and expected prices relative to the expected price as

$$(3) \qquad R_t = \left(\sum_{i=1}^{3} w^i(P_{t-4i} - PE_{t-4i})^2\right)^{1/2}/PE_t.$$

This specification of risk provides a measure of the accuracy of expectation formation relative to the level of expectations. Thus, the same degree of accuracy, as measured by the numerator, would imply less perceived risk if the price expectation is high than it would if the price expectation were relatively low.

Using information from previous studies, economic theory, and USDA commodity specialists, prior stochastic constraints were incorporated in the model through the mixed estimation technique [Theil and Goldberger]. Studies by Nerlove and Addison, Hammig (1978), Lin, and Traill give insights into the expected range of values for elasticities

[2]This value was obtained by solving the equation $w^3 + w^2 + w = 1$. The subscript, t, refers to a quarterly time period, thus t − 4i refers to an annual lag.

with respect to expected price, risk, and production costs. All sources of prior information agree that the elasticities of acreage with respect to expected price and variable production costs will be in the inelastic range. It has also been observed that acreage elasticities with respect to risk variables similar to the one used here fall between zero and −.1. Thus, the restrictions applied through mixed estimation, as used in this paper, are determined by first establishing the appropriate interval of acceptable values for the relevant parameter to be estimated. The midpoint of the interval is taken as the prior point estimate, and 95 percent probability limits, assuming normally distributed prior information, are established by assuming that two standard deviations span the interval on either side of the point estimate. Thus, the coefficients were stochastically constrained such that the mean level elasticities of acreage planted with respect to expected price, risk, and costs of production were 5. ± .5, −.05 ± .05, and −.5 ± .5, respectively, with .95 probability, and mixed estimation was applied to the hypothesized relation. All covariances among these restrictions were assumed to equal zero. (For a more detailed discussion of the prior information applied to the acreage planted equation see Hammig (1979).)

Acreage Harvested, Yield, and Pricing

The assumed goal of firms engaged in the production and sale of lettuce is to obtain the largest possible profit given certain operational constraints. Market demand forces constrain the amount of product that may be sold. Physical production requirements constrain the level of output that may be attained. The availability and accuracy of information regarding the general market situation further constrains the actions a firm may take.

Under perfect competition producers maximize their profits by providing supplies up to the point where marginal cost is equal to the market price, and the aggregate supply curve for the industry is the horizontal summation of the portions of individual firm marginal cost curves lying above average variable costs. Market price is established at the point where the aggregate supply curve intersects the aggregate demand curve.

In the case of the lettuce market, since a large portion of production is controlled by a small number of growers, the competitive supply price may not be attainable. That is, large growers, recognizing their power to significantly control supplies, may insist on a larger than normal profit margin in the lettuce they sell, and thus put upward pressure on the market price. The vigor with which such a course would be pursued would depend on the elasticity of competing supplies, and the elasticity of market demand for lettuce. If both elasticities are sufficiently inelastic, grower profit can be enhanced through relatively small reductions in the quantity of lettuce offered for sale.

Lettuce quantity supplied is, by definition, the product of the number of acres harvested and the yield per harvested acre. Yields vary directly with the frequency and intensity with which the field is harvested. Greater (within biological limits) and lesser yields per acre can be had through increased or decreased application of harvesting inputs (primarily labor). Acreage planted provides the upper bound on the potential number of acres harvestable. On the average, four to five percent of planted lettuce acreage is unharvested due to crop damage and due to economic decisions not to harvest.

In the absence of market power to affect price, the supply curve for lettuce could be specified in a standard manner where the supply price at harvest time would depend on the quantity supplied, and the prices of inputs used in harvesting and selling the crop. However, since a large portion of total production is concentrated in the hands of a few large growers, there is reason to believe that the large growers can influence the selling price. Thus quantity and input prices do not exhaust the list of variables influencing supply and pricing behavior. It is there-

fore hypothesized that the behavior of the large growers may be influenced by their perceptions of market conditions, especially the behavior of competing suppliers. Given the data available, this latter phenomenon was proxied in the supply price equation by including variables that represent the expected level of quantity demanded, the anticipated potential quantity of lettuce supplied, and variables identifying seasons of the year when lettuce production is more geographically dispersed and less concentrated in California (spring and summer).

