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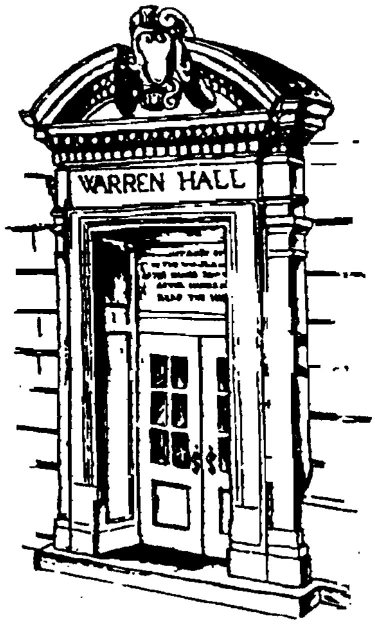

Staff Paper

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THE IMPACT OF LAG DETERMINATION ON PRICE RELATIONSHIPS IN THE U.S. BROILER INDUSTRY

John C. Bernard and Lois Schertz Willett[1]

"The movement of retail price is presumably a little later than that of wholesale."
-A.L. Bowley (1913)

In determining the relationships among prices at the farm, wholesale and retail market levels in the broiler industry, it is necessary to determine the lengths of time between influences and adjustments among them. For instance, it is commonly assumed, as Bowley pointed out many years ago, that changes in wholesale price will lead to changes in retail price at some point in the future. Within this time period, more than one change in a particular price may have affected the price at another level. The number of these past observations of one price variable used to describe another is called the lag length. Lag lengths are counted from zero, with a zero length lag containing only the current period's observation, a lag length of one consisting of the current period and the previous period, and so on.

Accurate determination of these lag lengths is required before specification of models suitable for causality, asymmetry, or other statistical testing can be completed. While Sarker notes many past causality studies have relied on ad hoc or arbitrarily chosen lag lengths, these tests have been shown to be extremely sensitive to the lag length selected (Saunders; Thorton and Batten). Correct lag lengths should also be crucial in asymmetry testing, as specification bias from an incorrect model can cause parameters to vary significantly from their true values. Lag structure may be determined based on theory, previous studies, arbitrarily selected values, biological factors or through model selection tests.

In this study of the broiler industry, theory and graphical analysis were used to generate hypothesized lags between price responses on the farm, wholesale and retail market levels. The data were then subjected to a variety of model selection tests to determine optimal lag lengths. The lag results using various criteria were than compared.

THE DATA

Two separate data sets, one monthly and one weekly, were assembled for this study. Both data sets cover the period

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January 1983 to December 1992 and contain 120 and 522 observations, respectfully. The weekly data set consisted of five price variables expressed in cents per pound. The first price variable was the Arkansas farm price for whole birds, collected by the Arkansas Livestock and Poultry Commission. This series was calculated by the Commission's weekly survey of the major integrators in the state, with high and low quotes dropped and the rest averaged. The prices were reported either as a range, with a 'mostly' price listed or as a single, dominant price. If a range was given, only the 'mostly' price was entered into the data set. The result should be a reliable indication of payments the growers are receiving under the contract system.

The next three price variables were composite wholesale prices for whole broilers in New York, Chicago and San Francisco. These prices were weighted averages of trucklot sales to 'first receivers' in the markets. These prices, collected by the USDA, are reported annually in their Agricultural Marketing Service's *Poultry Market Statistics*. The USDA began reporting the composite price used by this study on March 7, 1983. This new series included price data on branded products as well as Grade A and Plant Grade processed whole birds and whole birds without giblets (WOGS).

The last weekly price variable was the retail price of whole broilers, 2 to 3 pounds, in New York City. This price was collected by weekend surveys of retail stores in the city by *Weekly Insiders Poultry Report*.

The monthly data set contained ten price variables. The national, monthly, farm price came from the USDA. Also from the USDA were costs of the two primary feed ingredients: the Central Illinois price of #2 yellow corn and the Decatur price of soybean meal, 44% solvent.

The monthly wholesale price was a twelve city weighted average of the same composite prices as the weekly wholesale series.[2] The weighted average was calculated by dividing the country into three marketing regions, and then weighing prices in each region by their population. These prices were also unavailable prior to March 1983.

Retail prices for whole, fresh chickens were collected by the Bureau of Labor Statistics using four sampling regions. The four regions were West, South, North Central and Northeast. Additionally, a national price was calculated as a population weighted average of the regional prices.

For transportation costs, a national, retail price of gasoline was collected from *National Petroleum News*. This price was an average of all types of gasoline available and includes taxes and variations due to types of service.

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[2]The twelve cities were Boston, Chicago, Cincinnati, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, St. Louis and San Francisco.

Studies similar to this typically perform one or more transformations on the data. Common alterations include seasonal adjustments, adjusting for inflation, calculating logs and first differencing. However, no transformations or prefiltering were conducted on either data set in this analysis. It was believed that in changing the form of the data, important relational characteristics could be lost (Bernard and Streeter).

