Incorporating Seasonality, Product Volume, and Shiller Lags into a Price Lingake Model

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Abstract:
The price transmission model is extended by incorporating seasonality and Shiller lags. Symmetry is evaluated for the length of the adjustment as well as the amount. Retail/shipping point tomato prices are used to test the model. Transmission elasticities are estimated. Results suggest this market is efficient.

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A large body of research has focused on empirical tests to examine symmetrical price response between the farm and retail levels. The Houck procedure for estimating nonreversible functions has served as the basis for most of these studies. This methodology has been extended and applied across a variety of commodities (e.g., Boyd and Brorsen, Griffith and Piggott, Heien, Kinnucan and Forker, Mohamed et al., Pick et al., Powers, and Ward,).

Several limitations are inherent in these studies. First, firms are assumed to operate under constant returns to scale, but this precludes the possibility that retailers of highly perishable products adjust their prices as the volume of product harvested changes or that the parameters of the consumer demand function may change. Second, except for Griffith and Piggott, studies of price symmetry have implicitly assumed the estimated price transmission parameters do not vary seasonally. Griffith and Piggott used the traditional dummy variable slope shifter method of accounting for seasonality, which can be costly in terms of losing degrees-of-freedom. Recent work has offered a solution for this problem (e.g., Lambregts and Capps and Herrman et al.). However, to consider lagged effects of independent variables, these approaches also result in losing degrees-of-freedom. In addition, the Griffith and Piggott approach does not allow for differences in the harvest cycles of commodities across years (primarily due to weather).

A Price Linkage Model

Polynomial distributed lags have been used to account for the lagged effects of a particular independent variable (e.g., Ward, Kinnucan and Forker, and Boyd and Brorsen). Shiller developed a less restrictive procedure in which the troublesome decision of choosing the polynomial degree is replaced by a set of parameter restrictions that are stochastic.

Heien developed the theoretical underpinnings of the markup model. For an efficient market, lags in price linkages should equal the amount of time necessary to move the product from one level to the next, else price adjustment is inefficient (Powers). Retail level product is assumed to be marketed using fixed proportions. Firms are assumed to operate under constant returns to scale, which implies constant marginal costs. Firms are also considered to operate under competitive market structures.

The direction of causality for the markup model is considered to be from shipping point to retail levels. Methods for testing causality (e.g., Granger) have been shown to be misleading and unreliable (Conway et al.). Furthermore, previous studies of vertical price linkages in fresh produce that used the markup model have specified retail prices as functions of price movements at lower market levels (e.g., Ward, Pick et al., Mohamed et al., and Powers).

The Houck procedure allows for separate lags for increases and decreases in upstream price changes. For the ith commodity:

$$RP_{i,t} = \sum_{m=0}^{r} \delta_{1,i,m} SPR_{i,t-m} + \sum_{m=0}^{f} \delta_{2,i,m} SPF_{i,t-m} + \sum_{m=0}^{r^*} \delta_{3,i,m} TCR_{i,t-m} + \sum_{m=0}^{f^*} \delta_{4,i,m} TCF_{i,t-m} + e_{i,t} , \qquad (1)$$

where RP = retail price change from period 0 to period t, SPR = sum of all week-to-week increases in the FOB shipping point price from period 0 to period t, SPF = sum of all week-to-week decreases in the FOB shipping point price from period 0 to period t, TCR = sum of all week-to-week increases in transportation costs from period 0 to period t, TCF = sum of all week-to-week decreases in transportation costs from period 0 to period t, r = lag length for rising prices, f = lag length for falling prices, r^* = lag length for rising costs, f^* = lag length

for falling costs, and *e* is a random error term with the traditional assumptions.

To account for the different yearly seasonal effects, a vector *j* can be defined and assigned integers exogeneously based on variations in the data from year to year. Defining *j* in this manner can be interpreted as inserting a priori information into the estimation process, because weather patterns and other conditions affecting immediate production plans and harvest projections can be predicted with a fair amount of accuracy.[1] This allows the constant returns to scale assumption to be relaxed, since the volume of shipments will now be a variable in the price transmission process.

Equation (1), reflecting the information in *j*, can be rewritten as

$$RP_{i,t} = \sum_{m=0}^{r} \delta_{1,i,m}(j * SPR_{i,t-m}) + \sum_{m=0}^{f} \delta_{2,i,m}(j * SPF_{i,t-m}) + \sum_{m=0}^{r^*} \delta_{3,i,m} TCR_{i,t-m} + \sum_{m=0}^{f^*} \delta_{4,i,m} TCF_{i,t-m} + e_{i,t} \ . \quad (2)$$

The marginal effects depend on the volume of shipments. Use of the Shiller procedure with seasonally varying dta produces an additional modeling advantage concerning the effects of weather. There are currently no methods available to account for the effects of weather. However, requiring a model's seasonal parameters to vary smoothly can be regarded as a way of approximating the average effects of weather on the parameters (Gersovitz and Mackinnon).