The supply-price equation was specified as

$$(4) \qquad P_t = A_t(Qs,t)^{\alpha_1}(WG_t/PDY_t)^{\alpha_2}(IWPI_t)^{\alpha_3} e^{u_t},$$

where

$$(5) \qquad A_t = K \exp(b_0 + b_1(Qd^*,t/Qs^*,t) + b_2Dsp + b_3Dsum),$$

K is a constant; Qd*,t/Qs*,t is the ratio of expected quantity demanded to anticipated potential lettuce quantity supplied; Dsp and Dsum are dummy variables having the value 1 in the spring and summer quarters, respectively, and the value zero elsewhere; Qs,t is lettuce quantity supplied; WG_t is an annual index of migratory worker wage rates, 1967 = 100; PDY_t is an annual index of labor productivity in vegetable production, 1967 = 1.0; $IWPI_t$ is the quarterly industrial wholesale price index used to proxy for costs other than labor in the harvesting and sale of lettuce; and u_t is the disturbance term.

The variables Qd*,t, Qs*,t, Dsp, and Dsum are used to proxy perceptions of market power available to major lettuce producers. Spring and summer dummy variables are included as indicators of the time periods when total production is least restricted to the major producers and when competition for regional markets is significantly increased due to active lettuce production by producers throughout the nation. The ratio Qd*,t/Qs*,t is used to proxy perceptions of the relative demand/supply situation that could exist given demand expectations and expectations of potential maximum supplies forthcoming from the known planted acreage. In the same manner that the price expectation is formed by equation (2), the expected demand variable is defined as a geometrically declining weighted average of past demands,

$$(6) \qquad Q_d^*,t = \sum_{i=1}^{3} w^i Q^d_{t-i},$$

where w is as defined in (2). More information is available regarding potential supply, since the number of acres planted is known at harvest time. Expected potential quantity supplied is defined as the product of current acreage planted and expected yields; where the yield expectation is also formed in the same manner as (2) — a geometrically declining weighted average of past yields. It is hypothesized that as expected demand increases relative to expected potential supply in a harvest period, large producers perceive an increase in their ability to affect market outcomes, and the supply price — and ultimately the market price — will tend to increase. That is, large producers will act based on their expectations of the power they will have to control the market. In periods where they expect short supplies relative to demand they will exert more upward pressure on the price. However, in periods of more significant competition for markets (spring and summer), it is hypothesized that the market power of large producers is undercut, and supply-price and market price more nearly approach perfectly competitive levels.

The migratory worker wage index, deflated by an index of labor productivity, is included to represent the labor cost component of lettuce production. The IWPI variable is included to account for all other costs. Under either perfect or imperfect competition, market equilibrium prices will increase when costs are increased. The magnitude of

the price increase will depend on the market power exercised by producers and/or the elasticities of supply and demand for the given product. Johnson and Zahara have shown that labor constitutes up to 40 percent of total lettuce harvesting costs. Therefore, using mixed estimation, the coefficient on migratory worker wages was constrained to reflect an elasticity of .4 ± .3, .95 probability, in anticipation of the effect of labor costs on supply price.

The market price for lettuce is established when quantity demanded at a given price is equal to the quantity that will be supplied at that price. If the market price is to be established above the perfectly competitive price, a portion of production must be withheld from the market — presumably by the large growers who exercise their market control to achieve higher profit through higher prices. As stated previously, quantity supplied can be varied by changing the number of acres harvested and/or by varying the intensity with which harvesting is pursued. When the market is in equilibrium, the quantity demanded at the market price established must be equal to the number of acres harvested times average yield per acre harvested.

