Asymmetry in Retail, Wholesale, and Shipping Point Pricing for Fresh Vegetables

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The linkage among retail, wholesale, and shipping point prices for a select group of fresh vegetables is measured using Wolffram's asymmetry model. Procedures for dealing with discontinuous time series are shown, and Granger's causality test is used to show the direction of the price linkage. Wholesale prices are shown to lead both retail and shipping point prices. Asymmetry in the retail-wholesale response indicates that wholesale price decreases are reflected at the retail more so than are wholesale price increases. Wholesale price decreases are more fully passed through to the shipping point relative to wholesale increases.

Key words: asymmetry, fresh vegetables, prices, retail-wholesale-shipping linkage.

The linkages among retail, wholesale, and shipping point prices continues to be of considerable economic interest. As raw food products are transformed through packaging, distribution, and related services, the evidence of direct relationships among prices at different levels of exchange becomes increasingly difficult to evaluate. The extent of price change transmission through the vertical market system is particularly important at the end points. Producers view themselves as the residual claimants on the value of products, while consumers fear continually rising prices of many food items. Agricultural products having many uses and requiring considerable transformation should show weak price relationships among the exchange points. In contrast, price linkages should be stronger for perishable products requiring a minimal transformation.

Price leads and lags among retail, wholesale, and shipping points may arise, in part, because of differences in the assimilation of market information. Understanding these leads or lags is important to evaluating pricing efficiency among markets. The speed of price adjustments between vertical exchange nodes provides clues about structural rigidities and cumulative effects of price changes.

In this paper the price linkages among retail, wholesale, and shipping points will be analyzed in order to provide additional empirical evidence about price transmission. A distributed lag model is developed, and asymmetry in the price linkages is considered. The empirical analysis is limited to a few fresh vegetables, where price information is available at each point of exchange. Data include both continuous and discontinuous series, and econometric procedures for dealing with the data gaps are discussed. The vertical price linkages for fresh vegetables should be reasonably strong since these products have a limited number of uses and are transformed only via packaging. Since supplies are inelastic, shifts in demand should cause direct price adjustments throughout the vertical structure. The actual price responses will depend on the quality and timing of information received at each pricing level.

Price Transmission Model

Information exists throughout the market system and retail (R), wholesale (W), and shipping point (S) prices are some functions of this information. This information flow throughout the vertical system may not be equal and traders' abilities to assimilate and/or respond to market signals can differ at each exchange point. Structural differences and diversity at each level can influence how quickly prices

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reflect changes in market conditions. Clearly, the retail, wholesale, and shipping price series must be related since they are functions of the same basic information.

Complete quantification of market information is impractical and not essential to understanding pricing relationships. One can turn directly to the three price series. Arguments exist for both leads and lags among the three series. Most studies point to a causal linkage from shipping point to wholesale to retail (Heien, Silver and Wallace). Conditions can exist that suggest a different linkage. If the wholesale market quickly assimilates market signals from both consuming and producing points, the wholesale price may lead both the retail and shipping point prices. The period for measuring responses also would influence any measurement of leads. Likewise, product perishability may add importance to the wholesale function. Excess accumulation of perishable products at wholesale may directly affect shipping point prices. Ultimately, the existence of leads or lags is an empirical question and will be deferred until later.

Initially consider the situation where $R = f(W)$. The total retail response to wholesale price changes may not be immediate, but distributed over time. Heien suggested that the cost of making retail price adjustments and concern over pricing stability may create lags at retail. Furthermore, the response to rising prices at wholesale can differ from price declines. The retail market structure could be sufficiently oligopolistic so that price stickiness occurs, producing asymmetric response to wholesale price changes.[1]

Equation (1) illustrates the general case where the retail price is related to the wholesale price through a distributed lag function.

$$(1) \qquad R_t = \alpha_{0t} + \sum_{j=1}^{k} \alpha_j \, W_{t-j+1} + \epsilon_t.$$