REASONS FOR LAGS

> "...lags apparently occur as inputs move (vertically) through the marketing system. Time is required as farm inputs are transported, stored, processed, and moved through the wholesale and retail sectors."
>
> -Hall, Tomek, Ruther and Kyereme (1981)

Many studies have suggested reasons for the existence of price lags in various markets. An especially useful study in this regard is Hall, et al. (HTRK); with their above quote offering a useful refinement on Bowley's earlier note. They put forward four reasons to explain the existence of lags. The most obvious of these is the one contained within the quote; that being that time and alterations in form are required in getting product from farm to supermarket shelves.

A second rationale suggested by HTRK was the cost involved in price changes. Shonkwiler and Taylor, in examining why firms may hesitate to change prices (referred to as price rigidity or sticky prices) listed two major costs. The first was the administrative cost, consisting of the expense required in physically relabeling product and informing customers of these new prices, as through advertising. The other costs are indirect and difficult to gauge. These are the costs that could incur from unpredictable changes in revenue and market share brought about as a result of a price change. Competition and market structure both play a significant role in the determination of these. Both types of costs pertain predominately to the retail market level where Heien suggested managers attempt to use "smoothed" prices to avoid the expense and possible loss of good-will of customers owing to frequent price changes.[3]

Next, HTRK mentioned that lag length could simply be a product of the frequency with which data are collected or reported. Obviously, the length of time between data observations can affect the conclusions reached in any empirical analysis. Data collected infrequently may incorrectly suggest lags are not part of the price transmission process. In

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[3]Evidence that retailers attempt to keep price changes small in magnitude could be seen in the monthly data, where the percentage change in wholesale price was greater than that of the retail price in 89 of the 118 observations.

contrast, data collected over a short time interval may occur too frequently and not recognize distant lag effects.

Data considerations can also affect lag interpretations. A key concern is accounting for when, during a time period, data was actually measured. For instance, a monthly series may be based on an early, mid or late month calculation or an average of daily or weekly readings. Comparing a weekly series with an early week observation with a series from a late week observation can lead to mistaken inferences about the true lag.

HRTK's last assertion was that market imperfections, such as noncompetitive firms or poor transmission of information, can cause lags. This point is perhaps the most relevant from the perspective of this study. Theories on the adjustment time in the pricing behavior of noncompetitive firms abound and can be divided into two schools of thought. The first, the administered price theory of Means holds that prices are adjusted less frequently in concentrated markets. The reverse, known as the price leadership model, suggests concentration leads to more rapid price adjustments. Empirical studies have been so far unable to prove or disprove either possibility. Ginsburgh and Michel have, in fact, concluded that "under reasonable assumptions" either type of behavior can be found by empirical methods. As for other noncompetitive elements of structure, Kardasz and Stollery presented evidence that increased product differentiation, by making comparisons more difficult, slows price adjustments. These issues all require further research.

Better understood is the importance of information and a market level's ability to act upon it. Ward contended that structural differences among market levels in an industry will determine their abilities to assimilate information, and thus the speed of price adjustment. Informational advantages could allow for faster transmissions than other market levels, yielding at least temporarily higher margins and profits.

Taken together, the above make it clear lags are an important part of price transmission processes. Further, models constructed with single period observations would be insufficient to account for the dynamic's of a typical market.

HYPOTHESIZED LAGS

Hypothesized lag lengths between market prices in the broiler industry were generated before empirical testing was performed. In generating hypothesized lags, graphical methods and biological factors proved especially useful. Attempts were made to create separate hypotheses based on each of the two data sets.

In the monthly data set, for the farm to wholesale price link, the graphical investigation revealed that the wholesale price moved in the same direction as the farm price had the previous month in all but 9 of the 118 months in the sample (Figure 1). Such a clear relationship was not evident graphically in the Figure between wholesale and retail, although there was a slight suggestion of a two to four month adjustment lag. The hypothesized lag in the wholesale to retail price relation was therefore set at three months based on this suggestion coupled with the life cycle of a broiler flock. Since a new flock takes only eight to twelve weeks to produce (2 to 3 months), it is assumed that any necessary adjustments can be made within that time. Farm to retail effects were assumed to be slightly longer than wholesale to retail effects.

Lags were only hypothesized following the assumed direction of price transmission: from farm to wholesale to retail. Lags were hypothesized for the overall National retail price but not for the individual regions. The hypothesized lag lengths for the monthly data set are summarized in Table 1.

Weekly lag lengths were investigated in a similar fashion. Unfortunately, graphical analysis (see Figure 2) did not prove as useful as with the monthly data. In the end, the lags were hypothesized based on the monthly results in conjunction with a best guess at a graphical pattern.

As with the monthly data, lag hypotheses were only made following the assumed flow of price transmissions. No distinction was made between the various wholesale locations. The hypothesized lag lengths for the weekly data set are also summarized in Table 1.