The Shiller approach for incorporating lag structure into a regression model constrains the parameter means, instead of the parameters themselves. This permits a more flexible lag structure compared to prior approaches and thus constitutes a better representation of prior

[1] The value of *j* is assigned according to the level of shipments, which in the empirical work that follows is rounded to the nearest millionth digit.

information (Shiller and Taylor). Requiring the shipping point price parameters of equation (2) to lie on a polynomial of degree q imposes a set of restrictions that reflects information specific to the rising and falling segmented variables, respectively.

$$\delta_{1,i,m} = \alpha_0 + \alpha_1 m + \ldots + \alpha_q m^q \ , \ \delta_{2,i,m} = \alpha_0^* + \alpha_1^* m + \ldots + \alpha_q^* m^q \ .$$

Applying the Shiller approach to equation (2) also has implications regarding the seasonal effects in the model. An interpretation of smoothness priors is that the estimated coefficients can deviate from any polynomial as long as they do so smoothly (Maddala). This implies the lagged seasonal effects in the model will vary smoothly over time.

From equation (2), the sum of the $\delta_{1,i,m}$'s and $\delta_{2,i,m}$'s represent the price transmission process. The time required for the price adjustments to occur is reflected in r and f, and if they are equal, the transmission speeds are the same. A formal test of symmetry in price adjustment can be developed by constructing the hypothesis

$$\sum_{m=0}^{r} \hat{\delta}_{1,i,m} = \sum_{m=0}^{f} \hat{\delta}_{2,i,m} \ . \tag{3}$$

This null hypothesis can be assessed using an F-test composed of the sum of squared errors with and without the restriction (3). Also, the speed of adjustment (intra period) can be tested by the null hypothesis

$$\hat{\delta}_{1,i,0} = \hat{\delta}_{2,i,0} \ , \ \hat{\delta}_{1,i,1} = \hat{\delta}_{2,i,1} \ , \ \ldots \ , \ \hat{\delta}_{1,i,r} = \hat{\delta}_{2,i,f} \ . \tag{4}$$

Similarly, an F-test using the sum of squared errors with and without the restrictions in

equation (4) can be used to evaluate each of these equalities (Boyd and Brorsen).

Although Shiller's original work was presented in a Bayesian format, Taylor demonstrated the mixed estimation procedure developed by Theil and Goldberger (TG) is a straightforward method of incorporating smoothness priors into the estimation process. But Swamy and Mehta (1969) and Mittelhammer and Conway point out a logical inconsistency, so an alternative procedure should be employed. The Prior Integrated Mixed Estimator (PIME) developed by Mittlehammer and Conway overcomes the weakness.

PIME has two advantages relative to TG: 1) it has a smaller mean square error matrix and 2) it is consistent with Theil's notion of incorporating "best guesses" and Swamy and Mehta's (1983) belief that a researcher's best guess should be a constant (Venkateswaranet al.). Further, the subjective probability distribution defined by PIME subsumes TG as a special case. Lindley and Smith suggest a procedure to estimate equation (2).

Data and Empirical Model

Tomatoes were selected for an empirical application. They were chosen based on abundance of seasonal fluctuations throughout the growing periods and steady seasonal demand at the final consumption level. Weekly price data for shipping point and retail levels were used. Shipping point data were obtained from the Florida Tomato Committee and reflect the average weekly FOB price received by producers for a twenty-five pound box of tomatoes. The shipping cycle began in October and continued through June. Retail prices were obtained from a supermarket chain in a metropolitan area in the Southeast. They are for bulk tomatoes priced on a per pound basis. Both series covered the June 1988 through December 1993 period.

P_0 (the base period retail price) is determined for the start of each harvest season by using

the date of the initial price used to construct *SPR* and *SPF*. Model results from the Houck procedure can be sensitive to initial starting values of the data (Powers), therefore a four-week moving average of the retail price was used in place of $P_{i,0}$ at the start of each harvest cycle. Analyses of the shipping point price and volume data indicate that each year had its own pattern, primarily due to weather.[2]

Transportation costs have been used in previous studies of vertical price transmission (e.g., Powers). However, they are not used here. The retailer supplying the data purchases fresh produce from brokers and wholesalers in various locations, including those used in this study. Fresh produce transportation is part of the chain's distribution system, so transportation costs can be interpreted as fixed in the sense of no seasonal variation since warehouses, trucks, and drivers are part of the overhead (Eastwood et al.). Also, locally grown produce is not delivered directly to the chain's outlets.

