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## AN ANALYSIS OF MARKET STRUCTURE AND PRICING IN THE FLORIDA CELERY INDUSTRY

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### Abstract

The pricing behavior of the Florida celery industry under the current federal marketing order was examined by analyzing the implied market structure of the industry using a model proposed by Appelbaum. Point estimates of the oligopoly power index suggest that some degree of price enhancement above that which would be characterized by a perfectly competitive market may have occurred. However, the bulk of statistical evidence suggests that the departure from marginal cost pricing implied by the industry's pricing behavior is not statistically significant.

*Key words:* celery, market orders, oligopoly power, price enhancement.

The Secretary of Agriculture is charged with ensuring that market orders do not result in undue price enhancement. A price is generally considered acceptable if it allows firms to cover costs and realize a reasonable profit sufficient to keep firms in the industry. Any price that exceeds this definition may be considered as unduly enhanced. Thus, "producers should not be allowed to raise prices too fast or to achieve excess profits" (Polopolus et al., p. 13).

One provision of market orders that has the potential to lead to undue price enhancement is that which allows for quantity or volume control through volume management and market flow regulations (Jesse and Johnson, p. 4). Volume management consists of such provisions as producer allotments, market allocation, and reserve pools. Market flow regulations consist of handler prorates and shipping holidays. These provisions allow producers through a market order to adjust the quantity marketed. Quantity control provi-

sions are "often felt to possess the greatest potential for price enhancement" (Jesse and Johnson, p. 4).

The Florida celery industry has operated under some type of market order since 1961. From 1961 to 1964, the Florida celery industry operated under a state marketing order. Upon being declared unconstitutional, this order was replaced by a federal marketing order # CFR 967 (Brooke, 1979). The current federal marketing order contains provisions for producer allotments, shipping holidays, and prorate periods.

Using a weekly simultaneous equations model, Shonkwiler and Pagoulatos analyzed pricing in the Florida celery industry. Based on the similarity of the restricted and unrestricted reduced form equations and the fact that the estimated own price elasticity of demand was inelastic, they concluded that the pricing behavior of the industry was consistent with that of a competitive market. Updaw, in a comment on their article, was critical of the analysis on the grounds that the demand model was misspecified and that the use of weekly data essentially biased the model toward obtaining inelastic point estimates of the own price elasticity of demand. To support his contention, Updaw pointed out that the own price elasticity increases as the length of adjustment increases and suggested that generally "the demand for Florida celery would have been estimated to be elastic at observed prices and quantities if quarterly or annual observations had been used."

An additional criticism of Shonkwiler and Pagoulatos' study is that it entirely ignored cost of production. Thus, issues involving how prices compared to estimated marginal cost were ignored. This however is not surprising as cost data are only available on an annual basis and their use in conjunction with weekly price and quantity data would make establishing the existence of marginal cost

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pricing difficult.

The purpose of this paper is to provide an alternative analysis of pricing behavior in the Florida celery industry, using annual data and incorporating cost data into the model so that the pricing behavior of the industry may be judged in relation to marginal costs. By using annual data, it is hoped that some light may be shed on the objections raised by Updaw concerning the magnitude of the own price elasticity of demand. Furthermore, by incorporating cost of production into the model, inferences concerning the competitiveness of the industry can be made by analyzing the industry's pricing behavior directly rather than on the basis of the predictive ability of the model or the similarity of restricted and unrestricted reduced forms as was done by Shonkwiler and Pagoulatos.

To accomplish this, a model which Appelbaum proposed to analyze market structure is applied to the Florida celery industry. This model endogenizes the pricing behavior of firms in an industry within a dual model of the production technology and allows estimation of an oligopoly power index which provides a measure of the market structure implied by the pricing behavior of the industry. Recent studies based on variants of this model have been conducted by Azzam, Pagoulatos and Yanagida, and Schroeter.