LAG LENGTH DETERMINATION TESTS

> "The situation in which a model is assumed to be one of a sequence of nested alternatives arises with some frequency in econometric work. The most frequently studied case is that in which a distributed lag of unknown order is to be estimated."
>
> -Geweke and Meese (1981)

The most straightforward technique for model selection has been analysis of the adjusted R^2. This method is performed typically by minimizing the value of part of the numerator rather than maximization of the whole function. Unfortunately, the minimization rule requires the total sum of squares (the denominator) to be constant among the various models. While this is often true in model selection cases, it is not true for determination of lag lengths. The variation of lag lengths alters the number of observations, thus changing the total sum of squares (SST), making the minimization rule inconsistent. Use of the minimization rule in this case would presumably lead to the selection of longer than appropriate lags.

A number of criteria useful for lag length determination have been introduced over the past 25 years. Geweke and Meese divided existing criteria into two classes by recognizing that those proposed have been designed with two different goals in mind. The earliest goal was to identify the model yielding the smallest mean square error in predictions of the dependent variable, which will be referred to as prediction criteria. The rationale for this goal has been the observation, best expressed by Shibata, that "...one of the main objects of regression analysis is to make a good prediction of future observations." The other goal, to achieve efficient estimation of the parameters, is performed in the Bayesian context. This gives a result that should best fit the lag length for a given set of observations, without future considerations.

While inappropriate for lag determination testing, the minimization adjusted R^2 criteria (MRC), provides a useful base to describe the common format shared by both classes of criteria. The value of MRC is the variance of the maximum likelihood estimator (MLE). This variance is at the core of all other criteria, where the others each include the addition of a 'penalty term' that increases as more independent variables are added to the model. In fact, letting N be the number of lags, T be the number of observations and f be some function, Geweke and Meese have shown that all current criteria (C) can be written as:

$$C(N,T) = \text{Variance of MLE} + Nf(T) \qquad \textbf{(1)}$$

The penalty term, Nf(T), chooses a balance between the bias if too few variables were included and the higher variance of the MLE resulting from the inclusion of unnecessary variables. Penalties can grow rapidly as more variables are added and many of the criteria's functions, f, make the penalty proportional to 1/T. The penalty determines the chances the criteria have of either under or overestimating the true lag length. For example, since it includes no penalty term, the MRC is likely to overestimate the actual lag. Which of the two classes a criterion belongs to determines whether it would be more prone to under or overestimate the true lag.

Two of the most commonly used tests for lag determination are the prediction criteria designed by Akaike (1969,1974): the final prediction error criteria (FPE) and the information criteria (AIC). The FPE criteria is the most popular because it is believed that it balances the risk of either under or overestimating the correct lag (Hsiao 1979). Other lag length determination prediction criteria examined here include Craven and Wahba's generalized cross validation method (GCV) and Shibata's criteria (SHB). The only Baysian criteria (SC) used in this study was created by Schwarz. While SC asymptotically eliminates the possibility of overestimation at the cost of making it more prone to underestimation, the prediction criteria asymptotically eliminates the possibility of underestimation with a greater potential of overestimation (Geweke and Meese).

The formulas for the examined criteria are:[4]

$$AIC(N,T) = \ln(SSE_N/T) + (2N)/T \quad (2)$$
$$FPE(N,T) = SSE_N/T * ((T+N+1)/(T-N-1)) \quad (3)$$
$$GCV(N,T) = SSE_N/T * (1-(N/T))^{-2} \quad (4)$$
$$SC(N,T) = LN(SSE_N/T) + (N\ln(T)/T) \quad (5)$$
$$SHB(N,T) = SSE_N/T * ((T+2K)/T) \quad (6)$$

where N and T are as before, K is the number of coefficients, SSE_N is the sum of squared errors and SSE_N/T is the variance of the MLE.

The existence of these two classes of criteria creates a difficulty in market price analysis, since the goals may conflict. For example, causality testing can be linked closely to the goal of accurate predictions while asymmetry testing depends on accurate coefficients. Although past studies often selected a single criterion, recent research has been conducted by examining multiple criteria. For instance, Bessler and Babula used the FPE, SC and an unrestricted vector autoregression while Holmes and Hutton, noting "...different criteria may select different 'optimal' models..." (p. 486) used AIC, SC and two other criteria. In light of this, lag length determination testing was conducted using all the criteria described above.

METHODOLOGY

Testing was performed in two stages, following Hsiao's (1979) testing methodology for a bivariate autoregressive model.[5] The first stage involves discovery of the lag length of a univariate function, while the second stage considers the bivariate case. For a variable, Y, thought to be explainable by itself and another variable, X, the bivariate autoregressive model can be expressed:

$$Y_t = \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{j=0}^{n} \beta_{j+m+1} X_{t-j} + V_t \quad (7)$$

where m and n are to be estimated.

In both stages, lags were added sequentially. No lag lengths were bypassed or tested for removal once the lag length increased. True lag lengths were assumed to be finite.

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[4]Formulas for AIC and SC are from Judge, et al, FPE from Darrat and the remainder from Ramanathan.

[5]The methodology used in this study varied from Hsiao (1979) in that no prefiltering was performed on the data and he included only the FPE criteria. Additionally, post-analysis diagnostic checks were not conducted.

The first stage of the analysis consisted of univariate testing of each Y. The goal was to determine the order of each of the variables lagged on itself.

