Price Relationships Between Regionally Important Fresh Vegetable Markets*

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Introduction

Knowledge of lead-lag relationships between markets selling similar or identical commodities is of interest to industry participants such as retailers, wholesalers and producers, and to researchers concerned with interaction between and efficiency of those markets. Agricultural market applications have focused on temporal price behavior of selected commodity futures markets (Cargill and Rausser, 1975; Tomek and Gray, 1970). Leuthold and Hartmann (1979) demonstrated that the live-hog futures market could not be relied upon to reflect, on an accurate and consistent basis, subsequent cash prices. In other agricultural applications, Heien (1980) and Miller (1979, 1980) attempted to explain the lead-lag relationships between farm, wholesale and retail prices. Bessler and Schrader (1980) and Bessler and Brandt (1982) investigated causality between two price quotes for eggs and for cattle and hog prices, respectively. Adams et al. (1987) identified price relationships between adjacent market levels for shrimp size categories. However, the literature review revealed no applications of lead/lag analysis to interrelationships between important regional vegetable markets.

This article describes fresh vegetable price relationships in alternative wholesale markets in terms of whether prices tended to lead or lag one another. The markets are assumed to be nearly perfectly competitive. Shipment between markets after arrival at a market is unlikely. Market information is available on the produce industry at various levels from f.o.b. shipping point to retail, through private vendors and public sources such as USDA's Market News Service. Additionally, individuals in the trade use personal networks developed over time, which could be a source of information within and between the regional markets.

Leading and lagging markets may be hypothesized to be some function of several variables, including the trading of information between individuals in different markets; the increasing concentration of trade in relatively few hands (market power imbalances); and regional preferences that induce the trade to bid supplies of specific products away from other areas. These factors are beyond the scope of this analysis. Here our objective was to reflect and reveal differences that appear to have a geographic basis. Additional leads and/or lags that might be identified are, by implication, attributable to these other factors.

This paper has three parts. First, the methods for testing relationships between the price series from each market will be discussed. Next, the results and relationships between the markets will be presented. Conclusions and implications highlight important results.

*Approved for publication by the Director of the Louisiana Agricultural Experiment Station as publication number 88-05-2323.

Research Methods

A. Model and Hypothesis

The theoretical basis of this study is the efficient markets hypothesis. Pratt et al. and Leuthold and Hartmann assumed, in conjunction with this hypothesis, that information in the efficient market is shared or transferred, implying exchange between regional markets. Therefore, causal relationships may exist between these markets. "Following Granger, . . . variable X 'causes' variable Y, with respect to a given universe which includes at least X and Y, if current values of Y can be predicted better by using past values of X than by not doing so--all other information in the universe (including past values of Y) being used in either case" (Bessler and Brandt). The Granger definition of causality has been challenged by Jacobs (1979) and by Swamy and Muehlen (1987) on the statistical implications of whether a cause and effect relationship can be said to exist given the suggested procedure. Earlier, Granger and Newbold (1977) had suggested that the term "temporally related" could be more appropriate and descriptive. Granger's definition of lead/lag relationships does offer an empirically testable definition under certain restrictions and assumptions.

The general model of the relationship is a multivariate analysis whereby lagged price variables are regressed on other price series in a search for significant positive or negative relationships. The economic relationship assumed is described as a time lag causal relationship by Sullivan and Claycombe (1977). Independent variables are assumed to lead the dependent variable by some period of time. The model described can be expressed as:

$$Y_t = \beta_1 + \beta_n X_{n(t-1)} + \epsilon_t \qquad (1)$$

where:

Y_t = the dependent variable where subscripted values of (t) represent time

β_1 = the intercept for the equation

β_n = the coefficients for data series X_1, X_2, and X_3 which are the three market data series used as independent variables (where n = 1 to 3)

ϵ_t = a random disturbance term

The testable hypothesis can then be expressed as $\beta_1 = \beta_2 = \beta_3 = 0$, indicating that if any of the betas differ significantly from zero a causal relationship has not been ruled out and the null hypothesis can be rejected.