The model achieves the equality in the following way. Together with the establishment of supply offer curves associating quantities supplied with supply prices for individual growers, the profit maximizing mix of number of acres harvested and yield is established. It is hypothesized that for the aggregate supply-price curve, the higher the supply price and the associated quantity supplied, the greater will be the number of acres harvested and the higher will be the intensity of the harvest (yield). Since the number of acres available for harvest is fixed, while intensity of harvest may vary depending on prevailing conditions, it is further hypothesized that yield is more responsive to price than is acreage harvested. In addition, as real wages paid to labor increases, ceteris paribus, it would be expected that fewer acres would be harvested in the aggregate, and the intensity of the harvest (yield) would be decreased. Also, the aggregate level of acreage harvested relative to acreage planted may be affected by varying yield and weather possibilities in the spring and summer when the growing of lettuce is more geographically dispersed.

Of course, acreage harvested cannot exceed acreage planted, and thus the acreage harvested relationship was modeled in the following general form:

$$AH_t = \beta_t AP_t, \tag{7}$$

where AH_t is acreage harvested in acres; AP_t is acreage planted in acres; and $o \leq \beta_t \leq 1$. A particular functional form that exhibits the required bounds on β_t, and that performed well in empirical testing, was the logistic function.

$$\beta_t = 1/(1 + \exp(Z_t)) \tag{8}$$

where Z_t is a set of factors affecting the acreage harvested decision. In this study

$$Z_t = V_0 + V_1P_t + V_2(WG_t/PDY_t) + V_3Dsp + V_4Dsum + \epsilon_t \tag{9}$$

where all variables are as defined previously, with ϵ_t being the disturbance. By substitution of (9) into (8), and then (8) into (7), and with further algebraic manipulations and linearization in logarithms, the estimating equation was

$$\ln\left(\frac{AP_t}{AH_t} - 1\right) = \gamma_0 + \gamma_1P_t + \gamma_2(WG_t/PDY_t) + \gamma_3Dsp + \gamma_4Dsum + \epsilon_t. \tag{10}$$

In equilibrium, the average yield is determined as the value that when multiplied by acreage harvested results in a quantity supplied that is equal to quantity demanded, all at the established market price. Quantity demanded, acreage harvested, average yield, quantity supplied, and final market price are

all affected endogenously by consumers and producers in the lettuce market; where some producers may follow policies that restrict acreage harvested and/or yield in order to restrict quantity supplied and thus increase prices above perfectly competitive prices.

Derived Domestic Demand

The domestic demand for lettuce is specified at the grower level, following the conventional tenets of demand theory, as

$$(11) \quad Q_{dt}/POP_t = g_0 + g_1 P_t/CPI_t + g_2 I_t/(CPI_t \cdot POP) + g_3 T_t + U_t$$

where Q_{dt} is domestic consumption of lettuce in million cwts. in quarter t; P_t is the farm level price of lettuce in dollars per cwt.; I_t is disposable income in billions of dollars; CPI_t is the consumer price index with 1967 = 1.0; POP_t is population in millions; and T_t is a taste and habit shifter of demand. It is assumed that the marketing margin consists of fixed per unit and/or percentage markups, and thus no explicit reference to marketing margin components is made (see George and King, p. 56-59).

$$(12) \quad T_t = \delta_0 + \sum_{i=1}^{3} \delta_i (Q_{dt-4i}/POP_{t-4i})$$

with $\sum_{i=1}^{3} \delta_i = 1$. That is, the taste and habit shifter is a linear function of the weighted average of per capita consumptions for three previous corresponding quarters.[3]

Shiller's method [Shiller] was used to impose the hypothesis of smoothly declining weights on δ_1, δ_2, and δ_3 using the mixed estimation technique. The derivation of the implied stochastic constraint on the parameters of the demand equation appears in abbreviated form in the Appendix. In addition, through examination of the research of George and King, and through consultations with U.S.D.A. commodity specialists, prior stochastic constraints on the mean level elasticities with respect to price and income of $-.10 \pm .10$ and $.20 \pm .20$, respectively, with probabilty .95, were imposed using mixed estimation. The intervals for these constraints were generated in an independent manner. Thus the restrictions are assumed to be subjectively independent and the covariance between the two is zero.