Using the results from stage one, optimal autoregressive lag lengths were selected for stage two. Since overestimation could potentially cause problems in the bivariate stage by mimicking effects of the X variable, the lag lengths were selected using the SC.

In the second stage, each of the variables was in turn lagged on all the other variables with which it had a theoretical relationship. The dependent variable in each case was itself lagged to the extent discovered in stage one in each regression.

RESULTS

An interesting curiosity in using the criteria was their tendency to reach minimums, start to rise, then abruptly decline, frequently reaching new minimum values. Since it was unknown how long patterns like this could persist, the hypothesized lag values, and common sense, were used to judge the maximum number of periods necessary to test the lags. No tests were conducted with lag lengths over ten for the monthly data set or over twenty with the weekly data set. Most tests were continued until it seemed certain that the criteria would be unable to reach a new minimum (ie: the SSE had decreased little over three lags and/or the penalty alone had grown large as a percentage of the total). Unless the local minimum had strong theoretical backing, absolute minimums were used in model construction.

Tables 2 and 3 summarize the testing results from three of the criteria and from maximizing the adjusted R squared (R2C). The results from testing using SHB and AIC were not included because they were identical to those of the FPE criteria. The GCV, while included in the tables, differed from FPE in a single case (gas lagged on gas, monthly), and then only by not having a localized minimum at two lags; the overall minimum was identical. While some computer simulations have shown FPE to have superior small-sample properties over AIC (Shibata), the sample sizes of 120 and 522 were apparently large enough to equalize the results. Shibata has shown that asymptotically the AIC, FPE and SHB are equivalent. As expected, the SC had a tendency to produce smaller lags than the prediction criteria, although whether this implies it underestimated price transmission times or the prediction criteria have overestimated them could not be determined.

<u>Univariate Results</u>

Although no hypotheses had been made regarding the autoregressive (AR) lags, the time periods coming out of the tests seemed reasonable and justifiable. For the monthly data set, farm and wholesale prices both suggested either a one or three month AR process. All criteria pointed to a two month AR process for the National and Southern region retail prices, and one month for the other regions.

All criteria agreed on the lag lengths with the weekly data set and there were no local minimums. The three wholesale cities yielded lag results of four weeks, the farm three weeks and the New York City retail seven weeks.

Results from the monthly and weekly data sets were fairly consistent, especially when considering the SC. Looking at the monthly SC conclusions, the farm lag of one month compares favorably to the three week lag, the one month for wholesale matches the four week lag, and the one or two month lag for the retail regions fits with the seven week lag determined for the New York retail series.

Bivariate Results

The results from the wholesale price lagged on the farm price, and the reverse, appear similarly consistent between the monthly and weekly data sets. For farm on wholesale monthly, all criteria pointed to one month as the correct lag, with an accompanying large increase in adjusted R^2 over the AR model. The SC suggested a zero lag length on the monthly wholesale on farm series, while the other criteria suggested one month, implying a symmetric lag relationship between farm and wholesale price transmissions.

The zero lag conclusion of the SC does fit best with the ranges of zero to three weeks for the weekly data set. Regionally, all criteria chose a zero week lag between the San Francisco wholesale price and the Arkansas farm price, while the prediction criteria reached minimums at one week from the Chicago wholesale price and a zero or three week lag with the New York city price. The SC and R2C pointed to zero week lags in all cases, with little increase in adjusted R^2. These results suggest the prediction criteria may be slightly overestimating the monthly lag length.

In contrast, the weekly data set revealed lag lengths from the farm price to the wholesale price of zero to five weeks, with all criteria reaching their absolute minimum at four or five weeks. In this case, the results involving the wholesale prices in New York and Chicago matched closely while San Francisco showed greater variability and longer adjustment times. These results pair perfectly with the one month lag calculated from the monthly data.

The wholesale and retail links did not compare well across data sets. The monthly data set yielded results significantly closer to the hypothesized lag lengths, with wholesale price lagged on the national retail price exactly matching the hypothesized length of three months for all criteria. For all retail regions except the West, the prediction criteria reached local minimums at zero months and absolute minimums at two or three months with maximized adjusted R^2 also at the absolute minimums for these regions. The SC yielded lag lengths of zero for both the West and North Central region, despite suggesting three months for the aggregated National total.

The weekly data set results for the Arkansas farm price lagged on the New York City retail price did not correlate to the hypothesized values of 10 to 12 weeks. All criteria stopped at either zero or one week, with only a small improvement in adjusted R^2. This may be evidence that the link is weaker then expected, or is almost instantaneous. Another, more reasonable, possibility is that the price transmission process takes at least four weeks to develop; therefore making the first few weeks irrelevant. This would cause the criteria to reach minimums before the true relation between the prices was reached, and would also account for the zero lag local minimums in the monthly analysis.

The same breakdown between monthly and weekly occurred when investigating the lags between the farm price and the retail price. Again, the monthly results came closer to the expected results with all criteria suggesting the same three month lag as between wholesale and retail. For all regions, the prediction criteria reached minimums at two, three and four months, and did not have local minimums at zero. The SC still had local minimums at zero in some regions, but had absolute minimums for the West and North Central of one and two months respectively. The adjusted R^2 also showed greater improvement than when wholesale prices had been included, possibly indicating a direct farm to retail price linkage.