Estimates based on the Prais-Winsten procedure (Judge et al.) were used to identify the appropriate lag lengths for r and f.[3] In addition to identifying r and f, other model selection criteria included minimizing the mean square error and noting whether parameter signs were consistent with the Houck procedure. After the appropriate GLS model was identified for

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[2] A complete analysis of the data is available upon request from the authors.

[3] Initial estimates of equation (3) involved finding the "best" OLS model and then using these results to begin the Shiller procedure. This was accomplished by arbitrarily setting $r, f = 8$ and eliminating the last lag periods if they were insignificant, then re-estimating equation (3). This process was continued until the last lag period was statistically different from zero at the five percent level. These results indicated significant first-order autocorrelation for a no-intercept regression equation (Table Source: Farebrother). Consequently, Generalized Least Squares (GLS) was utilized to identify the "best" model to begin the Shiller procedure.

each equation, the parameter estimates and error variances were used to initiate the Shiller procedure. A lag length of five weeks was considered best for both *r* and f.

Empirical Results

Price correlations between the retail price series and lags of the shipping point prices are presented in table 1. A distinct pattern is revealed for the retail series. The correlations consistently increase up to period *t-2*, and then begin to decline. This pattern indicates a source of a priori information in that the lagged shipping point prices should follow a second degree polynomial. Differences in the correlation coefficients vary from period to period both up to and beyond their peak, thus the Shiller procedure is more appropriate for incorporating this a priori information rather than restricting the lagged coefficients to lie exactly on a polynomial.

The Shiller estimates of equation (2) are contained in table 2. The rising and falling coefficients are of the correct sign and are significant across all time periods, indicating significant price adjustments occur each week of the transmission process. The R^2 indicates fifty-five percent of variation in period-to-period retail price changes is explained by the lagged shipping point prices. The F-test for equation fit is significant at the .01 level.

The five week lag for both rising and falling shipping point prices leads to the conclusion that the chain used the same amount of time to adjust retail prices to rising and falling shipping point prices. The F-value for symmetry indicates the total impact of a positive shipping point price change is not significantly different from a negative one. For the pairwise comparisons within the same lag period, the F-value leads to the inference that there is no difference in the chain's retail pricing behavior with respect to rising versus falling shipping point prices.

Table 3 contains seasonal elasticities of the retail price with respect to shipping point

prices evaluated at the beginning, end, "peaks", and "valleys" of the shipping seasons. For the season-beginning elasticities, peak response at the retail level occurred in periods *t-1* and *t-2* for both the rising and falling prices. The peak responses of the season-ending elasticities occurred in periods *t-3* and *t-4* for both the rising and falling prices. Compared to the beginning of the shipping season, the chain seemed to wait longer to evaluate upstream price changes. Since shipments from the Florida market will soon end, the chain is likely beginning to assemble price information from other sources, therefore the priority placed on reaction to the last few weeks of the Florida market is diminished and thus occurs later in the transmission process.[4]

For elasticities evaluated at "peak" levels of shipments, the highest elasticity response for both the rising and falling prices clearly occurred in period *t-2*. This suggests that in periods of great supply, the chain will wait no longer than period *t-2* of the transmission process to make its largest retail price adjustment. Elasticities evaluated at "valley" levels of shipments indicate the highest retail level response for the rising prices was shared by periods *t-2* and *t-3*. A different result was found for the falling prices, where period *t-2* was clearly the peak retail response. The "peak" elasticities are much larger than those evaluated at "valleys". This suggests that when shipments are very large, the chain is more sensitive to upstream price changes relative to periods of very low shipments. The limited shelf-life of tomatoes likely causes the chain to be more sensitive to upstream price changes in times of great supply, therefore, moving the

[4] A different arguement could be made using the beginning of the shipping season as a point of reference. In order to capitalize on any potential trends that may be developing, the chain may choose to evaluate the Florida market more rapidly at the beginning of the season.

produce quickly through the system becomes a top priority.[5]

Conclusions

Empirical results suggest the retail chain is behaving efficiently in its reallocation of resources between what is available at the shipping point level and what is consumed at the retail level. This inference is supported by the results that the long-run effects of upstream price increases on retail prices are similar to decreases and that the retailer responds similarly to intra period rising and falling upstream price changes. Further, the results of the elasticities evaluated at various points in the Florida shipping cycle indicate market information from upstream sources readily influences retail level price responsiveness. For example, changes in the chain's peak response to rising and falling shipping point prices occur as it switches to and from reliance on the Florida market for its fresh tomatoes. Also, drastic changes in supply at the shipping point level are reflected at the retail level, as noted by the differences in elasticities at the "peaks" and "valleys" of the shipping seasons.

The price linkage efficiency found in this study is likely due to the biological nature of fresh tomatoes and how retailers in the distribution channel have adjusted to accommodate those demands. A tomato's limited shelf-life ensures retailers make timely changes in prices to ensure losses are minimized.. Also, to gain more control over the biological demands, most retailers can purchase fresh produce directly from shipping point sources. This practice can facilitate efficient price adjustment by eliminating intermediate channel participants who may provide barriers to smooth transition of information through the distribution channel.

