



*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*

## Which Broiler Part is the Best Part?

H.L. Goodwin, Jr., Andrew M. McKenzie, and  
Harjanto Djunaidi

Predominance of production and marketing contracts in the broiler industry suggests a traditional analysis of price relationships might no longer be appropriate. In this study, markets for broiler cuts are defined as spatial. Results of a vector autoregressive regression analysis of monthly USDA data from 1987 to 2000 verify the price relationship between white meat and whole broiler prices. Price shocks in the boneless skinless breast market have a greater effect than dark meat shocks, suggesting this market is most important in price transmission. These results will assist industry participants to form more effective marketing and pricing strategies, thus adding efficiency to the market.

*Key Words:* broiler markets, market structure, marketing contracts, price transmission

**JEL Classifications:** C4, D4, L1, Q0

Price relationship studies in the U.S. livestock sector have drawn considerable attention and have been an important area of research in the past (Babula, Bessler, and Schluter; Bessler; Goodwin and Holt; Hahn). Babula, Bessler, and Schluter's study of the poultry industry found that in the period 1970–1980, shocks in corn production affected consumer prices more quickly than those in mid-1950 to late 1960. Hahn studied price transmission in the pork and beef markets. His study suggested that there was strong evidence of price interactions among farm, wholesale, and retail prices.

Past studies of price relationships in different market structures explicitly assumed the existence of different market channels (wholesale, retail, and farm sectors). Therefore, a major theme of these studies was to look at the effect of price shocks in one sector of the mar-

ket as they related to the others. Great interest has developed to investigate how price shocks in the input markets affect, or are transmitted to, both wholesale and commodity retail prices. More recently, Goodwin and Holt and Goodwin and Harper, respectively, have conducted price transmission assessments in the livestock sector. It is the objective of this study to determine dynamic price relationships observed in traditional auction-type wholesale broiler markets in the presence of extensive industry contracting. Thus, in contrast to past studies that have analyzed price transmission between farm, wholesale, and retail market levels, we instead focus attention on the price transmission mechanism among different wholesale broiler markets. The contractual nature and structure of the broiler industry means that price discovery for the industry as a whole is primarily generated at the wholesale level. Hence, a better understanding of the price mechanism between wholesale broiler markets is of particular interest to all broiler market agents.

Price discovery in the broiler industry might be more complex than in the beef and

---

H.L. Goodwin, Jr., and Andrew McKenzie are associate professors and Harjanto Djunaidi is research associate, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, AR.

The authors thank two anonymous reviewers for their in-depth and incisive reviews of this manuscript.



pork industries because price linkages in different wholesale broiler markets are directly affected by the dominant presence of production and marketing contracts. Therefore, one might expect to find that the price discovery process is influenced by the way the industry conducts business. The contracting strategies applied in both input and output markets need to be taken into account through the price linkages in different markets to capture the latest developments in the industry. Currently, most food processors use contracts for buying inputs and selling their products in the market. This is particularly true in the broiler market. Most broiler integrators sell wholesale broilers without giblets (WOG) and different broiler cuts or parts (e.g., boneless skinless breast, BSB; wings, W; leg quarters, LQ; backs and necks, BN; etc.) through contracts with buyers such as fast food or grocery chains.

However, the interaction between poultry buyers and processors also supports actively traded traditional-type auction markets for broiler cuts and WOG. It is these auction-type markets that convey price signals observed in the broiler cut markets to the WOG market and vice versa. The WOG price can be thought of as the carcass price, and integrators commonly use WOG price as a market signal for product costing of different broiler cuts. The WOG price provides important information for integrators in making economic decisions such as input buying decisions and the level of price offered in sale contracts with other food processors. The WOG price is determined by market demand and supply conditions in its own market and in other chicken markets. A broiler is cut into different pieces by the integrators in order to meet both industry and consumer demand for fresh chicken. In this sense, the demand for WOGs comprises both derived demand for broiler cuts and primary demand for the WOG itself. Thus, fluctuations in demand for different broiler cuts help determine movements in WOG price. For example, increasing demand in one particular broiler cut market, such as BSB, will result in an automatic increase in supply of other broiler parts regardless of whether or not the market demand for these

parts increases. Therefore, there exist simultaneous forces in the whole broiler market that determine price movements in each wholesale chicken market.