Export Demand

Virtually all of the lettuce exported by the U.S. is shipped to Canada. In addition, in the winter, spring, and fall quarters, virtually all of the lettuce consumed by Canadians is imported from the U.S. Canadian production of lettuce is commercially significant only in the summer.

The demand for U.S. exports of lettuce is therefore essentially Canadian consumer demand in winter, spring, and fall, and Canadian excess demand in the summer. The export demand function utilized was

$$(13) \quad EXP_t = h_0 + h_1 P_t/(ER_t \cdot CPI_{can,t}) + h_2 I_{can,t}/CPI_{can,t} + h_3 POP_{can,t} - Q_{scan.t} + e_t$$

where EXP_t is quantity of lettuce exported in quarter t in million cwts; P_t in U.S. farm price in dollars per cwt; ER_t is the exchange rate expressed in dollars U.S. to dollars Canadian; $POP_{can,t}$ is Canadian population in millions; and $Q_{scan,t}$ is Canadian production of lettuce in million cwts. Stochastic prior constraints on the mean level price and income elasticities were applied in the same manner as for estimation of domestic demand, and mixed estimation was applied to (13).

Estimation Results

The structural equations requiring statistical estimation in the lettuce market model are presented in Table 1. Prior as well as sample information was available for all the

[3]Empirical testing of various lag lengths revealed that the three-year lag performed best.

TABLE 1. Results of U.S. Lettuce Market Structural Equation Estimation

1. Acreage Planted (OLS — mixed estimation)

$$AP_t = \underset{(4.09)}{27983.} + \underset{(5.54)}{3895.0}\ PE_t - \underset{(3.07)}{12985.0}\ R_t - \underset{(3.88)}{97.723}\ CP_t + \underset{(5.07)}{.51270}\ AP_{t-4} - \underset{(3.07)}{7450.8}\ D_{sp} - \underset{(3.28)}{6930.4}\ D_{sum} - \underset{(3.90)}{6854.7}\ D_{fall}$$

$R^2 = .751$ $\quad \theta_p = .084$ $\quad \chi^2_3 = 1.601$

2. Supply Price Equation (2SLS — mixed estimation)

$$\ln P_t = - \underset{(.47)}{.4466} + \underset{(1.58)}{.5187}\ \ln Q_{st} + \underset{(2.69)}{.2934}\ \ln(WG_t/PDY_t) + \underset{(1.81)}{.3611}\ \ln IWPI + \underset{(3.56)}{.9227} Q_{d^*}/Q_{s^*} - \underset{(3.74)}{.3429}\ D_{sp} - \underset{(3.59)}{.3361}\ D_{sum}$$

$r^2 = .606$ $\quad \theta_p = .076$ $\quad \chi^2_1 = 1.074$

3. Acreage Harvested (2SLS)

$$\ln\left(\frac{AP_t}{AH_t} - 1\right) = - \underset{(17.80)}{.37138} - \underset{(.63)}{.0433}\ P_t + \underset{(1.05)}{.2985}\ WG_t/PDY_t - \underset{(4.08)}{.5514}\ D_{sp} + \underset{(4.46)}{.6115}\ D_{sum}$$