Further evidence of association between markets may be evaluated by a one-way test of causality. Geweke (1983) and Bessler and Brandt tested the Granger definition by using ordinary least squares regression on levels of the series--that is, a test of causality from X to Y would use the following specification:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \epsilon_t \qquad (2)$$

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 X_{t-1} + \epsilon_t \qquad (3)$$

where:

ϵ_t terms are random disturbances

β_1 = the coefficient relating Y_t and its lagged value for one period

β_2 = the coefficient relating Y_t with the lagged value of X

The direct Granger test based on equations (2) and (3) is equivalent to testing the null hypothesis, $\beta_2 = 0$, with the F statistic:

$$F = \frac{SSE_1 - SSE_2}{q} \Big/ \frac{SSE_2}{N - q - p - 1}$$

where:

SSE_1, SSE_2 = the sum of squared errors from OLS regressions on (2) and (3)

N = the number of observations for Y_t

q = the number of lag periods of Y_t in equation (2)

p = the number of lag periods for X_t in (3)

Here, q = p = 1, where one lag identifies price in the previous week. Calculated values above the critical F value signal rejection of the null hypothesis. Models were estimated from first differenced data.

Lag values of one (1) were based on two criteria. For perishables, short lags appeared more appropriate. Daily price information, which would have been more revealing, was not available. Simple correlations of weekly price declined appreciably at two-week compared to one-week lag periods, implying that the shorter lag would be more appropriate.

Table 1

Descriptive Statistics for Selected Vegetable Prices
At Four Regional Markets, Weekly Data, 1980-1986

	Potatoes			Tomatoes			Broccoli		
Location	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.
Atlanta	6.76	1.94	28.78	9.33	2.98	31.94	8.41	1.45	19.53
Dallas	8.42	2.18	25.91	8.13	2.63	32.28	7.83	1.34	18.74
Chicago	6.18	2.46	39.82	8.82	3.04	34.48	8.38	1.63	17.08
St. Louis	6.05	2.15	35.63	8.94	3.06	34.15	8.30	1.56	17.23

C.V. is an abbreviation for coefficient of variation.
The number of observations in each series is 364.
Each mean value is reported in dollars per unit.

B. Data

Data were obtained from USDA Market News Service fresh vegetable reports for selected cities and years (USDA, 1980-86) and consisted of weekly prices from 1980-86 for the Atlanta, Chicago, Dallas, and St. Louis wholesale markets. An objective in constructing the data set was evaluation of the competitive position and market penetration potential of southern producing areas. These cities are major regional markets and are closer to southern growers than to West coast or Mexican sources, implying some competitive advantage on truck charges. The data represent a weekly quotation at each market. A market news reporter gathers price data daily. The daily reports form the basis for daily, weekly and annual reports. Each reporting office chooses a day whose price is used as the weekly price. Three commodities were chosen for analysis: broccoli, 14s, 20 lb. box iced; round red potatoes, 50 lb. sack; and tomatoes, 20 lb. lug, 5x6s, turning.

Results

Descriptive price statistics are included to provide basic information (Table 1). These prices should reflect production, transportation and marketing costs in addition to any regional differences in demand and market influence or leadership. The mean price of potatoes was considerably higher in Dallas at $8.42 than in the other three markets. The other three cities were relatively close in price, with Chicago and St. Louis exhibiting the greatest relative variation about the mean.

For tomatoes, the mean prices in Chicago, St. Louis and Atlanta were closely grouped, while Dallas had the lowest average price at $8.13 and standard deviation at 2.63. Chicago and St. Louis showed the largest coefficients of variation while Atlanta had the highest overall mean.

The broccoli price pattern was similar to that of tomatoes. The Dallas price was lowest while the other three price averages were similar. Standard deviation was lowest at Dallas. Compared to the other two commodities, both measures of price variability were lower for broccoli.

Autocorrelation as measured by the Durbin-Watson statistic did not appear to affect seriously the reliability of coefficient estimates (Table 2). All values are in the acceptable range for the three commodities in the Chicago, Dallas and St. Louis models. The Atlanta models for tomato and broccoli were in the critical range at the 0.05 level of confidence, but were quite close to the critical value. Choosing a level of 0.10 would have placed the statistic within the acceptable range. In this exploratory study, the 0.10 level could be used since the cost of accepting a null hypothesis when it is not true (finding significance when there is none) is greatly outweighed by the benefit of alternative sets of market evaluation information.