To distinguish the wholesale market price dynamics, we follow a vector autoregressive regression (VAR) time series modeling approach. The VAR model has been applied in many studies to explain how prices in different marketing channels react given a particular price shock in the system (Babula, Bessler, and Schluter; Bessler; Hahn). The VAR approach allows one to study both the lead-lag price relationships among different markets and the magnitude of the effects of price change in one market on the other markets. Interactions among prices in wholesale broiler markets are of particular interest for two reasons: 1) they determine the dynamic price relationships in different wholesale markets and 2) they determine the lead and lag price relationships in different wholesale markets. Determining these interactions are of interest for firms because decision makers might be able to anticipate, and therefore accommodate, price changes in one market and to predict not only the magnitude, but also the direction of price movements in other markets. Optimal economic results can then be attained while minimizing risk facing the traders in the markets.

## **Data**

Data used in this study are monthly price series for WOG, BSB, W, LQ, and BN obtained from USDA's Poultry Yearbook for the period January 1987–December 2000. Summary statistics for the level of each price series measured in cents per pound are shown in Table 1. Each of the price series (with the exception of BN) exhibits fairly large fluctuations over the sample period. In particular, BSB, the most valuable broiler cut in dollar terms, was also the most volatile of the price series over the sample period as measured by its variance, 928.33. All prices were transformed into natural logarithms. Augmented Dickey-Fuller (ADF) unit root tests were employed to test whether each of the price series was station-



**Table 1.** Basic Statistics of WOG and Different Chicken Wholesale Prices (cents per lb.), USDA Monthly 12 Cities Nominal Price (January 1987–December 2000)

	Mean	Variance	Minimum	Maximum
BSB	186.86	928.33	117.90	294.60
WOG	56.18	31.69	39.81	72.13
W	60.66	163.92	34.65	95.42
LQ	29.02	41.27	15.65	45.60
BN	11.48	0.86	9.40	13.35

ary. The evidence, on balance, suggested that the five price series were stationary in logged levels after adjusting for seasonality. Hence, the specification of a VAR model, rather than a vector error correction model (VEC), was deemed appropriate.<sup>1</sup>

<sup>1</sup> If two or more variables are nonstationary, the possibility exists that one or more cointegrating vectors exist that make specific linear combinations of the variables stationary. In this case, one could estimate the system as a VEC model, rather than as a VAR model in levels. However, in this study, a VAR modeling approach is chosen because the preponderance of evidence suggests that the deseasonalized prices are stationary in logged levels. Note that the final VAR model specification used in this study also accounts for seasonality by including dummies. Prior to testing the price series for stationarity, each series was seasonally adjusted by regressing the respective price variable on a set of 11 monthly dummies and a constant term. ADF tests were then conducted on the regression residuals. Dickey, Bell, and Miller show that the limiting distribution for the autoregressive coefficient in the typical ADF test equation is not affected by the removal of deterministic seasonal components; hence, the presence of unit roots can be tested using standard  $\tau$ ,  $\tau_\mu$ , and  $\tau_\tau$  test statistics. Evidence as to whether or not a constant, a trend term, or both should be included in ADF test equations was analyzed and the appropriate test statistic was determined for each of the price series tests. Test results indicated that the null hypothesis of a unit root could be rejected at the 10% level or lower for each of the price series variables. Results and tests were as follows:  $-3.19$ , ADF  $\tau_\tau$  for BSB;  $-3.56$ ,  $-ADF \tau_\tau$  for WOG;  $-3.92$ , ADF  $\tau_\tau$  for W;  $-2.75$ , ADF  $\tau$  for LQ; and  $-1.78$ , ADF  $\tau$  for BN. Therefore, there is supporting evidence that the deseasonalized prices in logged levels are probably stationary. A 10% significance level was used to determine stationarity. As noted by Harris, when dealing with smaller samples (as in this study because of monthly data), unit root tests are often biased toward falsely accepting the null hypothesis of nonstationarity when variables are stationary but close to having a unit root.