$r^2 = .418$

4. Domestic Demand (2SLS — mixed estimation)

$$Q_{dt}/POP_{US,t} = \underset{(2.06)}{.00834} - \underset{(2.96)}{.00136}\ P_t/CPI_{US,t} + \underset{(3.81)}{.00354}\ I_{US,t}/CPI_{US,t} \cdot POP_{US,t}) + \underset{(4.90)}{.49748} Q_{dt-4}/POP_{US,t-4} + .19576\ Q_{dt-8}/POP_{US,t-8} +$$

$$.09662\ Q_{dt-12}/POP_{us,t-12}$$

$r^2 = .764$ $\quad \theta_p = 1.64$ $\quad \chi^2_2 = 1.014$

5. Export Demand (2SLS — mixed estimation)

$$EXP_t + Q_{scan,t} = - \underset{(1.70)}{.35656} - \underset{(3.62)}{106.03}\ P_t/(ER_t \cdot CPI_{can,t}) + \underset{(2.05)}{3.018}\ I_{can,t}/CPI_{can,t} + \underset{(1.32)}{.3798}\ POP_{can,t}$$

$r^2 = .744$ $\quad \theta_p = .225$ $\quad \chi^2_1 = 1.475$

NOTE: Values in parentheses are absolute values of t-statistics. θ_p refers to the share of prior information in the posterior precision of the mixed estimators. χ^2 is the Chi-square test of compatibility of prior and sample information.

relations except acreage harvested, and the mixed estimation technique was applied in those cases. The prior information used in these relations, along with corresponding posterior estimates are given in Table 2. The acreage planted equation did not contain endogenous explanatory variables, so OLS was an appropriate estimation procedure. All other relations required a simultaneous equation estimation technique and 2SLS was used. Sample data for the years 1954-1977 were used to estimate the system.

Results of the acreage planted relation were as anticipated; all signs were as expected and the χ^2 test that the prior information is not contradicted by the sample data indicates that sample and prior information are compatible at conventional levels of type I error [see Theil]. Mean level elasticities with respect to expected price, risk, and costs of production were .4170, −.0561, and −.2011, respectively.

The 2SLS mixed estimation results of the supply price equation are shown in equation 2 of Table 1. Signs of all coefficients conform to expectations. The χ^2 test of compatibility indicates compatible prior and sample information. Elasticities of supply price with respect to production, wages, and other costs all fall in the inelastic range at .5187, .2934, and .3611 respectively. These results tend to confirm the hypothesis that imperfectly competitive behavior exists in the lettuce market. The significant negative effects of the spring and summer dummy variables imply that, in fact, prices are induced upward during periods of restricted competition. Total quantities produced and consumed remain remarkably constant across all seasons, lending some strength to the argument that the dummy variables are not mere proxies for seasonal demand shifts.

Estimated results of the acreage harvested equation appear in equation 3 of Table 1. Conventional theory suggests that the coefficient on price should be negative and the coefficient on wages should be positive. Given these signs, as price increases the proportion of acres harvested to acres planted will also increase, and as wages increase relative to productivity this proportion will fall. The results obtained in estimation conform to the expected pattern. Mean level elasticities of acreage harvested with respect to price and wages are .006 and −.009, respectively. The low elasticities suggest that economic variables have relatively minor impact on the harvesting decision.

The domestic demand and export demand equations incorporated the same prior notions regarding elasticities with respect to price and income. In the case of domestic demand, results were as anticipated. The mean level price and income elasticities of demand were estimated to be −.1223 and .1877, respectively.

In the export demand equation, the prior income elasticity was found to be incompatible with the sample information by a χ^2 test at the .05 level of type I error [see Theil], and the prior input was discarded. Prior knowledge of the price elasticity was quite compatible with the sample, and the results obtained using only the one constraint gave elasticities of export demand with respect to

TABLE 2. Comparison of Prior and Posterior Estimates in the U.S. Lettuce Market Model

Elasticity	Prior Estimate	Posterior Estimate
AP,PE	.5 ± .5	.417
AP,R	−.05 ± .05	−.056
AP,CP	−.5 ± .5	−.201
P,WG	.4 ± .3	.293
Qd,P	−.1 ± .1	−.122
Qd,I	.2 ± .2	.183
EXP,P	−.1 ± .1	−.102

price and income of −.1016 and .6750, respectively.

