LEAD-LAG RELATIONSHIPS BETWEEN PORK PRICES AT THE RETAIL, WHOLESALE, AND FARM LEVELS

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Knowledge of the lead-lag relationships among the retail, wholesale, and farm level prices of a livestock commodity is of obvious importance both in econometric model building and in evaluation of packers' and retailers' margins for that commodity. Though the lead-lag relationships for beef prices have been investigated in several previous studies (Barksdale et al.; Franzmann and Walker; King; Miller; National Commission on Food Marketing), the only known previous study of the lead-lag relationships for pork is that made by the National Commission on Food Marketing (hereafter abbreviated NCFM). As that study used data for 1962-1965, changes in the pork marketing system in subsequent years may have in turn occassioned changes in the lead-lag relationships. The changes in the pork marketing system include changes in market structure at the farm, packer, and retail levels, increased use of formula pricing, and the demise of terminal markets, among others. Also, as discussed hereafter, the statistical method used in the NCFM analysis of lead-lag relationships involved certain problems which may invalidate the conclusions drawn in that study.

The purpose of the present study is to reassess the lead-lag relationships of prices in the pork marketing system for a more recent sampling interval than that used in the NCFM study. Also, the method used to assess the lead-lag relationships does not have the statistical problems of the NCFM analysis. Subsequent sections provide discussions of background and method, data and empirical results, and conclusions.

BACKGROUND AND METHOD

The NCFM, using weekly data, regressed retail price changes on current and lagged wholesale price changes, and regressed farm level price changes on current and lagged wholesale price changes. The conclusion was that wholesale price changes led retail level changes by up to 6 weeks, with the largest response of retail prices occurring 1 week after a wholesale price change. However, the regression from which this conclusion was drawn had serially correlated residuals.

With respect to the wholesale-farm relationship, the conclusion was that wholesale price changes led farm level changes by up to 1 week, but the strongest association between wholesale and farm price changes was contemporaneous. It is interesting to note that most studies of lead-lag relationships between beef prices indicate that either farm and wholesale prices change instantaneously (Barksdale et al.; King), or farm level changes precede wholesale level changes (Miller; NCFM).[1]

As discussed by Pierce (1977a, p. 14), regressions such as those used by the NCFM may be misleading. If the regressand and/or regressor series are autocorrelated, the likely result is that the significance of statistical tests will be "grossly" overestimated; i.e., if autocorrelation in either series is not accounted for, nonexistent relationships may be asserted to exist.

The method used here, univariate residual cross-correlation analysis, accounts for autocorrelation in the series of interest, and thus is less likely to be misleading. This method is based on a concept due to Granger; i.e., a time-ordered variable X is said to lead another time-ordered variable Y if Y may be better predicted with the use of the history of X than without, with all relevant information (including Y's history) being used in either case. Haugh, and Haugh and Box, have adopted this criterion in assessing lead-lag relationships between time series. Because detailed discussions of the method are available elsewhere (e.g., Haugh; Haugh and Box; Miller; Pierce 1977a), only a brief sketch is given here.

Let X_t and Y_t be the realizations at time t of two stochastic processes. Associated with X_t and Y_t are white noise terms, u_t and v_t, respectively. Also, $E[u_t] = E[v_t] = 0$; $E[u_t^2] = \sigma_u^2$; $E[v_t^2] = \sigma_v^2$.

According to Haugh and Box, the theoretical cross-correlation between the u's and v's, defined at lag k as

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[1]An exception is the finding of a harmonic analysis study that wholesale beef prices lead farm prices (Franzmann and Walker). However, that approach has been criticized on the grounds that it does not permit distinction between a lead and a lag (Barksdale et al.).

$$(1) \quad \varrho_{uv}(k) = \frac{E[u_{t-k}, v_t]}{\sigma_u \sigma_v}$$

may be used to assess the lead-lag relationships between the original X and Y series. Some lead-lag relationships of interest as implied by patterns in the theoretical cross-correlation function follow (Pierce 1977a, p. 15):

Case I $\varrho_{uv}(k) = 0$ for all k → X and Y are independent,

Case II $\varrho_{uv}(o) \neq 0$ → X and Y are related instantaneously,

Case III $\varrho_{uv}(k) \neq 0$ for some $k > 0$ → X leads Y,

Case IV $\varrho_{uv}(k) \neq 0$ for some $k < 0$ Y leads X,

Case V $\varrho_{uv}(k) \neq 0$ for some $k > 0$ and for some $k < 0$ → feedback between X and Y.

Estimates of the u's and v's, denoted as the $\hat{u}$'s and $\hat{v}$'s, respectively, can be obtained via application of univariate time series modeling techniques (Box and Jenkins).[2] Statistical tests of the significance of the calculated cross-correlations between the $\hat{u}$'s and $\hat{v}$'s, denoted as the $r_{\hat{u}\hat{v}}(k)$'s, may be used to infer the lead-lag relationships between X and Y. If X and Y are independent, the $r_{\hat{u}\hat{v}}(k)$'s are asymptotically independently and normally distributed with zero mean and variance n^{-1}, where n is the sample size.