## Empirical Model

Following Sims and Bessler, a VAR approach is used to determine dynamic price relationships among different wholesale broiler cuts and WOG price. Specifically, the magnitudes and directions of price shocks in a particular market and their effects on other markets are analyzed. Different broiler cuts are treated as distinct products, and each is therefore assumed to have its own market; however, all markets are related. These broiler cut prices were modeled as a VAR model. VAR models comprise a set of distributed lag equations that capture the relationships among variables in the system. Sims argued that such a model reduces spurious *a priori* restrictions on the dynamic relationships.

A VAR system for  $n$  variables can be defined as

$$(1) \quad \mathbf{Y}_t = \bar{\mathbf{c}} + \sum_{k=1}^k \begin{bmatrix} b_{11}(k) & \cdots & b_{1n}(k) \\ \vdots & & \vdots \\ b_{n1}(k) & \cdots & b_{nn}(k) \end{bmatrix} \mathbf{Y}_{t-k} + \sum_{i=1}^{11} a_i D_i + \bar{\mathbf{e}}_t,$$

where  $\bar{\mathbf{c}}$  is a vector of constant terms;  $t$  is time ( $t = 1, \dots, T$ );  $\mathbf{Y}_t$  is an  $n$  by 1 vector of economic variables;  $k$  is the lag order of the system;  $b_{ij}(k)$  are the parameters to be estimated under the  $n$  by  $n$  system of equations, where  $i$  refers to each of  $n$  estimating equations in the system and  $j$  refers to each coefficient associated with each  $i$ ;  $D_i$  are 11 seasonal indicator variables;  $\bar{\mathbf{e}}_t$  is a vector of serially uncorrelated random errors, known as innovations, with constant variance.

By definition, the innovations or shocks on each variable will affect the forecast error variance (FEV), and the shocks can be decomposed into "own" shock and shock due to other variables. Each equation in the VAR system is estimated by ordinary least squares. Model selection in terms of the number of lags  $k$  to include in the system is determined with a battery of system residual diagnostic tests.

Applying the techniques used by Bessler, Featherstone and Baker, and Goodwin and



Schroeder, the estimated innovation vector  $\bar{\epsilon}_t$ , is then orthogonalized by Choleski decomposition, which transforms the covariance matrix of the innovations to an identity matrix. The Choleski decomposition of the VAR establishes a Wold causal chain that minimizes the problem of making false inferences with respect to the dynamic interactions caused by contemporaneous correlation of the innovations. To draw inferences regarding the dynamic adjustments in each of the variables to unexpected shocks in the series, the standard VAR system, with orthogonalized innovations, is converted to a vector moving average (VMA) representation that enables one to analyze the system dynamics with forecast error variance decomposition (FEVD) and impulse response functions.

First, the FEVD approach is implemented by computing conditional within-sample forecasts for each of the variables in the system over various forecast horizons. The forecast error variance, which comprises the innovations or shocks to each variable, can then be decomposed, and the relative proportion of the movements in a sequence from its own shocks versus shocks to other variables can be determined. If own-shocks explain all of the forecast error variance of a variable, the price series in question can be considered exogenous to the other variables within the system. However, if a large proportion of the forecast error variance associated with the sequence of a particular variable is explained by shocks to one or more of the other variables, then the price series in question would be considered to be endogenous to the system. The approach also allows one to draw inferences as to the relative importance in terms of the magnitude and sequence of influence among the system's variables.

The VMA representation of the system also enables one to determine the dynamic adjustments in terms of magnitude and direction for each price series in the system in response to shocks to the system's variables. Impulse response functions are visual maps of the dynamic responses of the system's variables to exogenous shocks to any one of the variables. These functions are generated by separately

shocking innovations for each of the variables by one standard deviation. Only significant impulse responses are of any interest, so Monte Carlo integration procedures outlined in Kloeck and Van Dijk are used to construct 95% confidence levels around the impulses. To complement the impulse response analysis dynamic price sensitivity (for more details see Babula; Babula and Bessler), multipliers are also calculated from the response functions. A multiplier is calculated by summing significant cumulative responses of a response variable and dividing this sum by the corresponding significant cumulative responses of a shock variable. The resulting multiplier demonstrates the strength or degree of overall responsiveness of a particular variable to a shock variable. It can be considered a reduced-form elasticity measure (although it is not divorced from time as is a true elasticity).