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[5] The result is more exaggerated here, however note that in general the *j* vector suggests that in periods of high shipments the chain will be more sensitive to upstream price changes.

Table 1. Descriptive Statistics and Lagged Price Correlations of the Shipping Point and Retail Price Series

Descriptive Statistics

	Retail	**Shipping Point**
Mean (dollars)	1.22	9.48
Range (dollars)	0.39 - 2.99	2.99 - 38.67
Coefficient of Variation	0.34	0.62

Lagged Price Correlations

	Shipping Point Price$_{t}$	**Shipping Point Price$_{t-1}$**	**Shipping Point Price$_{t-2}$**	**Shipping Point Price$_{t-3}$**	**Shipping Point Price$_{t-4}$**	**Shipping Point Price$_{t-5}$**	**Shipping Point Price$_{t-6}$**
Retail Series$_{t}$	.67	.73	.77	.69	.59	.46	.36

Table 2. Shiller Estimates of the Shipping Point to Retail Price Linkage Relationship [a]

Independent Variables	
SPR_t	0.00211 (0.00125)*
SPR_{t-1}	0.00551 (0.00081)**
SPR_{t-2}	0.00734 (0.00083)**
SPR_{t-3}	0.00748 (0.00082)**
SPR_{t-4}	0.00669 (0.00077)**
SPR_{t-5}	0.00573 (0.00124)**
SPF_t	0.00226 (0.00125)*
SPF_{t-1}	0.00514 (0.00082)**
SPF_{t-2}	0.00682 (0.00083)**
SPF_{t-3}	0.00739 (0.00082)**
SPF_{t-4}	0.00683 (0.00078)**
SPF_{t-5}	0.00520 (0.00120)**
R^2	0.55
Equation F	11.905**
Symmetry F[b]	0.04365
Intra Period F[c]	0.00793
Durbin-Watson	1.289

[a] Standard errors are in parentheses. A single asterisk indicates significance at the .10 level, double asterisks, the .01 level.
[b] Distributed as F(1,119) under the null hypothesis.
[c] Distributed as F(6,119) under the null hypothesis.

Table 3. Seasonal Elasticities of Retail Price With Respect to ShippingPoint Prices Evaluated at Beginning, End, "Peaks", and "Valleys" of the Shipping Seasons[a]

	Beginning		**End**		**"Peaks"**		**"Valleys"**	
	j		*j*		*j*		*j*	
Elasticity	1	4	1	4	1	4	1	4
ε_t	0.279	1.116	0.545	2.179	3.564	14.254	0.067	0.270
ε_{t-1}	0.591	2.365	1.654	6.617	6.745	26.980	0.177	0.707
ε_{t-2}	0.531	2.123	2.719	10.876	10.592	42.368	0.188	0.752
ε_{t-3}	0.351	1.406	3.666	14.665	7.436	29.744	0.191	0.766
ε_{t-4}	0.228	0.912	3.666	14.664	8.151	32.603	0.146	0.585
ε_{t-5}	0.122	0.486	3.078	12.313	6.983	27.931	0.102	0.407
ε^*_t	0.446	1.785	0.605	2.421	4.124	16.494	0.029	0.116
ε^*_{t-1}	0.760	3.039	1.586	6.342	7.023	28.092	0.043	0.172
ε^*_{t-2}	0.628	2.512	2.589	10.357	11.033	44.133	0.057	0.229
ε^*_{t-3}	0.335	1.341	3.639	14.556	7.759	31.036	0.024	0.097
ε^*_{t-4}	0.218	0.870	3.623	14.492	8.409	33.637	0.022	0.090
ε^*_{t-5}	0.115	0.459	2.693	10.770	5.760	23.041	0.017	0.068

where

$$\varepsilon_{t-m} = \varepsilon_{SPR_{i,t-m},\, RP_{i,t}} = \left(\hat{\delta}_{1,i,m} * j\right) * \left(\frac{SPR_{i,t-m}}{RP_{i,t}}\right)$$

$$\varepsilon^*_{t-m} = \varepsilon_{SPF_{i,t-m},\, RP_{i,t}} = \left(\hat{\delta}_{2,i,m} * j\right) * \left(\frac{SPF_{i,t-m}}{RP_{i,t}}\right)$$

[a] For the beginning (end) of the shipping season, SPR_{t-m}, SPF_{t-m} , and RP_t were defined as their averages over the first (last) two weeks of each growing season for which observations were available on all independent variables. Their values corresponding to the "peaks" ("valleys") of the shipping season were defined as averages taken over the significantly high (low) levels of shipments across the various seasons.

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