As discussed by Pierce (1977a, p. 15), the hypothesis that X and Y are linearly independent (Case I holds) may be rejected at significance level α if

$$(2) \quad Q_{2m+1} = n \sum_{k=-m}^{m} \left| r_{\hat{u}\hat{v}}(k) \right|^2 > X_{\alpha}^2, 2m+1$$

where X_{α}^2, 2m+1 is the upper α percentage point of the chi-square distribution with d.f. = 2m+1; and m is chosen so as to include all $\varrho_{uv}(k)$'s expected to differ from zero. The contention that X leads Y (Case III holds) is supported at significance level α if

$$(3) \quad Q_m = n \sum_{k=1}^{m} \left| r_{\hat{u}\hat{v}}(k) \right|^2 > \chi_{\alpha}^2, m.$$

Similarly, Y leads X (Case IV) may be asserted at α if

$$(4) \quad Q_{\bar{m}} = n \sum_{k=-m}^{-1} \left| r_{\hat{u}\hat{v}}(k) \right|^2 > \chi_{\alpha}^2, m.$$

If the inequalities in equations 3 and 4 hold simultaneously, a feedback relationship between X and Y (Case V) is indicated.[3] Also, the significance of an individual $r_{\hat{u}\hat{v}}(k)$ may be determined by comparison with its standard error, $n^{-1/2}$.

DATA AND EMPIRICAL RESULTS

The statistical method described was applied to weekly changes of retail, wholesale, and net farm pork values for January 1974 through June 1978 (USDA).The sampling interval produced 234 observations. Let R_t, W_t, F_t equal changes between weeks t and t−1 of retail, wholesale, and net farm pork values, respectively. Estimated autocorrelations of the R's, W's, and F's for up to 10 lags are given in Table 1. The standard errors of individual autocorrelations may be approximated by $n^{-1/2}$; here $234^{-1/2} = .07$. From Table 1, both the retail and farm level series have autocorrelations which exceed the value .07 by a factor of two or more, indicating that these series are autocorrelated. Regressions of the sort used by the NCFM which do not account for this autocorrelation may suggest relationships between the R's and W's, and/or the W's and F's, which do not exist. Univariate residual cross-correlation analysis is less likely to be misleading in this situation.

TABLE 1. ESTIMATION AUTOCORRELATIONS OF WEEKLY PRICE CHANGES AT THE RETAIL, WHOLESALE, AND FARM LEVELS.

Lags									
1	2	3	4	5	6	7	8	9	10
Retail Level									
.19	.16	.19	.17	.15	.17	.10	.18	.01	.08
Wholesale Level									
.09	.09	.03	−.07	.03	.06	.05	.10	.09	−.09
Farm Level									
.39	.20	.01	−.07	.03	.01	.11	.11	−.01	−.03

Univariate time series models were fitted to the retail and farm level series by the iterative model building process described by Box and Jenkins. Because the wholesale level series was not autocorrelated, it was described by a random walk model. The time series models follow.

$$(5) \quad \text{Retail:} \quad \hat{a}_t = R_t - \underset{(.08)}{.88778} R_{t-1} + \underset{(.11)}{.74255} \hat{a}_{t-1},$$

[2]The subjective nature of the Box-Jenkins model building process may result in different univariate models being identified by different researchers. The sensitivity of the results of univariate residual cross-correlation to the univariate filters employed is deserving of more research.

[3]Sims has argued that the foregoing tests are strictly valid only when the independence of two series is being tested. For a rebuttal, see Pierce (1977b, p. 25).

$\hat{\sigma}_a = 1.74,$

(6) Wholesale: $\hat{b}_t = W_t, \hat{\sigma}_b = 2.84,$

(7) Farm: $\hat{c}_t = F_t - \underset{(.04)}{.3876} F_{t-1}, \hat{\sigma}_c = 2.33,$[4]

where the $\hat{a}$'s, $\hat{b}$'s, and $\hat{c}$'s are white noise residuals. The residuals were judged to be white noise on the basis of the results of chi-square tests with 5 percent significance levels (Box and Jenkins, pp. 290-1) and the random patterns in the residuals' estimated autocorrelation and partial correlation functions. Estimated cross-correlations of the residuals of equations 5 and 6, and equations 6 and 7 for 10 $\leqslant$ k $\leqslant$ 10, along with the Q-statistics (for m=10) discussed, are reported in Tables 2a and 2b.

TABLE 2a. ESTIMATED CROSS CORRELATIONS BETWEEN WHITE NOISE RESIDUALS OF WEEKLY RETAIL AND WHOLESALE PORK VALUE CHANGES.