If asymmetry occurs, then α_j differs depending on whether $W_t \gtreqless W_{t-1}$. Papers by Wolffram, Houck, and Young have dealt with estimating asymmetric parameters. Using Young's framework, equation (1) can be written as

$$(2) \quad R_t = \beta_{0t} + \sum_{j=1}^{k} (\alpha'_j \, W'_{t-j+1} + d''_j \, W''_{t-j+1}) + \epsilon_t,$$

where

$$W'_t = \sum_{i=0}^{t} (W_{t-i} - W_{t-i-1}) Z'_{t-i},$$

$$W''_t = \sum_{i=0}^{t} (W_{t-i} - W_{t-i-1}) Z''_{t-i},$$

$$Z'_{t-i} = \begin{cases} 1 & W_{t-i} \geq W_{t-i-1} \\ 0 & \text{otherwise, and} \end{cases}$$

$$Z''_{t-i} \quad \begin{cases} 1 & W_{t-i} < W_{t-i-1} \\ 0 & \text{otherwise.} \end{cases}$$

Using Gollnick's derivation, it also follows that (2) can be simplified to

$$(3) \quad R_t = \beta_{0t} + \sum_{j=1}^{k} [\alpha'_j (W_{t-j+1} - W_0) + (\alpha''_j - \alpha'_j) W''_{t-j+1}] + \epsilon_t.$$

The estimate of $(\alpha''_j - \alpha'_j)$ gives a direct test of the asymmetry condition.[2] Note that α'_j measures the response to rising wholesale prices, while α''_j relates to a declining wholesale price.

Polynomial lags can be adapted easily to the two distributed lag series in equation (3). If one is willing to assume that the peak retail response to a wholesale price change is immediate, then a first-degree polynomial is appropriate. Letting ϕ_j be some weighting of the lags, the polynomial in (4) could be incorporated into (3). Only four parameters are unknown in (4) in contrast to $2k$ unknown pricing parameters in (3). Hence, the estimation problem is greatly simplified with (4).

$$(4) \qquad \begin{aligned} \alpha'_j &= \lambda'_0 + \lambda'_1 \phi_j, \text{ and} \\ \alpha''_j - \alpha'_j &= \lambda''_0 + \lambda''_1 \phi_j. \end{aligned}$$

For some products, gaps in the price series

[1] The top four food retailers, on the average, held approximately 50% of the market in 218 major metropolitan areas in 1963. Concentration was above 65% in sixteen of the markets (Bucklin, p. 125). Little change in concentration has taken place since then (Grinnell 1980b, p. 7). Competition in retailing is a local and regional affair where firms are aware of the pricing tactics used (Bucklin, p. 130). In contrast to the oligopolistic argument, Baumol, Quandt, and Shapiro suggest that while lsupermarkets are aware of each other, they take no account of competitors' reaction because of cost, complexity, and data imperfections (p. 347). Also, see Grinnell for a recent discussion of food retailers' pricing policies (1980a, p. 10–11).

[2] Consider a simple model where $R_t = \pi_0 + \pi_1 W_t$. Wolffram's model, allowing for asymmetry, would be $R_t = \pi_0 + \pi'_1 W_t + \pi''_1 W''_t$, where W'_t and W''_t are defined in equation (2) of the text. Gollnick clearly shows that $W_t = W_0 + W'_t + W''_t$ or $W'_t = W_t - W_0 - W''_t$. Substitution for W'_t in the functional equations gives the estimable model $R_t = \pi_0 + \pi'_1(W_t - W_0) + (\pi''_0 - \pi'_1) W''_t$. This equation is simply expanded to a distributed lag form in equation (3) (Young, p. 178).