Overall the results of estimation of the five structural equations support the hypothesized relationships inherent in the structure of the lettuce market. All signs agree with the expected direction of forces operating in the market, and the compatibility tests uniformly confirm that sample and prior information are, in fact, compatible. As noted above, the model is completed by identities to determine quantity supplied (the sum of domestic and export demands) and yield (quantity supplied divided by harvest acreage). The complete model can then be used to simulate activities in the lettuce market.

Model Simulation

Since the reduced form of the lettuce market model in nonlinear, the Gauss-Seidel technique was used to simulate the system. Model solutions were obtained for the years 1960 through 1977, and these results were compared to actual market outcomes to measure the validity of the complete model. Measures of goodness of fit are presented in Table 3.

Recent union activity on behalf of lettuce harvest laborers in California indicates that the possibility exists for harvest labor costs to significantly increase in coming years. The effects of increased wages on the lettuce market can be examined by the simulation model. The United Farm Workers (UFW) has announced a goal of obtaining wage increases of approximately 40 percent above current levels [Washington Post, Washington Star]. Many lettuce producers are resisting UFW pressure to obtain such increases.

The impact on the market of large wage increases was evaluated by comparing simulation results obtained under two sets of assumptions. Baseline projections were made assuming normal trend adjustments in wages (seven percent per year) and other factors as an average of changes over the past five years. A second set of projections was developed for the market under the assump-

TABLE 3. Complete Model Goodness of Fit Test Results

Endogenous Variable	Mean Absolute Percent Error				Actual vs. Estimate Squared Correlation				Theil U Statistics			
	winter	spring	summer	fall	winter	spring	summer	fall	winter	spring	summer	fall
Acreage Planted	10.36	9.05	6.45	5.17	.24	.49	.12	.47	1.03	.98	1.01	.98
Acreage Harvested	11.31	8.97	6.38	4.36	.29	.46	.07	.43	1.03	.99	1.00	.99
Yield	6.40	6.38	8.00	3.85	.79	.82	.49	.92	.99	.97	1.11	.94
Quantity Supplied	8.75	12.23	6.39	6.93	.40	.89	.86	.93	1.01	.89	1.05	.87
Quantity Demanded	9.83	13.46	6.26	7.05	.23	.87	.85	.91	1.01	.91	.97	.90
Supply Price	15.79	21.96	11.44	14.02	.58	.22	.72	.62	.96	1.00	.99	1.03
Exports	15.19	7.52	43.45	14.43	.74	.79	.68	.81	.96	.98	1.61	.96

NOTE: These measures were generated by inserting observed values of exogenous variables and predicted values of lagged endogenous variables recursively through the prediction sequence.

tion of similar normal trend adjustments for all factors except wages. Wages were increased in the first year by 40 percent and subsequent annual wage increases were held at seven percent. The comparison of the two simulations is, therefore, of an effective wage difference of 33 percent in 1979 increasing moderately in following years. Both simulations were extrapolated over the period 1979-83 to allow lagged effects to be resolved over time. Simulation results for domestic quantity demanded, quantity supplied, and the supply price are presented in Table 4.

The effect of the 33 percent immediate wage increase over normal levels is to reduce slightly quantities demanded and supplied, and to increase prices. However, the magnitudes of the differences are relatively small. Quantities differ by less than two percent for all seasons over the five year period. Price differences average slightly over seven percent for the same period.