## THEORETICAL CONSIDERATIONS<sup>1</sup>

Assume that an industry is composed of  $F$  firms, each producing a homogeneous product,  $y$ , with input vector  $x = (x_1, \dots, x_n)$ . Further, assume that firms operating in the industry are price takers in input markets with input price vector  $w = (w_1, \dots, w_n)$  and face the industry demand curve

$$(1) y = y(p, z),$$

where  $p$  is output price,  $z$  denotes a vector of exogenous demand shift variables, and  $\partial y / \partial p \leq 0$ . Given the existence of a well-defined technology, the profit maximization problem for the  $j$ th firm may be written as

$$(2) \max [py_j - c_j(y_j, w) \mid y = \sum_j y_j],$$

where  $c_j(y_j, w)$  denotes the cost function of the  $j$ th firm and  $y = \sum_j y_j$ .

The cost functions for all firms are assumed to be twice differentiable and well defined in the sense of satisfying the requisite theoretical regularity conditions.<sup>2</sup> It should be noted that the profit maximization problem in (2) essentially represents the second of two optimization stages since the decision variable in (2) is  $y_j$ .

In the first stage optimization, firms choose inputs in order to minimize the cost of producing the level of output chosen. This optimization is embodied in the cost function in (2). The input demand functions (conditional on  $y_j$ ) for the  $j$ th firm may be obtained by application of Shephard's Lemma

$$(3) x_j = \Delta c(y_j, w) / \Delta w,$$

where  $x_j$  denotes the input vector of the  $j$ th firm and the left hand side of (3) is the gradient vector of the cost function.

The second stage optimization determines the profit maximizing level of output. The optimal condition for this second stage optimization is found by differentiating (2) with respect to  $y_j$  to yield

$$(4) p(1 - \theta_j \xi) = \partial c(y_j, w) / \partial y_j,$$

where  $\theta_j$  denotes the conjectural elasticity<sup>3</sup> of the  $j$ th firm:

$$(5) \theta_j = (\partial y / \partial y_j)(y_j / y),$$

and  $\xi$  is the negative of the inverse price elasticity of demand given by

$$(6) \xi = -(\partial p / \partial y)(y / p).$$

The relationship in equation (4) basically states that the optimal output decisions of firms occur at the point where perceived marginal revenue is equated to marginal cost.

It may be noted that the perceived marginal

<sup>1</sup>This section is basically a summary of the theoretical model presented in Appelbaum.

<sup>2</sup>In the present analysis, a well-defined cost function is assumed to be non-negative, continuous in  $w$  and  $y$ , homogeneous of degree one in  $w$ , non-decreasing in  $w$  and  $y$ , and concave in  $w$ .

<sup>3</sup>The conjectural elasticity is the elasticity from the  $j$ th firm's conjectural variation  $(\partial y / \partial y_j)$ , which measures the reaction of other firms in the industry when the  $j$ th firm alters its output level.

revenue of the  $j$ th firm is dependent on both the conjectural elasticity and the inverse price elasticity of demand. Indeed, it is the dependency of this relationship on the conjectural elasticity that ties equation (4) to market structure. More specifically,  $\theta_j$  provides a rough index of market structure. For example, under perfect competition,  $\theta_j = 0$  and marginal cost pricing results, while under pure monopoly,  $\theta_j = 1$ . It can be seen from these two polar cases that  $\theta_j$  is bounded by zero and one.

In addition to using  $\theta_j$  as a measure of market structure, Appelbaum (p. 290) also defines an index of the degree of oligopoly power exhibited by the  $j$ th firm as

$$(7) \alpha_j = \theta_j \xi.$$

Referring back to equation (4), it can be seen that the oligopoly power index in (7) is essentially the Lerner index (Waterson p. 19),  $[p - \partial c(y, w) / \partial y_j] / p$ , for the  $j$ th firm. Although this index is firm specific, Appelbaum (p. 290) develops an industry level generalization of (7) to obtain the industry measure of oligopoly power

$$(8) L = \sum_j \alpha_j S_j,$$

where  $S_j$  denotes the share of industry output attributable to the  $j$ th firm. This index can be seen to be the weighted sum of each firm's output share times each firm's oligopoly power index.