Table 1. *F*-statistic for Granger's Causality Test

	Prefilter[a] Level "k"	Retail → Wholesale		Wholesale → Retail		Wholesale → Shipping		Shipping → Wholesale	
		F-Statistic[b]	ρ	F-Statistic	ρ	F-Statistic	ρ	F-Statistic	ρ
Carrots (Chicago)	.00	.419	.278	24.891	.303	4.586	.533	3.434	.502
	.25	.652	−.218	14.861	−.135	4.156	−.024	2.235	−.061
	.75	1.046	−.592	3.664	−.631	.777	−.647	.545	−.621
	1.00	1.238	−.064	3.281	−.655	.707	−.669	.563	−.646
Carrots (New York)	.00	2.064	.224	3.544	.064	1.124	.321	1.914	.386
	.25	2.785	−.239	2.324	−.369	2.268	−.113	1.949	−.064
	.75	1.305	−.615	2.271	−.679	5.762	−.517	.364	−.504
	1.00	.919	−.638	2.631	−.699	6.309	−.542	.249	−.525
Celery (Chicago)	.00	3.037	.219	13.091	.193	8.803	.419	1.300	.233
	.25	3.978	−.156	8.582	−.184	6.199	−.253	1.387	−.235
	.75	4.030	−.439	3.472	−.539	2.803	−.573	.292	−.597
	1.00	3.278	−.566	3.997	−.559	2.865	−.591	.109	−.617

Note: The results for all series studied are available upon request (USDA). The only exception to the implied linkage occurred with some of the lettuce series where unidirectional relationships were indicated.

[a] See Bishop for a discussion of the filtering procedure.

[b] Sample sizes are reported in tables 2 and 3. In each situation comparison of the calculated F to a table $F \approx 3.00$ is near the 95% confidence level.

exist because supplies do not flow to market throughout the year. For example, if a product is marketed only during the first six months of each year, carryover effects would not occur during the initial months of each season. At each season's outset, the only relevant price information would be current wholesale prices. Later in the season, current retail prices may be influenced by prior wholesale prices. The distributed lag model specified earlier must reflect whether or not lagged information exists at period t^*. If t^* is the first period of a new season and the series is discontinuous, no lag information exists. During the next month, the price information from t^* would enter the analysis for $t^* + 1$. Likewise, during $t^* + 2$ both prices from t^* and $t^* + 1$ enter the analysis.

The presence or absence of prior information can be handled with dummy variables. If the distributed lag model is estimated with three lags, then three dummy variables can be defined to indicate if any particular lag should be included in the model. The dummy variables shown in equation (5) illustrate the concept for a season when a data gap exists between the last value of the prior season and the first value of a new season. Each row represents one observation containing the current period and three lags. Each D_j is multiplied times the corresponding W_{t-j+1} in (3), assuming three lags. W_t always enters the model, while W_{t-1} enters after the first period t^*. Finally, by the fourth period in the example, all three lags are included. The matrix $\mathbf{D}$ may differ with each commodity depending on the discontinuity of each series.

$$
(5) \qquad \mathbf{D} = \begin{array}{c} \begin{matrix} D_1 & D_2 & D_3 & D_4 \end{matrix} \\ \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} \end{array}
$$

Econometric Linkage Model

Instead of t observations as in equations (2) and (3), now assume that there are l seasons and t observations in each season. Each variable then carries the additional subscript l, and the relevant parameters are assumed constant across seasons (Wolffram, p. 358). With this model, the Wolffram asymmetric procedure starts over with each season. The starting value for W' and W'' is W_{t0}. Incorporating (4) and (5) into (3) and accounting for the various seasons, a general model for estimating the price linkage follows in equation (6).