Imposing the Choleski decomposition on the covariance matrix of the residuals in turn imposes a recursive system on the error structure of the model. In this case, the ordering of the variables in the VAR implicitly assumes a specific sequence of effects among the variables in the system. Only innovations in the first ordered variable of the system can have a contemporaneous effect on the other variables in the system. Innovations in the second ordered variable in the system can have a contemporaneous effect on all the other variables in the system with the exception of the first ordered variable, and so on. Innovations in all of the variables are allowed to have a lagged effect on all of the other variables.

In this analysis, the VAR system is triangularized in order from highest to lowest as follows: BSB, WOG, W, LQ, and BN. Ordering was based on economic theory and prior industry knowledge. First with respect to economic theory, price endogeneity and information flow within the wholesale broiler complex can be explained by both WOG supply and the relative demand for WOG and broiler cuts. Supply-induced price movements primarily result from WOG production shocks. On the other hand, demand shocks generated in broiler cut markets could theoretically lead to derived demand-induced price responses in



**Table 2.** VAR System Residual Diagnostics

	BSB	WOG	W	LQ	BN
LB(16)	12.95 (0.07)	11.41 (0.12)	18.29 (0.01)	17.15 (0.02)	14.14 (0.05)
JB(2)	0.97 (0.62)	2.82 (0.24)	1.70 (0.43)	2.33 (0.31)	184.58 (0.00)
ADF(4)	-5.82	-6.31	-5.38	-6.08	-5.58

Notes: LB(16) refers to Ljung-Box  $Q$ -statistics for 16th-order autocorrelation. JB(2) refers to Jarque-Bera (chi-square statistics with two degrees of freedom) for normality. ADF(4) refers to Augmented Dickey-Fuller unit root test statistics (for which an optimal lag length of four was chosen with Schwartz Bayesian Information Criterion).

the WOG market. In addition, demand shocks in both broiler cut markets and the WOG market could potentially cause price substitution effects that would be transmitted across wholesale markets. Bearing this in mind, the relative importance of WOG price in transmitting supply-induced price effects to other markets is recognized by placing it second within the variable ordering.

Second, prior industry knowledge directed our ordering of broiler cut prices. Placement of BSB first in the variable ordering reflects the fact that white meat is the most valuable part, in dollar terms, of a broiler in the United States and that the decision of how much WOG and dark meat to produce depends heavily on the market demand for white meat. Ordering of W, LQ, and BN prices also reflect their respective dollar value contributions of the total value of a broiler. BN in particular can be regarded as a by-product and is deemed unlikely to induce significant price moves in other wholesale broiler markets. Preliminary testing using alternative variable orderings, and based upon the magnitude of their respective FEVDs, indicated that our chosen ordering was reasonable.

## Results and Discussion

Preliminary diagnostic testing on lag lengths from 1 to 14 months indicated that a 9-month lag specification is necessary to adequately model the system. Table 2 presents system diagnostics for a nine-order VAR model that is used as the final model specification and to which all subsequent model estimation and results pertain. The nine-order VAR model also

includes a constant term and a series of 11 indicator variables in each of the system's equations to account for seasonality. Ljung-Box  $Q$ -statistics for 16th order autocorrelation show that no significant residual autocorrelation is present in any of the equations at the 1% level. In addition, the Portmanteau test for joint residual autocorrelation ( $\chi^2_{275} \approx 294.88$  and  $p$ -value = .20) provides further evidence that our model specification does not suffer from autocorrelation. Jarque-Bera test statistics presented in the second row of Table 2 show that, with the exception of BN, the null hypothesis of normality cannot be rejected for each of the system residuals. Model adequacy is also confirmed in terms of stationarity of the system residuals. ADF test statistics presented in the final row of Table 2 reject the null hypothesis of nonstationarity for each of the series residuals. Overall system residual diagnostic tests suggest that our chosen VAR model is adequately specified.