In principle, equations (1), (3), and (4) constitute a system of (nonlinear) equations that can be estimated. By specifying  $\theta_j$  to be a function of the exogenous variables, estimates of the conjectural elasticities and oligopoly power index which vary over time may be obtained. However, as noted by Appelbaum, the time series cross section data on individual firms necessary to accomplish estimation are seldom available. Hence an aggregate formulation of the model is required for most empirical applications.

In general, the aggregate formulation of the cost function (and hence input demands) and market demand function is straightforward. Where potential difficulties arise is in specifying an aggregate measure of the conjectural elasticity.

Appelbaum solves this problem by assuming that, in equilibrium, all firms possess the same marginal cost and hence have the same perceived marginal revenue. However, an implication of all firms having the same perceived marginal revenue is that all firms have the same equilibrium conjectural elasticity (see equation [4]).

Defining  $c(y, w)$  to be the aggregate industry cost function, the aggregate "optimality" condition for the industry thus becomes

$$(9) p(1 - \theta \xi) = \partial c(y, w) / \partial y,$$

where  $\theta$  represents the equilibrium conjectural elasticity common to all firms. The implied aggregate oligopoly power index then becomes  $L = \theta \xi$ .

## EMPIRICAL MODEL AND RESULTS

Empirical implementation of the Appelbaum model requires specification of an aggregate cost function and a market demand function. The cost function for the Florida celery industry is expressed in terms of the aggregate inputs, labor ( $x_l$ ), capital ( $x_k$ ), and intermediate materials ( $x_m$ ), with respective input prices  $w_l$ ,  $w_k$ , and  $w_m$ . Output is measured by total Florida celery production and is denoted by  $y$ . A complete discussion of the data is presented in the appendix.

The parametric form of the aggregate cost function is given by the quasi-homothetic<sup>4</sup> form of the Generalized Leontief function (Diewert, 1971)

$$(10) c = [\sum_{i,j} a_{ij} (w_i w_j)^{1/2}] y + \sum_i c_i w_i, i, j = l, k, m$$

where  $a_{ij} = a_{ji}$ . Quasi-homotheticity embodies the least restrictive assumption that can be maintained on the underlying production technologies of individual firms to establish the existence of an aggregate cost function. In contrast to the usual assumption of homotheticity wherein all firms have identical and linear expansion paths emanating from the origin, quasi-homotheticity maintains the assumption that the expansion paths of individual firms are linear and parallel, but allows them to differ across firms. Since this implies all firms have equal marginal costs, aggregation across firms is possible.

<sup>4</sup>The quasi-homothetic form of the cost function is synonymous with the Gorman polar form commonly used in specifying aggregate expenditure functions in consumer demand applications of duality.

As the analysis is conducted at the grower level, the relevant industry demand function is wholesale (shipping point) demand for Florida celery. The parametric form of the demand function is specified to be

$$(11) \ln(y_f) = b + b_f \ln(p_f/e) + b_c \ln(p_c/e) + b_d \ln(p_d/e),$$

where  $y_f$  is the wholesale demand for Florida celery measured as total Florida celery production,  $p_f$  and  $p_c$  denote the FOB price of Florida and California celery respectively,  $p_d$  represents the price of diesel fuel, and  $e$  is total wholesale expenditures on Florida and California celery. The price of California celery is included in the demand equation since California is the main competitor with Florida in the U.S. celery market. The inclusion of the price of diesel fuel in equation (11) is to provide a proxy measure for the cost of transporting celery to wholesalers. The choice of total expenditures on Florida and California celery at the shipping point rather than some measure of consumer income in equation (11) reflects the fact that this equation represents the derived demand for celery at the wholesale level rather than retail demand for Florida celery. It may be noted that deflation of prices by expenditures in equation (11) implicitly imposes homogeneity of degree zero in prices and expenditure.