In the weekly data set, all criteria suggested a zero week lag from farm to retail. However, the adjusted R^2 jumped from 0.6144 in the univariate case to 0.9211 with the inclusion of the single farm price. Again, it appears there may be a closer price link from farm to retail than from wholesale to retail.

Results of retail price lagged on farm and wholesale in the weekly data set showed a zero lag length in all cases except the adjusted R^2 from retail to farm which pointed to one week, but with a significantly lower value than farm on farm alone. The retail to wholesale linkages in the monthly analysis varied from one to four months and showed larger improvements in goodness-of-fit. For the transmissions to the farm price, the results of National and the Southern region matched exactly, as did the Northeast and North Central results.

The other hypothesized relations between variables in the monthly data set did not fare well. Particularly disappointing were the results of corn and soybean prices lagged on the farm price. All criteria pointed to a lag length of zero months, and the adjusted R squared and FPE criteria for both were lower than the result of farm lagged on itself, suggesting neither feed variable fits the model.[6] Due to the strong theoretical rationale for including the feed cost variables, further testing will be required before this result can be explained.

[6]Hsiao (1979,1981) has suggested comparing the level of the FPE between the univariate and bivariate cases as a causality test, with causality being implied by a lower FPE in the bivariate case. In this method, the input prices were the only ones not to show causality; two way causality existed between all other prices.

A similar problem arises with the cost of gasoline lagged on the wholesale price. While the gasoline price, as a proxy for transportation, should be an important component of the wholesale price, the FPE and adjusted R squared declined with its inclusion. This conflict between theory and empirical evidence may be due to the aggregated, averaged nature of the two series.

AN ALTERNATIVE METHOD AND SPATIAL ANALYSIS

The results from the two stage procedure can be contrasted to the typical, one stage model selection test as outlined in Judge, et al. (p. 728). In the one stage model form, the dependent variable is not included in lagged form on the right hand side as in the bivariate case. In other words, a variable Y is considered to be best explained by X alone as in:

$$Y_t = \beta_0 + \sum_{j=0}^{n} \beta_{j+1} X_{t-j} + V_t \qquad (8)$$

A sampling of the bivariate results obtained using this method on the monthly data set is given in Table 4.

The two most apparent distinctions between the one and two stage procedures were the higher lag lengths and the lower adjusted R^2 values in the Judge analysis. Since adding the lagged dependent variable to a model improves typical goodness-of-fit measures, the adjusted R squared difference should be anticipated. The lags are longer because the penalty term is based on a single lag length instead of two, making it smaller at every lag relative to the other method.

While inappropriate for lag selection, the Judge method revealed geographical differences in lag adjustment. Table 5 shows the results of regressing various lags of the retail regions onto wholesale while Table 6 shows the reverse. For both directional flows, the South region fits better across all lag lengths, while the Northeast fits poorly. The Northeast does show greater fit improvement, however, when past retail prices are used to describe the wholesale price.

Several hypotheses can be constructed from the results in Tables 5 and 6. The obvious possibility is that the wholesale and retail prices for broilers are most closely linked in the South. This has theoretical backing as already discussed: since the South is the center of production, there are less costs (such as transportation) separating the levels. The variation in geographical lag also suggests it may be the retail price in the South, rather than the national wholesale price, that is influencing retail prices in the West and Northeast.

CONCLUSION

Accurate model specification for price analysis depends on the inclusion of appropriate lags for several variables. Lags in price responses, in particular, will occur due to processing and transportation times, the costs associated with price changes as well as from any market imperfections. Data periodicity can also create lags or perhaps hide lags; data should be collected at least as frequently as hypothesized lag intervals.

Hypothesized lag lengths can be determined using theory, graphical analysis, biological factors, or values from previous studies. However, to assure correct specification, these lags should be checked with lag length determination tests.

This study examined test criteria with two different goals: predictive ability and efficient parameter estimation. Predictive criteria may tend to overestimate true lags, while parameter criteria may underestimate lengths. A bivariate framework was utilized to allow lag lengths among the different market level prices in the broiler industry to be empirically analyzed.

The Schwarz criteria did have a tendency in some cases to point to shorter lag lengths than the prediction criteria. There was very little variation in results among the prediction criteria, with Akaike's final prediction error and information criteria, and Shibata's criteria matching exactly. Many of the calculated lag lengths matched well with the hypothesized lags generated through graphical and biological analysis. However, some lengths failed to match between the monthly and weekly data sets, reaffirming the importance of data frequency. Analysis also showed geographical variations in lag lengths may be substantial in broiler markets.

Further research could consist of an examination of the impacts of various directions of causality on the lag determination process. In addition, lag structure could be determined for price increases and price decreases within an industry. Further exploration could be focused on the impacts of changing industry concentration on the lag structure of price transmission processes. Lag determination, then, can be an essential component of many types of price analysis research.