Lags									
1	2	3	4	5	6	7	8	9	10
Positive Lags of $\hat{a}_t$ (k > 0)									
.03	-.07	.09	.04	-.03	.20	.07	-.02	-.03	-.10
Negative Lags of $\hat{a}_t$ (k < 0)									
.20	.37†	.11	-.01	.02	.07	-.04	.03	.11	-.04

Note: $r_{\hat{a}\hat{b}}(0) = .19$, $234^{-\frac{1}{2}} = .07$, $Q_{21} = 74.72$, $Q_{10} = 16.99$, $Q_{\overline{10}} = 49.28$

TABLE 2b. ESTIMATED CROSS CORRELATIONS BETWEEN WHITE NOISE RESIDUALS OF WEEKLY WHOLESALE AND FARM PORK VALUE CHANGES.

Lags									
1	2	3	4	5	6	7	8	9	10
Positive Lags of $\hat{b}_t$ (k > 0)									
-.01	-.01	-.01	-.06	.10	-.06	.16	.01	-.04	.00
Negative Lags of $\hat{b}_t$ (k < 0)									
.23†	.23†	.06	-.17	.12	-.03	-.04	.20	.03	.10

Note: $r_{\hat{b}\hat{c}}(0) = .51$† , $Q_{21} = 119.57$, $Q_{10} = 10.48$ $Q_{\overline{10}} = 48.23$

†At least three times greater than its standard error.

In Table 2a, $Q_{\overline{10}}$ exceeds the critical value of $\chi^2_{5,10} = 18.3$, the implication being that wholesale changes lead retail changes. Also, Q_{10} is less than 18.3, indicating the absence of feedback between the retail and wholesale levels. The largest individual cross-correlation is at the second negative lag of $\hat{a}_t$, indicating that the largest response of retail price to a change in wholesale price occurs in less than 3 weeks. This adjustment period is shorter than the 6-week adjustment period found by the NCFM.

In Table 2b, $Q_{\overline{10}}$ is greater than 18.3, but Q_{10} is not. These results indicate that farm level changes lead wholesale value changes, and that feedback from the wholesale to the farm level is apparently absent. The largest individual cross-correlation is at a zero lag, and other large cross-correlations are at the first two negative lags of $\hat{b}_t$. The implication is that whereas the largest response of wholesale level changes to farm level changes is instantaneous, farm level changes precede wholesale changes by less than 3 weeks. This result is in sharp contrast to the finding of the NCFM that wholesale level changes precede farm level changes.

Because both sampling intervals and statistical methods differ between the present study and the earlier NCFM investigation, it is not possible to ascertain whether the conflicting results of the two studies are due to changes in the lead-lag relationships over time or to the methods employed. This issue could be resolved by application of the present method to the NCFM data; however, the requisite data for such an analysis were not available to the author.

The results presented here should be useful in the specification stage of econometric model building for the pork sector. Haugh and Box discuss techniques for specification and estimation of distributed lag models based on the lead-lag relationships identified by univariate residual cross-correlation analysis. In the present case, the discovered lag relationships of retail to wholesale prices and wholesale to farm prices may be used in the specification of distributed lag models explaining retail prices with wholesale prices and wholesale prices with farm prices, respectively. Such models are now being developed by the author. When constructed, these models should be helpful in evaluating retailers' and packers' marketing margins. The models should also result in better forecasts of weekly retail and wholesale pork prices than can be derived from univariate forecasting models of those series.

In closing, it is interesting to compare the lead-lag relationships of the beef and pork marketing systems. The present study of pork lead-lag relationships is most easily compared with Miller's study of beef lead-lag relationships because sampling intervals and methods are identical in the two studies. With respect to beef lead-lag relationships, it was found that wholesale beef price changes precede retail level changes by less than 3 weeks, and that farm level changes lead wholesale level changes by as much as 1 week. The results for

[4]Standard errors are shown in parentheses.

pork are similar, although there is some indication that the time elapsed between farm and wholesale level changes may be about a week longer for pork than for beef. These results are not surprising, given the similarities between the beef and pork marketing systems.

SUMMARY AND CONCLUSIONS

The purpose of this study is to make an empirical assessment of the lead-lag relationships of pork prices between the retail, wholesale, and farm levels. Both a more recent sampling interval and an improved method differentiate the present study from an earlier investigation of the same topic by the National Commission on Food Marketing. Empirical results from univariate residual cross-correlation analysis indicate that farm level pork prices lead wholesale prices by up to 2-3 weeks and, in turn, wholesale prices lead retail prices by up to 2-3 weeks. The results presented here should be useful in the specification stage of econometric model building for the pork sector. Identified lead-lag relationships may be used in the construction of distributed lag models explaining retail prices with wholesale prices, and wholesale prices with farm prices. Such models should be helpful in evaluating retailers' and packers' marketing margins, and should provide better forecasts of retail and wholesale pork prices than those given by univariate forecasting models.

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