Given these specifications for the aggregate cost function and wholesale demand, the complete system to be estimated with cross price symmetry imposed is given by

$$\begin{aligned} x_1 &= [a_{11} + a_{1k}(w_k/w_1)^{1/2} + a_{1m}(w_m/w_1)^{1/2}]y + c_1 + b_1 x_1 - 1, \\ x_k &= [a_{kk} + a_{1k}(w_1/w_k)^{1/2} + a_{km}(w_m/w_k)^{1/2}]y + c_k + b_k x_k - 1, \\ (12) \quad x_m &= [a_{mm} + a_{1m}(w_1/w_m)^{1/2} + a_{km}(w_k/w_m)^{1/2}]y + c_m + b_m x_m - 1, \end{aligned}$$

$$\ln(y_f) = b + b_f \ln(p_f/e) + b_c \ln(p_c/e) + b_d \ln(p_d/e), \text{ and}$$

$$\begin{aligned} p_f &= [a_{11}w_1 + a_{kk}w_k + a_{mm}w_m \\ &\quad + 2a_{1k}(w_1w_k)^{1/2} + 2a_{1m}(w_1w_m)^{1/2} + 2a_{km}(w_kw_m)^{1/2}]/(1 + \theta(w)/b_f). \end{aligned}$$

Lagged dependent variables,  $x_j, -1, j=1, k, m$ , were included in the input demand equations to allow for sluggish adjustment of these factors to equilibrium levels. As noted by Lau, this is tantamount to assuming that the adjustment path of each input is characterized by a partial adjustment process and that the rate of adjustment of each input is independent of that of the other inputs.

To allow the conjectural elasticity to vary over time,  $\theta$  in the above equation system is approximated by the linear function<sup>5</sup>

$$(13) \theta(w) = g + g_1w_1 + g_kw_k + g_mw_m.$$

This specification merits additional discussion. It may be recalled that  $\theta$  is the elasticity form of the conjectural variation, which measures the aggregate output response of rival firms when any one firm alters its output. Furthermore, it has been shown that in equilibrium the conjectural elasticity of all firms will be equal. Given that all firms face the same demand curve (i.e., same own price elasticity of demand), it is reasonable to assume that the output responses of rival firms to an output change by any one firm will be influenced by their (marginal) cost functions which are in turn dependent on input prices. Thus, expressing  $\theta$  in terms of input prices should adequately account for changes in the equilibrium value of the conjectural elasticity.

The data used for estimation spanned the 1961 to 1982 period and thus include 22 observations. The individual equations in (12) were appended with disturbance terms to reflect errors in optimizing behavior. The disturbance vectors of the individual equations are assumed to be joint normally distributed with mean zero and non-singular covariance matrix,  $\Omega$ , satisfying

<sup>5</sup>Several alternative specifications for approximating the conjectural elasticity were tried. The linear in input prices approximation used in the final model provided the best empirical results.

TABLE 1. PARAMETER ESTIMATES FOR RESTRICTED AND UNRESTRICTED SYSTEMS

Parameter	Unrestricted model	Standard error	Restricted model	Standard error
$a_{ij}$	0.06544	0.20444	-0.01492	0.17990
$a_{ik}$	0.58727	0.22058	0.47702	0.21032
$a_{im}$	-0.01324	0.14297	0.04876	0.14531
$c_i$	-0.29583	0.17823	-0.13548	0.13897
$b_i$	0.61074	0.11963	0.58754	0.11006
$a_{kk}$	-1.79870	0.51935	-1.55250	0.47705
$a_{mk}$	0.60304	0.27513	0.52649	0.26537
$c_k$	1.07170	0.23589	0.90802	0.21213
$b_k$	0.51009	0.19640	0.62969	0.20867
$a_{mm}$	0.01138	0.18177	0.22496	0.18247
$c_m$	-0.09845	0.16724	-0.32856	0.17877
$b_m$	0.44079	0.15610	0.44638	0.17099
$b$	-0.39731	0.22858	-0.23730	0.20118
$b_f$	-0.42431	0.21416	-0.27208	0.18750
$b_c$	0.00072	0.17844	0.01050	0.06826
$b_d$	-0.21596	0.05270	-0.18197	0.04337
$g$	0.16013	0.13413	—	—
$g_i$	-0.20119	0.14803	—	—
$g_k$	0.21602	0.22920	—	—
$g_m$	-0.08747	0.18095	—	—