Table 2. Asymmetric Price Linkage between Wholesale and Retail Prices

			Parameter Estimates[a]					
Commodity	Units	City	Intercept	H_1	H_2	H_3	H_4	T
Carrots	$/48-lb. bags	Chicago	10.9881	.8050	−.5482	−.1322	.1666	.0487
			(12.0633)	(6.6157)	(−3.9637)	(−.7173)	(.8681)	(1.3678)
Celery	$/60-lb. crate	Chicago	12.3069	.6188	−.2705	.4121	−.4411	.0392
			(11.0806)	(7.582)	(−2.5916)	(2.2306)	(2.2991)	(.6119)
Cabbage	$/50-lb. crate	Chicago	3.4523	.4850	.1060	.6136	−.3745	.0220
			(4.1516)	(2.5729)	(.4661)	(2.6100)	(−2.1933)	(3.0154)
Corn	$/crate	Boston	2.5296	.2259	−.0394	.5519	−.3805	.0278
			(5.8089)	(1.6135)	(−.2482)	(5.8992)	(−5.1458)	(6.3210)
Cucumbers	$1 ¼ bushel	New York	9.0729	.5439	−.4567	.0284	.1109	.0467
			(15.5350)	(10.5365)	(−7.4135)	(.4881)	(2.1028)	(7.8122)
Green peppers	$/30 lbs.	New York	8.9460	.4351	−.2154	.3153	−.2089	.0428
			(14.1133)	(7.1053)	(−2.6297)	(3.9133)	(−3.3428)	(6.8542)
Potatoes	$/100 lbs.	Los Angeles	6.4467	.5754	−.5113	.2969	−.1890	.0243
			(10.6001)	(3.3506)	(−2.5289)	(2.6525)	(−2.0573)	(2.8019)
Tomatoes	$/20-lb. carton	Chicago	4.2280	.5085	−.5049	.3803	−.2728	.0596
			(3.8856)	(4.5462)	(−4.0737)	(2.4714)	(−2.5729)	(7.7520)
Tomatoes	$/20-lb. carton	New York	4.2672	.3285	−.2702	.5776	−.3364	.0442
			(5.5065)	(3.1906)	(−2.4400)	(5.2482)	(−4.3107)	(4.6302)

Note: Data obtained from USDA.
[a] See equation (6) for interpreting H; t-values shown in parentheses.
[b] Mean lags and cumulatives are not calculated because H_2 was insignificant and of the wrong sign.

$$(6)\quad R_{lt} = \lambda_{0(lt)} + \lambda'_0 H_{1(lt)} + \lambda'_1 H_{2(lt)} + \lambda''_0 H_{3(lt)} + \lambda''_1 H_{4(lt)} + \epsilon_{lt},$$

where

$$H_{1(lt)} = \sum_{j=0}^{3} [W_{l(t-j)} - W_{l(0)}] D_{jl(t)'}$$

$$H_{2(lt)} = \sum_{j=0}^{3} [W_{l(t-j)} - W_{l(0)}] \phi_j D_{jl(t)'}$$

$$H_{3(lt)} = \sum_{j=0}^{3} W''_{l(t-j)} D_{jl(t)'}$$

$$H_{4(lt)} = \sum_{j=0}^{3} W''_{l(t-j)} \phi_j D_{jl(t)}.$$

While (6) is illustrated assuming the retail market lags the wholesale market, a precise test of the leads or lags for both retail and shipping points must be made.[3] Furthermore, the function ϕ_j must be specified.

Retail, wholesale, and shipping point price data on seventeen fresh vegetables were included in the study. Retail prices from a number of cities were reported for some of the vegetables. Of these, carrots, celery, and lettuce were the only fresh produce supplied continuously throughout the season. Empirical evidence for measuring leads or lags can be made using Granger's causality test on these continuous series (Bishop). Granger's test presumes that causality may flow in either direction between two variables (Granger). Applying the Granger procedure and using the appropriate F-test, the direction of causality becomes clear. Table 1 includes the F-values calculated for causality between retail-wholesale and wholesale-shipping point.

Although a total of eleven continuous data series was available, only a sample of the Granger tests are reported in table 1. The empirical evidence from table 1 and from results not reported suggests that retail prices tend to lag wholesale prices. Such results are consistent with most other studies (Heien, Silver). In contrast, the results for the wholesale-shipping point analysis suggest that the wholesale price series led shipping point prices. Wholesale markets are generally more concentrated, and information can be more readily assimilated. In contrast, shipping points are generally diverse, and information flows are less complete. Although beyond the scope of this analysis, a detailed study of buyers versus seller concentration could add more insight into this observed relationship. Also, the geographical concentration of suppliers likely would influence this price linkage.

The monthly leads must arise where information is first and most quickly assimilated. While some exceptions are evident, the lead linkage from wholesale to both retail and shipping points is assumed for the remaining analysis.[4]

[3] Each H is derived by summing over j. It will always be true that $D_{jl(t)} = 0$ when $j > t$.