Table 2

Multiple Regression Results for Determining Wholesale Vegetable Price Relationships

Independent Variables (lagged markets)	Dependent Variable: Atlanta	Chicago	Dallas	St. Louis
		POTATOES		
Atlanta		.101* (0.050)	.032 (0.063)	.149* (0.064)
Dallas	.090*[a] (0.044)	.023 (0.042)		.015 (0.053)
Chicago	.136* (0.054)		.143* (0.065)	.072 (0.066)
St. Louis	-.001 (0.044)	.175* (0.042)	.124* (0.052)	
F value	4.22*	8.47*	4.31*	3.03*
R^2	0.03	0.06	0.03	0.02
Durbin Watson[b]	2.09	1.82	2.12	2.11
		TOMATOES		
Atlanta		-.066 (0.058)	.020 (0.065)	-.005 (0.062)
Dallas	.203* (0.044)	.328* (0.052)		.415* (0.054)
Chicago	.146* (0.054)		.023 (0.070)	-.133* (0.058)
St. Louis	.068 (0.051)	-.013 (0.051)	-.081 (0.065)	
F value	22.35*	14.99*	0.63	19.49*
R^2	0.15	0.11	0.005	0.14
Durbin Watson[b]	2.45	2.30	2.08	2.35
		BROCCOLI		
Atlanta		-1.179* (0.074)	-.259* (0.051)	-.292* (0.067)
Dallas	.010 (0.058)	.336* (0.080)		.378* (0.073)
Chicago	.186* (0.059)		.120* (0.057)	-.102* (0.050)
St. Louis	.206* (0.065)	.008 (0.061)	.139* (0.062)	
F value	18.866*	6.255*	11.34*	10.68*
R^2	0.14	0.05	0.09	0.08
Durbin Watson[b]	2.51	2.37	2.23	2.23

[a]Coefficients and standard error (in parentheses).
[b]The range for the Durbin Watson where rho = 0 is 1.61 to 2.39 for k = 3 and n = 362.
*Significant at the .05 level.

This study has been structured to identify price differences that are of geographic origin. More than 50 percent of potato shipments in an average year originate in nine northwestern states (USDA/ERS, 1987). Thus price reactions at destination markets should occur first in the more western markets of Dallas and St. Louis, and last in Atlanta. Other production areas, specifically seven northeastern states with over 10 percent of production, may affect price patterns. Results indicated that Atlanta was influenced by Dallas and Chicago; Chicago by Atlanta and St. Louis; Dallas by Chicago and St. Louis; and St. Louis was influenced only by the Atlanta market (Table 2). These results suggest that origin is a factor in price leads and lags. The Granger one-way tests tend to confirm the initial analysis, with Atlanta price significant only for St. Louis; Chicago significant for Atlanta and Dallas; Dallas significant only for Atlanta; and St. Louis was a significant influence on both Chicago and Dallas (Table 3).

Changes in price seem to flow from west and north toward the east and south. The St. Louis market may be the first market to receive and report information from the Northwest. However, the Atlanta market affects the St. Louis market, while the Dallas market affects the Atlanta market. This pattern suggests that other factors apparently are operating to create the price leads and lags. Two possible explanations are that each market is looking at different markets to obtain information from the two production areas, or the uncertainty of information from the two production areas influences each individual market to view the other as an information source about the alternative production areas.

The regression analysis of influence of lagged prices can show, in addition to the influences on specific markets, those markets which appear to be more dominant. Reading across Table 2 by city, the number of times each city was a significant impact on the other three cities can be ascertained. With respect to potato markets, the Chicago market has a significant influence on the Atlanta and Dallas markets. This influence is intuitively appealing given the relative proximity of the Chicago market to both major and minor producing areas. The St. Louis market is significant for both the Chicago and the Dallas market price series, and the Atlanta price influences both Chicago and St. Louis. These three markets seem to be equally influential.