$$(14) E[u_i(t)u_j(s)] = \Omega \text{ if } t = s \\ = 0 \text{ if } t \neq s,$$

where  $u_i$  denotes the disturbance vector of the  $i$ th equation. Estimation of the system was accomplished using non-linear three stage least squares.

The parameter estimates and corresponding asymptotic standard errors are presented in the first two columns of Table 1. Of the 20 parameters estimated, 8 (40 percent) have values that exceed two times their respective asymptotic standard errors.

In any use of dual functions, a primary concern is whether or not the estimated equations are consistent with the regularity conditions implied by theory. In the estimated model, both symmetry and homogeneity of degree one in input prices are maintained *a priori*. Hence, only the properties of monotonicity and concavity must be evaluated.

Monotonicity may be evaluated by inspecting the predicted values generated from the estimated input demand functions. If all predicted values are non-negative, monotonicity will be satisfied over the closed set defined by the data. Inspection of the

predicted values obtained from the estimated input demand functions indicated that monotonicity was indeed satisfied at all data points.

Concavity of the cost function requires that the Hessian matrix of the cost function be negative semi-definite. For the Generalized Leontief, a sufficient condition for global concavity is  $a_{ij} \geq 0$  for  $i \neq j$ . Inspection of the parameter estimates indicates this condition is violated by  $a_{im}$ . However, as the estimated value of this parameter is both small in magnitude and not statistically different from zero, global concavity of the cost function, at least in a "statistical" sense, is not disproved.

One empirical result of note is the fact that the estimated own price elasticity of demand,  $b_f$ , is -0.42 and is statistically significant. Thus, it appears Updaw was incorrect in surmising that the own price elasticity of demand would be greater than one if annual as opposed to weekly data were used.

The estimated conjectural elasticities and oligopoly power index along with their respective standard errors<sup>6</sup> are presented in Table 2. The point estimates for conjectural elasticities and oligopoly power index indicate some degree of price enhancement above that which

<sup>6</sup>Standard errors for the conjectural elasticities and oligopoly power index were calculated using a second order Taylor series as an approximation to the true standard errors.

TABLE 2. ESTIMATED CONJECTURAL ELASTICITIES AND OLIGOPOLY POWER INDEXES

Year	Conjectural elasticity		Oligopoly power index	
1961	0.15052	(0.1480) <sup>a</sup>	0.35474	(0.2712) <sup>a</sup>
1962	0.15157	(0.1492)	0.35721	(0.2735)
1963	0.15284	(0.1508)	0.36021	(0.2765)
1964	0.14578	(0.1486)	0.34356	(0.2764)
1965	0.13529	(0.1446)	0.31885	(0.2743)
1966	0.12911	(0.1422)	0.30429	(0.2732)
1967	0.12583	(0.1417)	0.29654	(0.2746)
1968	0.11501	(0.1390)	0.27106	(0.2754)
1969	0.11600	(0.1409)	0.27340	(0.2794)
1970	0.11803	(0.1435)	0.27818	(0.2846)
1971	0.12629	(0.1485)	0.29764	(0.2912)
1972	0.12258	(0.1493)	0.28889	(0.2961)
1973	0.10999	(0.1479)	0.25923	(0.3014)
1974	0.10351	(0.1496)	0.24394	(0.3106)
1975	0.08620	(0.1476)	0.20315	(0.3167)
1976	0.08770	(0.1526)	0.20668	(0.3274)
1977	0.08749	(0.1576)	0.20619	(0.3398)
1978	0.04698	(0.1550)	0.11073	(0.3519)
1979	0.03352	(0.1581)	0.07901	(0.3638)
1980	0.05896	(0.1694)	0.13895	(0.3820)
1981	0.09004	(0.1877)	0.21220	(0.4125)
1982	0.01046	(0.1693)	0.02466	(0.3968)
Mean	0.10471	(0.1519)	0.24677	(0.3167)