One final potential concern with respect to model adequacy relates to structural change within the broiler industry and the possibility of a structural break in the data series. Babula, Bessler, and Schluter found evidence of a structural change in retail poultry prices in 1970 during a sample period from January 1956 to November 1985. They noted that a number of demand and supply changes occurred in the poultry industry over their sample period since the 1950s. For example, on the supply side, technological advancements shifted poultry supply rightward, while consumer demand for poultry also grew dramatically. Acknowledging that structural breaks in the data series could pose potential problems



**Table 3.** Contemporaneous Correlation Coefficients of VAR System Residuals, January 1987–December 2000

	BSB	WOG	W	LQ	BN
BSB	1 (0.00)				
WOG	0.49 (0.00)	1 (0.00)			
W	0.25 (0.00)	0.46 (0.00)	1 (0.00)		
LQ	0.25 (0.00)	0.49 (0.00)	0.22 (0.00)	1 (0.00)	
BN	-0.04 (0.64)	0.04 (0.61)	-0.06 (0.41)	0.05 (0.50)	1 (0.00)

in terms of model stability, we argue that over our sample period (January 1987–December 2000), much of the structural change noted by Babula, Bessler, and Schluter was already incorporated into the broiler industry. Therefore, although we do not formally test for structural change over our sample period, we do not believe that our model results are compromised.

Prior to imposing a recursive system on the VAR, the contemporaneous correlations of the equation residuals are examined and presented in Table 3. This procedure allows for any simultaneous interaction and contemporaneous price linkages among prices to be considered. All of the correlation coefficients between broiler cut price residuals and WOG price residuals are significantly different from 0 at the 1% level, except for BN. This indicates that a significant portion of information is reflected in price adjustments between WOG and white and dark meat prices within the current month. A strong contemporaneous correlation could mean that the markets respond rapidly and efficiently (within the sample interval) to new information (Goodwin and Schroeder). The residual correlation coefficients are of approximately the same magnitude between WOG and BSB prices, WOG and W prices, and WOG and LQ prices. This suggests that WOG price movements in the current period are closely linked to both BSB prices on the one hand and W and LQ prices on the other hand. One possible explanation for the strong relationship between current period WOG price

movements and other broiler part price movements could be that production shocks emanating in WOG market are simultaneously, and at least partially, transmitted across other broiler part markets (again with the exception of BN).

Further examination of FEVD shows other evidence of price linkages in the markets and enables one to determine which of these markets are exogenous or endogenous relative to one another at different forecast horizons. Forecast error variance decomposition and standard errors for in-sample forecasts for periods 1, 6, 12, 18, 24, and 36 months ahead are reported in Table 4. The longer lag periods (12 months or more) roughly correspond to lengths of time necessary to alter numbers of parent, grandparent, and pedigree flocks that produce broiler chicks for feeding and slaughter. In all cases, as the forecast horizon increases, the standard errors grow, as would be expected, but tend to level off, providing additional evidence that the system is stationary (Bessler). The proportion of the forecast error explained by innovations in all of the system variables is documented with respect to BSB, WOG, W, LQ, and BN prices.

Perhaps most notably, a strong relationship between BSB and WOG prices is evident, with innovations in both price series explaining relatively large proportions of the other price's FEV. In particular, BSB price has a major influence on WOG price FEV (e.g., BSB accounts for 50% of WOG FEV from month 6 onward). In contrast, other cuts contribute little to the explanation of WOG prices.

BSB price is relatively exogenous over a 1-year forecast horizon, accounting for approximately 70% of own-variation. Thereafter, other broiler cut prices contribute between 25 and 30% explanatory power of BSB FEV, and within 3 years, WOG price accounts for as much as 20% of BSB FEV.

Regarding the other broiler cut prices, it is noticeable that WOG price explains a nontrivial and, in some cases, substantial percentage of unexpected price movements in all broiler cut markets over most forecast horizons. This is likely, at least in part, because of supply-side (production) shocks in WOG that result

**Table 4.** In-Sample Forecast Error Variance Decomposition Attributed to Innovations in Respective Series, January 1987–December 2000