Some implications of these results can be interpreted by examining the cost structure of lettuce production. Using the work of Johnson and Zahara it can be shown that, for 1975, a 33 percent increase in wages would translate to a 6.5 to 14.0 percent increase in lettuce harvesting costs. Since harvesting costs constitute about two-thirds of total variable costs of production, the costs of producing lettuce would increase by 4.3 to 9.3 percent due exclusively to the change in wages paid. Based on the results of this

TABLE 4. Lettuce Market Simulation Results under Baseline Assumptions and with Increased Wages

	Baseline Projections			Projections with Increased Wages		
Year/ season	Quantity Supplied	Quantity Demanded	Price	Quantity Supplied	Quantity Demanded	Price
	1,000 cwt.		$/cwt.	1,000 cwt.		$/cwt.
1979						
Winter	14.64	13.50	8.44	14.53	13.40	9.11
Spring	15.25	14.07	8.85	15.15	13.97	9.52
Summer	14.61	14.32	8.34	14.52	14.23	8.98
Fall	14.24	13.08	9.25	14.14	12.98	9.93
1980						
Winter	15.03	13.86	8.81	14.90	13.74	9.36
Spring	15.62	14.41	8.85	15.49	14.28	9.41
Summer	14.88	14.60	9.09	14.74	14.47	9.76
Fall	14.68	13.50	9.78	14.53	13.35	10.55
1981						
Winter	15.41	14.21	9.30	15.24	14.04	9.90
Spring	15.95	14.71	9.20	15.79	14.55	9.79
Summer	15.15	14.90	9.17	14.98	14.73	9.82
Fall	15.04	13.83	10.43	14.84	13.64	11.25
1982						
Winter	15.72	14.49	9.84	15.51	14.29	10.57
Spring	16.22	14.96	9.75	16.02	14.76	10.42
Summer	15.41	15.18	9.20	15.21	14.99	9.85
Fall	15.36	14.43	10.93	15.12	13.89	11.75
1983						
Winter	16.00	14.74	10.38	15.74	14.49	11.27
Spring	16.45	15.17	10.39	16.22	14.94	11.14
Summer	15.64	15.44	9.46	15.41	15.21	10.19
Fall	15.66	14.41	11.27	15.39	14.14	12.13

study, the seven percent increase in prices, projected by the simulation including higher wages, would translate into revenues accruing to growers between 6.5 and 7.2 percent above those that would be obtained under the baseline scenario. Revenue increases between 6.5 and 7.2 percent concurrent with cost increases between 4.3 and 9.3 percent imply that the bulk of the cost increases will be passed forward by producers to other participants in the lettuce marketing system.

Conclusion

This study has endeavored to present an econometric model representing a market where elements of imperfect competition potentially exist. Through the modeling of the supply price relationship, imperfectly competitive behavior is allowed to enter the determination of market activities. Though the results of estimation and simulation of the complete model are not conclusive as to the existence of imperfectly competitive behavior in the U.S lettuce market, the structure of the production side of the market suggests that imperfect competition warrants concern, and empirical results do not rule out the possibility that lettuce growers exercise some degree of market power.

References

George, P. S. and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections for 1980*. Giannini Foundation Monograph Number 26, March 1971.

Hammig, M. D. *Supply Response and Simulation of Supply and Demand for the U.S. Fresh Vegetable Industry*. Unpublished Ph.D. dissertation, Washington State University, 1978.

Hammig, M. D. "Regional Acreage Response by Quarter for Fresh Tomatoes: An Example of the Use of Mixed Estimation." *Southern Journal of Agricultural Economics*, 11 (1979): 69-74.

Johnson, S. S. and M. Zahara. "Lettuce Harvesting and Packing: Hand and Machine Harvest Alternative." *Vegetable Situation*. ERS, USDA, May 1976.

Lin, W. "Measuring Aggregate Supply Response Under Instability." *American Journal of Agricultural Economics*, 59 (1977): 903-907.

Nerlove, M. "Estimates of the Elasticities of Supply of Selected Agricultural Commodities," *Journal of Farm Economics*, 38 (1956): 496-509.

Nerlove, M. and W. Addison. "Statistical Estimation of Long-Run Elasticities of Supply and Demand," *Journal of Farm Economics*, 40 (1958): 861-880.