<sup>a</sup>Asymptotic standard errors in parentheses

would be observed in a perfectly competitive market wherein price is equated to marginal cost. This is especially evident during the initial years of the analysis where the oligopoly power index is in excess of 0.30. Both the conjectural elasticities and oligopoly power index, however, exhibit a downward trend over time. This implies that the degree of price enhancement as measured by point estimates of the oligopoly power index has declined somewhat over the period of analysis.

It is difficult to precisely interpret the downward trend in the oligopoly power index. However, two plausible explanations can be offered. First, it is possible that the industry in the initial years of the market order tended to enhance prices to a larger degree than was necessary as part of a learning process. Over time, however, as the ability to gauge the market improved, the degree of price enhancement that was deemed appropriate declined.

A second explanation for this downward trend relates to the fact that California, as noted by Shonkwiler and Pagoulatos, has been

increasing its share of the celery market. Thus, it is possible that the increased competition from producers in California has served to increasingly limit the ability of the Florida industry to increase prices above marginal cost.

Although the point estimates of the oligopoly power index indicate that some degree of price enhancement has been observed, the question of whether or not the degree of price enhancement implied by the conjectural elasticities and oligopoly power index represents a statistically significant departure from the prices that would be obtained from perfectly competitive pricing has not been established. This is somewhat difficult to evaluate in a precise statistical manner. Although the hypothesis that  $g = g_1 = g_k = g_m = 0$  is nested within the model and can therefore be tested using conventional statistical procedures, this hypothesis represents only a sufficient condition for  $\theta = 0$ . A rejection of this hypothesis does not preclude  $\theta = 0$ , since  $\theta$  is not specified to be constant but rather a function of the ex-

ogenous variables.

The parameter estimates and asymptotic standard errors for the restricted model are presented in the last two columns of Table 1. It may be noted that, as was the case with the unrestricted model, the estimated model is not inconsistent with the requisite theoretical regularity conditions. Using the testing procedure suggested by Gallant and Jorgenson, the hypothesis that  $g = g_l = g_k = g_m = 0$  yields a test statistic of  $T^0 = 17.1816$ . The critical value of the  $\chi^2$  distribution at the  $\alpha = 0.01$  level of significance with 4 degrees of freedom is 13.3. Thus, the hypothesis that  $g = g_l = g_k = g_m = 0$  is rejected.

As noted, however, a rejection of this hypothesis alone does not provide sufficient information to conclude the absence of marginal cost pricing. Appelbaum suggested that an alternative, and perhaps more informative, means to judge the empirical results is to compare the estimated conjectural elasticities and oligopoly power indexes with their respective standard errors and locally evaluate their significance (p. 296).

Examining Table 2, it is apparent that the estimated conjectural elasticities and oligopoly power indexes are not statistically significant at conventional significance levels at any observation. Similar results hold for the conjectural elasticity and oligopoly power index evaluated at the mean of the sample. Thus, on the basis of these "tests" it appears that no departure from the marginal cost pricing rule that would typify a perfectly competitive market can be concluded for the Florida celery industry.