	Month Ahead	Standard Error	BSB	WOG	W	LQ	BN
BSB	1	2.19	98.19	0.27	0.26	1.22	0.06
	6	2.97	89.36	3.74	0.57	2.09	4.25
	12	3.41	71.92	7.24	8.00	3.44	9.42
	18	3.60	64.70	10.24	9.28	3.63	12.15
	24	3.82	57.34	14.92	9.19	6.52	12.03
	36	4.18	47.98	21.64	8.78	11.47	10.13
WOG	1	1.90	24.06	75.94	0.00	0.02	0.43
	6	3.11	51.76	41.38	2.03	3.23	1.60
	12	3.25	49.56	40.47	4.07	3.12	2.78
	18	3.30	48.14	41.24	4.20	3.56	2.87
	24	3.34	47.22	40.53	4.35	4.78	3.13
	36	3.42	45.45	39.25	4.83	5.80	4.68
W	1	3.79	13.47	19.55	65.92	0.23	0.83
	6	6.06	21.76	8.70	52.85	11.81	4.87
	12	6.72	20.64	8.37	48.04	18.40	4.56
	18	7.02	20.26	12.52	44.15	18.74	4.34
	24	7.19	20.07	15.63	42.15	18.01	4.14
	36	7.32	19.51	17.96	40.88	17.40	4.25
LQ	1	4.29	12.05	16.54	0.16	70.99	0.26
	6	6.99	11.10	12.08	0.66	75.20	0.97
	12	7.65	9.91	11.42	2.08	74.54	2.06
	18	8.09	9.08	11.22	2.04	72.70	4.96
	24	8.30	8.64	10.92	2.28	70.01	8.15
	36	8.64	8.05	12.51	2.49	65.20	11.76
BN	1	1.05	0.09	2.16	0.57	0.51	96.66
	6	1.63	4.13	22.24	5.18	6.99	61.46
	12	2.14	4.52	32.69	4.17	7.01	51.61
	18	2.37	3.73	35.03	3.93	11.84	45.47
	24	2.56	3.48	34.18	4.49	18.58	39.27
	36	2.90	2.89	32.25	6.15	24.19	34.52

in similar price movements transmitted across all markets in the chicken complex (e.g., the supply of WOGs directly affects the supply of other broiler cuts).

Interestingly, BSB price accounts for approximately 20% of W price shocks (W can be considered a quasi-white meat), whereas the explanatory power of BSB with respect to LQ FEV is more muted at around 10% and nonexistent for BN, which as mentioned previously is essentially a market by-product.

Table 4 results also indicate that W price is fairly endogenous over forecast horizons beyond the first month. In addition to WOG and BSB prices, which account for approximately

30% of W FEV over all forecast horizons, LQ has some influence explaining 20% of W FEV beyond 6 months. Clearly this influence appears to be unidirectional (W has no influence on LQ). This result is probably related to slow price adjustments in W price in response to export market shocks primarily affecting LQ prices. A substantial amount of U.S. dark meat production is exported, and LQs make up a major proportion of dark meat exports.

LQs appear to be the most exogenous product within the broiler market complex, with 70% or more of its price variability attributed to own-variation. This is again consistent with the fact that a large proportion of LQs are mar-



keted for export; hence, domestic market broiler prices would have less influence on LQ price.

BN price is relatively endogenous beyond the first month. WOG price accounts for 22–35% of BN FEV over most forecast horizons, and LQ has some influence on BN FEV within 24 months. These results would be consistent with both supply-induced price movements reflected in WOG price and export market effects reflected in LQ price. The by-product status of BN would also account for the lack of any discernible relationship with either the white meat BSB or the quasi-white meat W.

In general, FEVD results show substantial influence among various wholesale broiler markets over what appears to be relatively long time periods. For example, BSB price accounts for a large percentage of WOG FEV over all forecast horizons. Likewise, the influence of WOG price increases over longer forecast horizons with respect to BSB, W, and BN FEVs. Also, a greater proportion of both W and BN FEV are attributed to LQ price at forecast horizons beyond 12 months. The slow and prolonged nature of dynamic price adjustments in the wholesale broiler markets can be explained by the contractual nature of the industry. Integrators frequently contract with retailers several months ahead of time; hence, price signals transmitted from traditional wholesale auction markets might take a long time to be fully absorbed.

Table 4 results highlight the important role played by BSB price in driving WOG price movements. In contrast, the prices of other cuts appear to have little influence on WOG prices. These results are consistent with the less important role in price determination that dark meat plays because these parts are considered to have less value by most integrators in the industry. WOG price itself is found to have some influence across all broiler part markets (probably through supply side-induced price shocks).