[4] Monthly retail prices are the averages over Tuesday, Wednesday, and Thursday's prices for each week within a month. Wholesale prices are averaged over each Tuesday's price for the same week that retail prices are collected. The shipping point price is the monthly average of the prices for each week preceding the wholesale and retail prices. Hence, the monthly shipping point

Table 2. (Continued)

Statistics			Season		Mean Price			Mean Lag		Cumulative	
Observed	R^2	F	1st	Last	Retail	Wholesale	Shipping	Rising	Falling	Rising	Falling
114	.886	173.19	Jan	Dec	10.361	6.144	4.306	.443	.816	1.191	1.279
120	.885	179.94	Jan	Dec	13.515	7.305	4.150	1.079	.405	1.474	1.489
63	.792	43.31	Dec	May	8.816	4.357	2.829	*b	*	*	*
46	.861	49.45	Jan	June	7.929	5.536	3.881	1.381	.882	.758	1.557
74	.826	64.69	Nov	May	16.004	10.148	7.668	.138	.714	.631	1.009
69	.831	62.04	Jan	June	16.147	9.909	8.015	.976	.820	.943	1.431
77	.509	14.74	Sept	Apr	10.588	6.522	4.545	.100	.165	.639	1.044
42	.764	23.32	Jan	May	10.052	7.138	5.816	.007	.111	.512	.999
47	.805	33.97	Jan	May	12.371	8.122	6.034	.151	.491	.387	1.378

The polynomial specification in equation (4) implicitly assumes that the peak effects occur at the outset followed by a smooth decline. Preliminary results consistently suggested a geometric decay function. While a range of values for ϕ_j that have similar geometric decay properties can be adapted to (4), the final specification is where $\phi_j = \sqrt[3]{j}$ and $j \geq 0$ (Ward and Myers, p. 5). Using this specification, $\partial\alpha'_j/\partial_j < 0$, $\partial^2\alpha'_j/\partial_j^2 > 0$, $\partial\alpha''_j/\partial_j < 0$, and $\partial^2\alpha''_j/\partial_j^2 > 0$. The carryover effect from previous price levels declines from the outset. Both α'_1 and α''_1 represent the immediate effect of price changes at wholesale.

The empirical results using equation (6) with a subset of fresh vegetable data are reported in tables 2 and 3, table 2 giving the wholesale-retail linkages and table 3, the wholesale-shipping point relationship.[5] In both tables, parameter values for H_1 and H_2 correspond to λ'_0 and λ'_1 from equation (4), and H_3 and H_4 correspond to λ''_0 and λ''_1. The first two equations are for commodities with continuous data sets, while the remaining estimates are based on discontinuous data. In general, the results were consistent across the items studied, and all statistical values can be readily interpreted in terms of significance and economic implications.

Asymmetric Linkage

The significance tests on H_3 and H_4 in tables 2 and 3 are direct tests of asymmetry in retail and shipping point price responses to wholesale price changes. The immediate effect of a wholesale change is α'_1 for rising prices and α''_1 for falling prices, where $\alpha'_1 = \lambda'_0$ and $\alpha''_1 = \lambda'_0 + \lambda''_0$. The retail results, without exception, lead to one of two conclusions. Either the responses are symmetric, or retail markets respond more to declining wholesale prices than to rising prices. Symmetry in the initial period exists for the carrot and cucumber markets, but H_3 is positive and significant for the remaining items. Even though retail responses vary across commodities, the general conclusion of significant asymmetry holds for the majority of products studied.

The asymmetric responses provide new insight into the performance of the wholesale-retail market for this commodity sample and, possibly, for perishables in general. First, the models point to some retail resistance to price rises.[6] This may be explained partially by re-

price is based on an average over a weekly series that lags the retail and wholesale by one week.