## SUMMARY AND CONCLUSIONS

The purpose of this analysis was to assess the pricing behavior of the Florida celery industry under the current federal marketing order. In order to accomplish this, the market structure as measured by the conjectural elasticity and an index of oligopoly power implied by the pricing behavior of the industry was estimated using the model proposed by Appelbaum. This model is well suited to the evaluation of pricing behavior under market orders as it provides a direct means to assess the degree to which prices have or have not been enhanced above those that would result from perfectly competitive pricing. Of course, what constitutes excessive price enhancement cannot be addressed by the model. However, as correctly pointed out by an anonymous

reviewer, what exactly constitutes excessive price enhancement under a federal marketing order is a normative question. What the model can provide, however, is evidence on whether or not the pricing behavior of a given industry represents a statistically significant departure from that which would be found in a perfectly competitive market.

The weight of empirical evidence obtained in this study suggests that the Florida celery industry has not enhanced price above a level that would be consistent with a perfectly competitive market. A test of the hypothesis that  $g = g_l = g_k = g_m = 0$  was rejected. However, this test only evaluated a sufficient condition for  $\theta = 0$ . Hence, its rejection cannot be considered as sufficient evidence to conclude a departure from marginal cost pricing. Local "tests" conducted by comparing the estimated conjectural elasticities and oligopoly power indexes to their respective standard errors indicated a lack of statistical significance at every observation and at the mean values of the input prices. Thus, it may be concluded that the pricing behavior of the Florida celery industry does not represent a statistically significant departure from that which would be characterized by a perfectly competitive market. These results are consistent with those found by Shonkwiler and Pagoulatos using a simultaneous equation model based on weekly data.

It may also be noted that the data contain only actual costs of production and have not been adjusted to include opportunity cost or, equivalently, some measure of normal profit. Inclusion of such data would likely result in a decrease in the point estimates of the oligopoly power index. This would further support the contention that the empirical results suggest that the pricing behavior of the Florida celery industry has not represented a significant departure from marginal cost pricing.

Another interesting empirical result relates to the own price elasticity of demand which was estimated to be  $-0.42$  and was statistically significant. This result appears to refute Updaw's contention that the elasticity of demand would be greater than one if a model based on annual data as opposed to weekly data were used.

Finally, it should be noted that the results of this analysis, as in any application of dual theory, are conditioned by the need for the cost function to satisfy empirically the requisite regularity conditions. In the present analysis, the cost function was shown to



satisfy monotonicity at every data point. A sufficient condition for global concavity of the cost function could not be rejected in a "statistical" sense. In this vein, it should be noted that the input demand functions were

negatively sloped at every data point, indicating that a necessary condition for concavity was indeed satisfied. Symmetry and homogeneity of degree one in input prices were maintained a priori.

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### Appendix

The data used to measure the quantity and price of labor, capital, and materials were constructed in several steps. The primary data source for the obtaining measures of these inputs for the Florida celery industry was cost of production data obtained from Brooke (selected issues), Taylor, and Taylor and Wilkowske. As these data include only expenditures on various inputs, it was necessary to construct price and quantity indexes.

The input prices used in the analysis correspond to regional price indexes constructed for the southeastern U.S. which includes the states of Alabama, Florida, Georgia, and South Carolina. The price indexes were formed by using regional quantity indexes obtained from the production and efficiency statistics published by USDA and corresponding cost of production data obtained from Lucier, Chesley, and Ahearn and applying Fisher's weak factor reversal test (Diewert, 1976).

Quantity indexes for labor, capital, and materials used in celery production were formed by applying Fisher's weak factor reversal test (Diewert, 1976) to the celery cost of production data and the regional input price indexes. Labor expenditure used in forming the labor quantity index included both preharvest and harvest labor. Expenditures used in forming the capital quantity index included both depreciation and repair and maintenance costs. The materials quantity index included expenditures on seed, fertilizers, agricultural chemicals, energy, licenses and insurance, and a miscellaneous category.

The price and quantity data for Florida celery were obtained from annual issues of *Vegetable Summary (Florida Agricultural Statistics)*. Quantity is measured as total production in millions of crates. Price data for California celery were obtained from annual issues of *Vegetables—Fresh Market Annual Summaries* (USDA). Finally, diesel fuel price data were obtained from annual issues of *Agricultural Prices* (USDA).