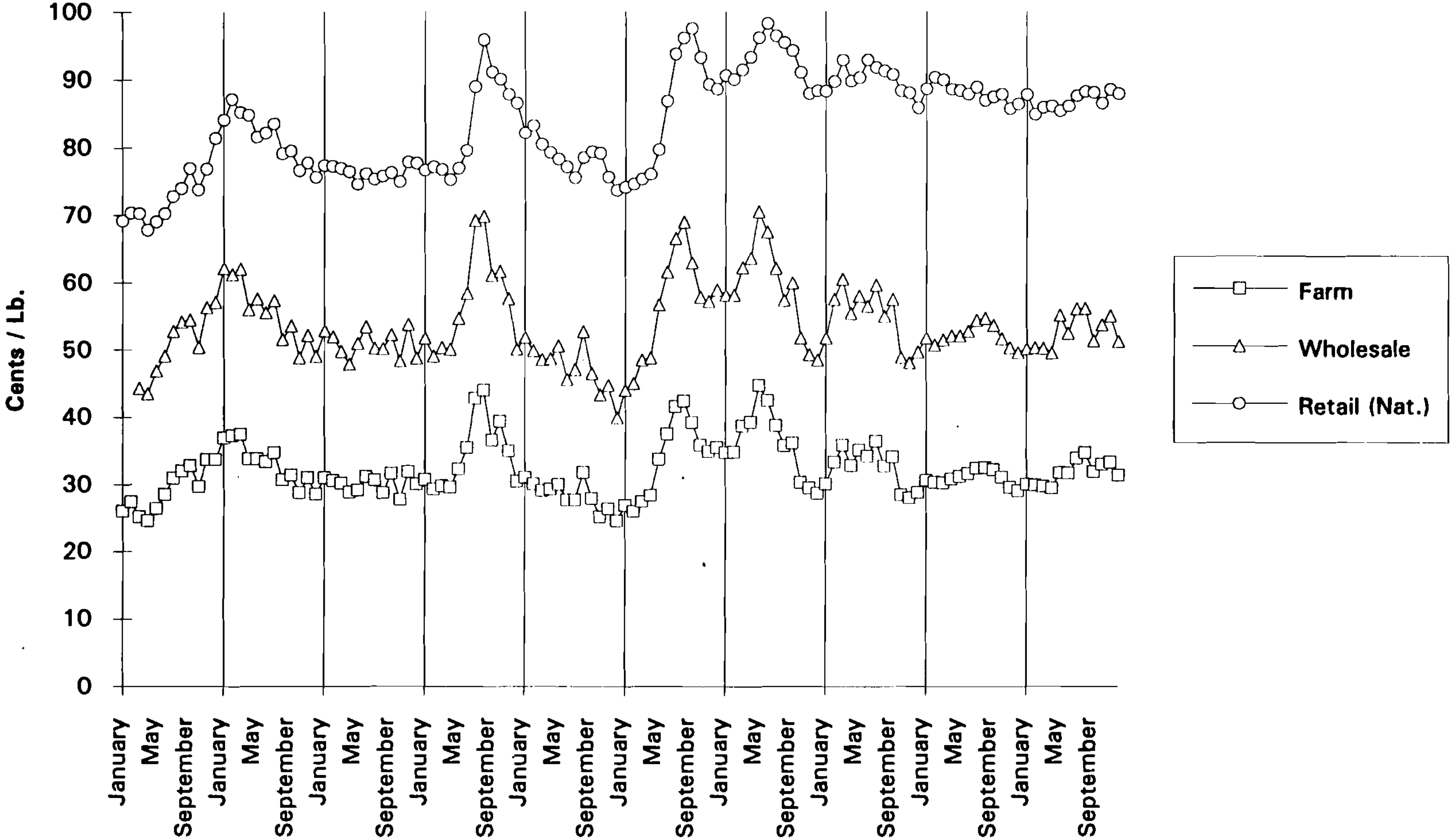

FIGURE 1 Monthly farm, wholesale and retail prices of broilers, 1983 to 1992

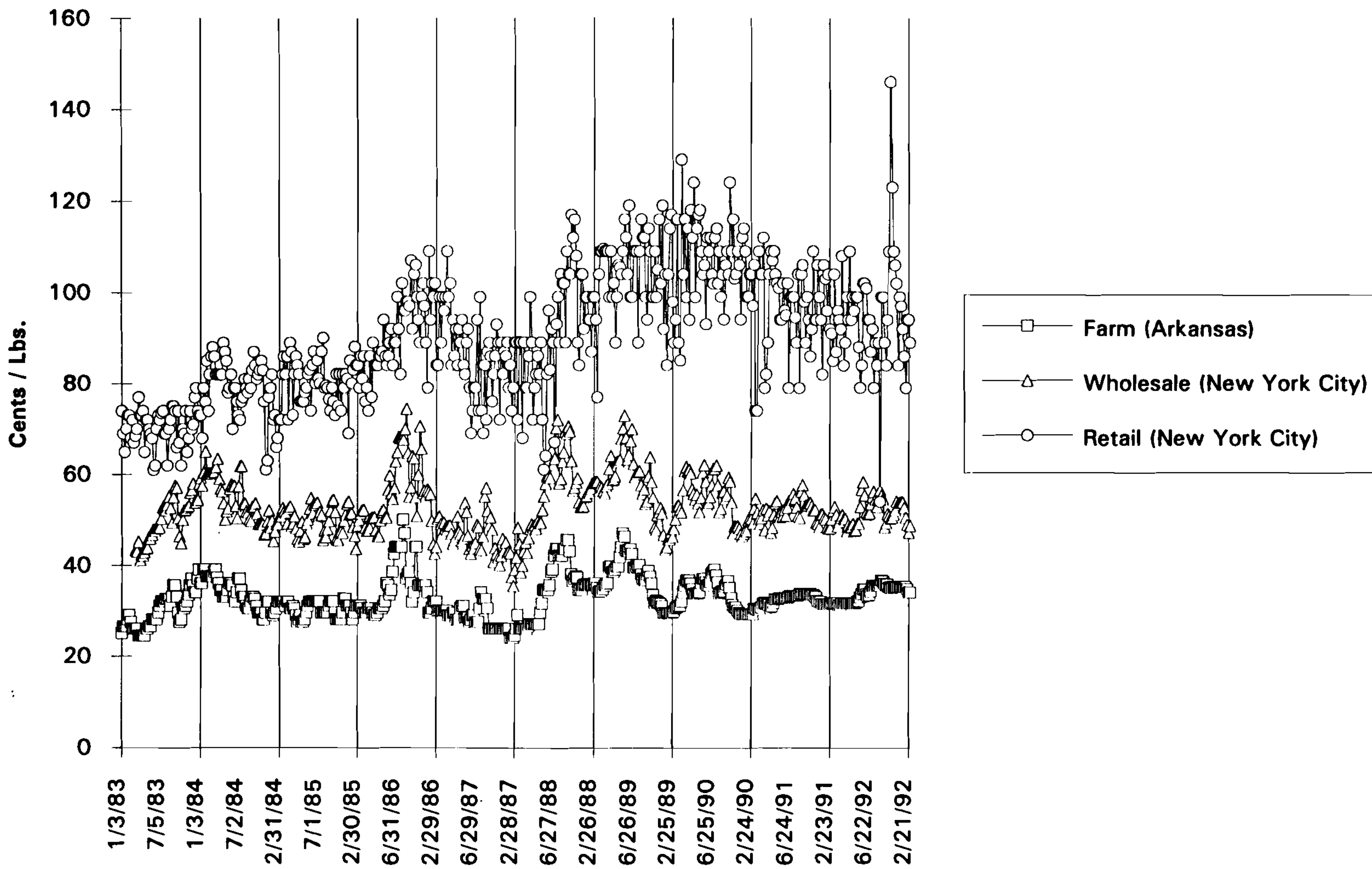

FIGURE 2 Weekly farm, wholesale and retail prices of broilers, 1983 to 1992

TABLE 1 Hypothesized lag lengths among broiler prices at the farm, wholesale and retail market levels

DEPENDENT VARIABLE	LAGGED VARIABLE			
	Monthly		Weekly	
	Farm	Wholesale	Farm	Wholesale
Farm	-		-	
Wholesale	0 or 1	-	1 to 4	-
Retail	3 to 5	3	12 to 15	10 to 12

TABLE 2 Monthly lag length determination test results using Hsiao's method

		CRITERIA				
DEPENDENT	LAGGED	FPE	GCV	SC	Adjusted R Squared	
VARIABLE	VARIABLE	Months	Months	Months	Months	Value
Corn	Corn	3	3	2	3	0.9486
Soybean	Soybean	1	1	1	1	0.8776
Farm	Farm	1,3	1,3	1	3	0.6856
Gas	Gas	2,4	4	2	4	0.9357
Wholesale	Wholesale	1,3	1,3	1	3	0.6516
Retail (Nat.)	Retail (Nat.)	2	2	2	2	0.8994
Retail (W)	Retail (W)	1	1	1	1	0.7999
Retail (NE)	Retail (NE)	1	1	1	1	0.9236