Tomato price patterns would be affected by flows from production areas in California throughout the summer, and from Mexico and Florida in the winter season. The analysis indicates that Atlanta was led by Dallas and Chicago; Chicago by Dallas; Dallas was not influenced by other markets in this group; and St. Louis was led by Dallas and by Chicago. Thus geographic flow and transportation cost are price components. In the one-way tests, Atlanta leads none of the markets; Chicago leads only Atlanta; Dallas leads all three other markets; and St. Louis leads both Atlanta and Chicago. The estimated coefficients measuring the influence of the Dallas market were among the highest in absolute magnitude and significance. The initial analysis appears to be confirmed by the one-way Granger causality test; changes in prices occur in the more western markets of Dallas and St. Louis first. The Dallas market, closest to Mexican suppliers, exhibits a strong relationship with the other three markets. The Atlanta market price series had no influence on other markets. The St. Louis market appears to have a significant impact on the Atlanta and Chicago prices, and the Chicago series affects only the Atlanta market.

The most influential market of the group as measured by number of significant influences on other market price series was Dallas, which led all the other markets. Chicago was important to two other markets; the Atlanta and St. Louis markets exhibited no significant leads or lags over any other market included in the analysis.

Broccoli price pattern influences are derived from geographic origins similar in direction to but probably more concentrated than tomatoes. California, with a range of climates that provides the option of production across the entire year, provides the vast majority of production for the fresh market. The expected relationship is that price leadership would be indicated in the western markets. Thus we find that the Atlanta price is led by Chicago and St. Louis; that Chicago is lagged by Atlanta and led by Dallas; that Dallas is lagged by Atlanta and led by Chicago and St. Louis; and that St. Louis is lagged by both Atlanta and Chicago and led by Dallas. For Dallas to be lagged by Atlanta was expected, although the significant leads by Chicago and St. Louis were not. For Dallas and Chicago, a lead relationship is found in both directions. In terms of the Granger one-way test, we find that Atlanta price leads Dallas; that Chicago leads Atlanta and Dallas; and Dallas and St. Louis lead each of the three alternative markets. These latter results are consistent with transportation flows hypothesis, since the western city markets lead the more eastern markets. The Atlanta and Chicago markets appear to be

Table 3

One-Way Granger Causality Tests for Vegetable Prices in Selected Terminal Markets

	Potatoes		Tomatoes		Broccoli	
Direction	F-Test	D.W.	F-Test	D.W.	F-Test	D.W.
ATL → CHI[ab]	3.24	2.01[c]	0.07	2.00	2.07	2.08
ATL → DAL	2.44	2.00	0.06	2.01	3.86*	2.10
ATL → STL	8.07*	2.01	0.37	2.02	1.53	2.05
CHI → ATL	8.20*	2.03	43.02*	2.14	77.49*	2.08
CHI → DAL	7.12*	2.02	0.00	2.01	16.35*	2.05
CHI → STL	3.37	2.04	3.31	2.04	0.039	2.06
DAL → ATL	5.97*	2.01	48.00*	2.18	53.96*	2.20
DAL → CHI	0.43	2.01	54.48*	2.07	24.79*	2.13
DAL → STL	0.88	2.00	83.87*	2.08	12.25*	2.08
STL → ATL	0.03	1.99	37.41*	2.10	80.26*	2.18
STL → CHI	19.25*	2.01	10.64*	2.01	12.37*	2.12
STL → DAL	7.00*	1.99	0.54	2.00	16.68*	2.10

[a]Abbreviations are as follows: ATL = Atlanta; CHI = Chicago; DAL = Dallas; STL = St. Louis.

[b]The arrow indicates the direction of causality.

[c]The range for the Durbin Watson where rho = 0 is 1.61 to 2.39 for k = 3 and n = 362.

*Denotes F statistic above critical value at 5% level: $F_{.05}(1,359) = 3.84$ (see equation 4 for further explanation).

most influential--a significant relationship was found in all cases. However, both Dallas and St. Louis were significant influences on two other markets. The broccoli markets appear more closely interrelated, compared to the potato or tomato markets.

Analysis of broccoli models generally indicate a more distinct geographic flow. For example, Atlanta price significantly lags the other three markets. From the one-way tests, Dallas and St. Louis have an influence on each of the markets east of themselves. Atlanta and Chicago do not exhibit as much breadth of lead/lag relationships, although there is some evidence of a similar recursive factor between the two as illustrated in the tomato market.

Discussion

The descriptive statistics shown are noteworthy because they reflect basic differences in production, transportation and marketing costs. In addition, these prices may reflect regional differences in demand and supply relationships at the regional markets.