Some bias in the relationship between prices at different exchange points could arise with this weekly lag. Suppose that prior results suggest that Y_t leads X_t and the data are reported in three alternative series, i.e., (Y_t, X_t), (Y_t, X_{t-1}), or (Y_t, X_{t+1}). Using Granger's causality test, the first series would have no effect on the results, the second series would be biased against the prior lead of Y_t over X_t, and the third series would be biased in support of the lead. Subsequent analyses will show that the wholesale price (e.g., Y_t) leads the shipping price (e.g., X_t). Both are monthly averages but the X series does have a one week built-in lag. If the week lag affects the results, it is biased against showing that Y_t leads X_t. Also, the Granger test relates to monthly leads and lags, while the differences in series is limited to one week. Most of the effects of one week is likely averaged out when calculating the monthly average.

[5] Only a subsample of fresh produce results are reported in tables 2 and 3. Since most estimates not reported were similar to those reported, this subsample is adequate for presenting the study's general conclusions.

[6] One may question this result since, in general, supermarkets often price using standard margins over invoice cost. Holdren's studies showed that for fresh fruits and vegetables the pricing formula was much less structured (p. 85). Most produce prices are not highly competitive, margins are high, and price dispersions are wide across firms. Asymmetry in the wholesale-retail margin is discussed in Holdren, where greater differences are seen with the more aggressive firms (p. 93–94).

Table 3. Asymmetric Price Linkage between Wholesale and Shipping Point Prices

			Parameter Estimates					Statistics			Mean Lag		Cumulative	
Commodity	City	Intercept	H_1	H_2	H_3	H_4	τ	Obs.	R^2	F	Rising	Falling	Rising	Falling
Carrots	Chicago	5.4102	.6663	−.5569	−.1098	.1347	.0143	117	.842	118.51	.141	.257	.776	.715
		(11.7258	(10.8111)	(−7.9506)	(−1.1768)	(1.3851)	(.7933)							
Celery	Chicago	4.8053	.5074	−.3072	.2566	−.2639	.0185	129	.843	132.14	.711	.282	.893	1.001
		(8.6805)	(10.6146)	(−5.2526)	(2.4660)	(−2.4766)	(.5358)							
Cabbage	Chicago	.8008	.5304	−.2334	.3913	−.2506	−.0028	64	.729	30.79	1.074	.915	1.258	1.895
		(1.7082)	(4.9918)	(−1.8199)	(2.9520)	(−2.6033)	(−.6834)							
Corn	Boston	1.2132	.4566	−.3890	.2569	−.1923	.0150	55	.801	38.53	.129	.156	.524	.846
		(3.6187)	(5.5910)	(−3.9301)	(3.6938)	(−3.5708)	(4.7473)							
Cucumbers	New York	4.5883	.5655	−.5171	−.0071	.0650	.0129	55	.742	39.09	.079	.160	.614	.665
		(8.0132)	(11.1726)	(−8.5620)	(−.1248)	(1.2580)	(2.2053)							
Green peppers	New York	4.8194	.6976	−.5698	.0145	.0056	.0096	69	.793	48.18	.155	.175	.825	.861
		(7.1722)	(10.7453)	(−6.5634)	(.1703)	(.0840)	(1.4461)							
Potatoes	Los Angeles	2.1681	.5264	.4108	.3140	−.1815	−.0037	75	.615	22.04	.205	.369	.651	1.183
		(5.8939)	(5.0689)	(−3.3577)	(4.6185)	(−3.1910)	(−.6895)							
Tomatoes	Chicago	1.4670	.5776	−.5465	.4167	−.2505	.0107	45	.647	14.33	.051	.166	.609	1.192
		(2.2078)	(6.1856)	(−5.2698)	(4.5057)	(−3.8610)	(1.6203)							
Tomatoes	New York	1.1229	.4359	−.4003	.4406	−.2350	.0056	47	.729	22.09	.075	.330	.472	1.194
		(1.8554)	(5.4196)	(−4.6286)	(5.1771)	(−3.8558)	(.7564)							

sistance to raising the price of perishable products that require high turnover. Rising prices could reduce retail sales and increase the incidence of spoilage. Second, an oligopolistic structure among large retail outlets suggests upward price stickiness and, hence, resistance to price increases.