Retail (S)	Retail (S)	2	2	2	2	0.8343
Retail (NC)	Retail (NC)	1	1	1	1	0.7827
Farm	Corn	0	0	0	0	0.6760
Farm	Soybean	0	0	0	0	0.6829
Farm	Wholesale	1	1	0	1	0.9792
Farm	Retail (Nat)	1	1	1	1	0.8293
Farm	Retail (W)	3	3	1	3	0.7466
Farm	Retail (NE)	1,3	1,3	1	3	0.7297
Farm	Retail (S)	1	1	1	1	0.8006
Farm	Retail (NC)	1,3	1,3	1	3	0.7679
Wholesale	Farm	1	1	1	1	0.9770
Wholesale	Gas	0	0	0	0	0.6465
Wholesale	Retail (Nat)	1	1	1	3	0.7938
Wholesale	Retail (W)	2	2	2	3	0.7207
Wholesale	Retail (NE)	1,3	1,3	1	3	0.6997
Wholesale	Retail (S)	1,4	1,4	1,4	4	0.7655
Wholesale	Retail (NC)	3	3	1	3	0.7452
Retail (Nat.)	Farm	3	3	3	3	0.9626
Retail (W)	Farm	1,4	1,4	1	1	0.8473
Retail (NE)	Farm	2	2	2	2	0.9459
Retail (S)	Farm	3	3	0,3	3	0.9256
Retail (NC)	Farm	2	2	0,2	2	0.8655
Retail (Nat.)	Wholesale	3	3	3	3	0.9558
Retail (W)	Wholesale	1	1	0	0	0.8344
Retail (NE)	Wholesale	0,2	0,2	0,2	2	0.9429
Retail (S)	Wholesale	0,3	0,3	0,3	3	0.9167
Retail (NC)	Wholesale	0,2	0,2	0	2	0.8529