The Dallas average market price for potatoes was more than $1.50 above the Atlanta market, which itself was half a dollar higher than the Chicago and St. Louis markets. Dallas is about as close to northwestern production as is Chicago, although northeastern sources and production areas in Lake states are much more distant. Thus location of production in the northern tier of states gives Chicago and St. Louis lower transportation cost compared to Dallas and Atlanta. However, this does not provide an explanation for the large price difference between the latter two markets.

For tomatoes and broccoli, the average prices seem better explained by transportation cost differences. In both cases, the largest producers of tomatoes for fresh consumption are California and Mexico, with the implicit transport savings reflected in the averages. The Dallas price was lowest for both commodities while the other three markets were rather similar.

Results from analysis of potato markets are unclear. The Chicago market influences the Atlanta and Dallas markets. This is intuitively appealing, given the relative proximity of the Chicago market to both major and minor producing areas. The Atlanta market is significant for both northern markets, whereas the Dallas market is significant only for the Atlanta market. The St. Louis market is significant for both the Chicago and the Dallas market. The pattern suggests a reverse flow of information. Chicago, St. Louis and Atlanta appear to be trading information, perhaps recursively. The effects of broadly based production may cloud these results. While the patterns of price leads suggested by product flows can be seen, there appear to be other factors at work. Other possibilities are the gathering and filtering of price information through alternative markets, the activity of trader information networks or the influence of coordinated activity by chain food stores.

The tomato and broccoli market leads and lags largely mirror each other and better illustrate the geographic flow. There are more significant influences for broccoli than for either potatoes or tomatoes. Generally, price influences in the tomato markets tended to flow one way while those for broccoli flowed both ways. In these two markets Dallas was the price leader while Atlanta prices lagged but seldom led other markets. For tomatoes, even the northern markets of Chicago and St. Louis led Atlanta, while there was no clear relationship between Chicago and St. Louis. The Chicago-Atlanta relationship may be spurious or it may be due to the difference of trade activity occurring. The Chicago market may trade more often or in larger quantities and, therefore, may react to changes occurring in the market place prior to the Atlanta market.

For broccoli, more of the estimated price influences were significant compared to potatoes and tomatoes; only the Atlanta-Dallas and the Chicago-St. Louis relationships were not significant. The uni-directional indication that each market tends to influence the others leads to some confusion in interpretation of results; however, the flow patterns were generally as expected.

Summary and Implications

Summary

A theoretical background for relationships between price data obtained at regional markets was established. Statistics describing the three commodities were presented. The hypothesis that lead/lag relations exist between regional markets was tested using both a multivariate and a Granger causality (one-way) approach. Significance and signs of coefficient estimates generally appeared to support the product flow hypothesis for the markets over the time period presented, while other flows of information were revealed that would indicate alternative explanations such as information exchange and regional demand factors. Although the potato price relationships are less clear, price patterns for tomatoes and broccoli in particular support the hypothesized relationships.

Implications

The procedure employed in this paper has important implications for individuals who buy and/or sell produce. Though the data were limited by the use of weekly rather than daily reports, the economic relationships generally were supported. Other patterns, which were not the current object of study, may be extracted from other applications of this procedure. However, the following observations seem warranted. First, the industry should expect to make price evaluations on individual products rather than generalizations across products. For each product, specific markets may have a lead or lag relationship with other markets, providing information to those with knowledge of past relationships. This statement, however, should not be construed to exclude analysis of groups of products that have similar characteristics and patterns. The similarity of outcomes between tomato and broccoli provides such an example. Secondly, these results should prove useful in development of price expectations and may have implications for offers and counter-offers. Finally, buyers and sellers constantly search for information through established information networks and other ways. Evaluation of methods that lend themselves to analysis of information quality such as lead/lag analysis should enhance the acquisition of and confidence in information from alternative sources and geographic areas.

In several studies reviewed strong causal factors were not found when there were theoretically strong economic relationships, implying that the absence of unambiguous relationships in this study should not result in rejection of the approach. Further attempts to clarify the relationships for the markets may include additions to or deletions from the set of markets currently under consideration. Further research into the effects of quantity of goods sold at the markets and application of the approach using other vegetables with similar supply characteristics may also prove useful.

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