Shiller, Robert J. "A Distributed Lag Estimator Derived From Smoothness Priors." *Econometrica*, 41 (1973): 775-788.

Theil, H. "On the Use of Incomplete Prior Information in Regression Analysis," *Journal of American Statistical Association*, 58 (1963): 401-414.

Theil, H., and A. S. Goldberger. "On Pure and Mixed Statistical Estimation in Economics." *International Economic Review*, 2 (1961): 65-78.

Traill, W. B. "Risk Variables in Econometric Supply Response Models." Paper presented at AAEA annual meeting, State College, PA, 1976.

U.S. Department of Agriculture, "Vegetables — Fresh Market Annual Summary." Washington, D.C.: SRS, 1978.

Washington Post. "Chavez's Lettuce Walkout is Wilting." Washington, D.C., April 29, 1979.

Washington Star. "Chavez on the Lettuce Strikers." Washington, D.C., April 27, 1979.

Appendix

The Shiller method of imposing smoothness priors on model parameters incorporates prior information on finite differences involving the function $\delta_i = f(i)$ which represents the relationship between the weight and the lag length. In the case at hand,

$$T_t = \delta_o + \sum_{i=1}^{3} \delta_i(Q_{dt-4i}/POP_{t-4i})$$

with $\sum_{i=1}^{3} \delta_{i=1}$. It is further assumed that $\delta_1 \geq \delta_2 \geq \delta_3$, i.e., weights decline over time, or

at most remain unchanged, which, therefore implies that $.333 \leq \delta_1 \leq 1$, $0 \leq \delta_2 \leq .5$, and $0 \leq \delta_3 \leq .333$. The first difference of the weights are given as $\Delta\delta_{12} = \delta_1 - \delta_2$ and $\Delta\delta_{23} = \delta_2 - \delta_3$. The second difference of weights is given as $\Delta^2\delta_{123} = \delta_1 - 2\delta_2 + \delta_3$, and it is this linear combination of parameters that will be concentrated on. Specifically, we wish to establish maximum and minimum values for $\Delta^2\delta_{123}$ that are possible given the constraints imposed on δ_1, δ_2, δ_3. This problem can be stated in terms of a simple linear program as

$$\begin{aligned} &\text{MAX or MIN } \Delta^2\delta_{123} = \delta_1 - 2\delta_2 + \delta_3 \\ &\text{s.t.} \quad \Sigma\, \delta_i = 1 \\ &\qquad \delta_1 \geq \delta_2 \\ &\qquad \delta_2 \geq \delta_3 \\ &\qquad \delta_1, \delta_2, \delta_3 \geq 0 \end{aligned}$$

The problem can be solved to obtain the results that MIN $\Delta^2\delta_{123} = -.5$ when $\delta_1 = \delta_2 = .5$, and $\delta_3 = 0$; and MAX $\Delta^2\delta_{123} = 1$ when $\delta_1 = 1$, and $\delta_2 = \delta_3 = 0$. Thus, $-.5 \leq \Delta^2\delta_{123} \leq 1.0$.

However, the parameters δ_1, δ_2, and δ_3 are multiplied by the constant g_3 as they appear in the demand equation, and thus prior bounds on $g_3\Delta^2\delta_{123} = g_3\delta_1 - 2g_3\delta_2 + g_3\delta_3$ are required. It is suggested that $0 \leq g_3 \leq 1$, which allows for the effects of habit to decay over time, and also implies strict stability of the difference equation that is implied by the demand equation. The stochastic constraint imposed in estimation was specified as

$$\Pr\,(g_3\delta_1 - 2g_3\delta_2 + g_3\delta_3 = .25 \pm .75) = .95$$

where the prior was assumed to be normally distributed with point estimate = .25 and variance = $(.375)^2$. The prior is not considered unduly restrictive, since the interval reduces as $g_3 \rightarrow 0$.