Nat. = National
W = West region
NE = Northeast region
S = South region
NC = North Central region

TABLE 3 Weekly lag length determination test results using Hsiao's method

		CRITERIA				
DEPENDENT	LAGGED	FPE	GCV	SC	Adjusted R Squared	
VARIABLE	VARIABLE	Weeks	Weeks	Weeks	Weeks	Value
Farm (Ark)	Farm (Ark)	3	3	3	3	0.9212
Wholesale (NY)	Wholesale (NY)	4	4	4	4	0.8326
Wholesale (SF)	Wholesale (SF)	4	4	4	4	0.8751
Wholesale (Ch)	Wholesale (Ch)	4	4	4	4	0.7949
Retail (NY)	Retail (NY)	7	7	7	7	0.6144
Farm (Ark)	Wholesale (NY)	0,3	0,3	0	0	0.9251
Farm (Ark)	Wholesale (SF)	0	0	0	0	0.9225
Farm (Ark)	Wholesale (Ch)	1	1	0	0	0.9235
Farm (Ark)	Retail (NY)	0	0	0	1	0.6211
Wholesale (NY)	Farm (Ark)	4	4	1,4	4	0.8895
Wholesale (SF)	Farm (Ark)	2,5	2,5	2,4	6	0.9233
Wholesale (Ch)	Farm (Ark)	4	4	0,4	4	0.8588
Wholesale (NY)	Retail (NY)	0	0	0	0	0.8327
Retail (NY)	Farm (Ark)	0	0	0	0	0.9211
Retail (NY)	Wholesale (NY)	1	1	0	1	0.6191

Ark = Arkansas
NY = New York City
SF = San Francisco
Ch = Chicago

TABLE 4 Monthly lag length determination test results using Judge's method

DEPENDENT VARIABLE	LAGGED VARIABLE	CRITERIA FPE Months	GCV Months	SC Months	Adjusted R Squared Months	Adjusted R Squared Value
Farm	Corn	1	1	1	1	0.0448
Farm	Soybean	6	4,6	0	6	0.2068
Farm	Wholesale	1	1	1	2	0.9771
Wholesale	Farm	1	1	0	0	0.9754
Wholesale	Gas	0,3	0,3	0	0	0.0097
Wholesale	Retail (Nat.)	7,14,16	7,14,16	4,13	17	0.8042
Wholesale	Retail (W)	8	8	0,5,8	8	0.6107
Wholesale	Retail (NE)	4,14	4,13	3,13	14	0.6453
Wholesale	Retail (S)	4	4	2,4	4	0.7025
Wholesale	Retail (NC)	6,8	6,8	4	8	0.6379
Retail (Nat.)	Wholesale	6,8	6,8	2,4	9	0.5674
Retail (W)	Wholesale	8	8	2,6	9	0.4548
Retail (NE)	Wholesale	4	4	2	6	0.2103
Retail (S)	Wholesale	6	5	2	6	0.7184
Retail (NC)	Wholesale	2,6	2,6	1	6	0.5858

Nat. = National
W = West region
NE = Northeast region
S = South region
NC = North Central region

TABLE 5 Adjusted R squared values for various retail regions lagged on wholesale using Judge's method, monthly data

RETAIL	MONTHS RETAIL PRICE LAGGED					
REGION	Current	One	Two	Three	Four	Five
West	0.3894	0.3975	0.4329	0.4603	0.4763	0.5275
Northeast	0.1856	0.2792	0.3583	0.4373	0.4362	0.4362
South	0.5721	0.6476	0.6713	0.6771	0.7025	0.6978
North Central	0.5047	0.5281	0.5615	0.5973	0.6094	0.6165

TABLE 6 Adjusted R squared values for wholesale lagged on various retail regions using Judge's method, monthly data

RETAIL	MONTHS WHOLESALE PRICE LAGGED					
REGION	Current	One	Two	Three	Four	Five
West	0.3894	0.4296	0.4338	0.4194	0.4179	0.4302
Northeast	0.1856	0.2405	0.2399	0.2357	0.2297	0.2175
South	0.5721	0.6956	0.7113	0.7088	0.7105	0.7163
North Central	0.5047	0.5808	0.5807	0.5759	0.5799	0.5842

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