Consumers generally can expect to benefit immediately from falling wholesale prices because price decreases tend to be rapidly passed through to retail. In contrast, price increases are passed through to a much lesser degree during the same period. The retail price response to falling wholesale prices is particularly important to industries which rely on price promotions initiated at the wholesale level since the lower prices generally would be passed on to the consumer. On average, the retail response to rising wholesale prices in the current period is approximately 50% of the retail response to equivalent falling wholesale prices.

Asymmetry is also evident in the wholesale-shipping point relationships, table 3. The estimators indicate that wholesale price decreases are more fully felt at the shipping point than are price increases. Recall that only the current period effect is being considered. In contrast to the results showing the consumer to benefit potentially from asymmetry, this latter linkage should raise concern among producers since the results suggest that wholesale price increases are not immediately passed back to the shipping point to the same degree as are decreases.

Lag Distribution

The lag distributions in equation (4) were specified as a first-degree polynomial, where $\phi_j = \sqrt[3]{j}$. Evidence of lag responses between retail and wholesale differed depending on whether wholesale markets were rising or falling. The existence of a lag during rising markets was questionable for cabbage and corn, while evidence of some decay remained apparent for the other products. In contrast, significant lag responses were observed for every item during periods of falling prices.

Considerable differences in lag responses occur across commodities, as shown by the differences in mean lags, tables 2 and 3 (Pindyck and Rubinfeld, p. 232). In all cases, the carryover effect is generally small, ranging from nearly zero for tomatoes to more than a one-month mean lag for corn. In most cases, decays are generally very rapid. Similar mean lags appear for the shipping point-wholesale markets, table 3. Again, the carryover price effect is small. In general, the major responses to wholesale price changes is immediately evident at both retail and shipping points.

The cumulative effect of a wholesale price change was calculated as either $\sum_{j=1}^{\max 4} \alpha'_j$ for a rising market or $\sum_{j=1}^{\max 4} \alpha''_j$ for a falling market. Each summation was taken over the α_j values up to the point where $\alpha'_j < 0$, $\alpha''_j < 0$, or $j = 4$, whichever occurred first. These cumulative effects are shown in tables 2 and 3. Without exception, the cumulative effect on the retail market was greater for declining wholesale prices. That is, for this sample of commodities, the model indicates that the full price decline eventually is reflected in retail price changes. In contrast, a wholesale price increase is not always fully reflected at the retail. The New York fresh tomato market is particularly noteworthy because the difference between the cumulatives is quite large.

The differences in cumulatives for the shipping point, table 3, are not as pronounced as the wholesale-retail differences. In general, the asymmetry results at the shipping point indicate that declining wholesale prices tend to be more fully passed through to the shipping point than for wholesale price increases. However, the difference is minimal for several of the products.

Spread Adjustments

The final model included a trend adjustment to measure the tendency for spreads between wholesale, retail, or shipping point prices to change. This is shown by T in both tables 2 and 3. The empirical results clearly show that the retail-wholesale price spread has widened over time. This is as expected because of the increases in service and distribution costs. Spread adjustments between the shipping point and wholesale markets are mixed and most T parameters are statistically insignificant. It is apparent that the major portion of the spread increase from shipping point to retail is occurring at the retail end.

Summary

This price linkage model used Wolffram's asymmetry procedure with a distributed lag model estimated over continuous and discontinuous data series. Price transmission measurements were made for a subset of fresh vegetables. The results show that the wholesale market tends to be a major node for pricing. Both retail and shipping point prices generally lag wholesale price changes.

The asymmetric results are particularly interesting because they suggest a deviation from the traditional concept of constant percentage markup. For this sample of fresh vegetables, the evidence clearly shows that price changes are not transmitted throughout the vertical system, at least not in the same time period. Wholesale price increases are not totally reflected at the retail, whereas retail prices tend to adjust to lower wholesale prices. In contrast, shipping point prices tend to reflect more fully wholesale price decreases relative to increases.

The analysis offered alternative reasons for the asymmetry, ranging from the structural considerations to the nature of the products. Perishability may be a major contributing factor.

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