Impulse responses generated by shocks of one standard deviation in each of the wholesale price series permit evaluations of the dynamic adjustment paths of the prices. Only impulses that are different from 0 at the 5%

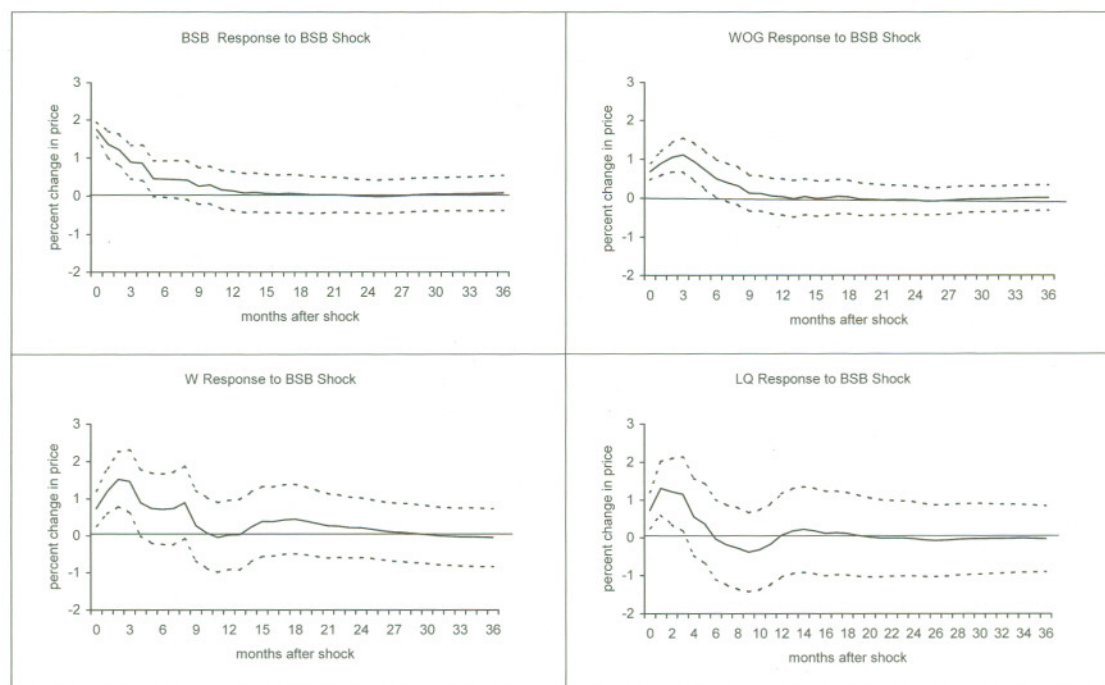
**Table 5.** Dynamic Price Response Sensitivity Multipliers

Shock to Variables	Price Response of Variables				
	BSB	WOG	W	LQ	BN
BSB	1.00	0.89	0.82	0.73	0.00
WOG	0.10	1.00	0.60	0.88	0.87
W	0.00	0.03	1.00	0.00	0.00
LQ	0.00	0.00	0.18	1.00	0.02
BN	0.00	0.00	0.00	0.00	1.00

significance level are presented in Figures 1–4. The statistical significance of each impulse response is illustrated by graphing 95% confidence intervals around the point estimates for the impulse responses. In addition, dynamic price response multipliers presented in Table 5 uncover the overall strength of the price responses to each shock variable.

Figure 1 includes a panel of four impulses generated by a shock to BSB price. The initial shock to BSB price represents approximately a 1.75% price change and takes 5 months to be fully realized before the BSB market returns to preshock levels. This reflects a relatively slow adjustment process for BSB price to unexpected own-price shocks.

The initial increase in BSB price induces similar positive price responses in WOG, W, and LQ market prices. For example, significant WOG price responses occur over a 7-month period, whereas significant W and LQ responses are both 4 months in duration. Corresponding dynamic price response sensitivity multipliers indicate that BSB price shocks generate strong reactions in other wholesale broiler markets (with the exception of BN). Each percent of BSB price change is associated with a percent change of almost equal magnitude in WOG and W markets—specifically, 0.89% change in WOG price and 0.82% price change in W price. These results are consistent with the FEVD results and underscore the strong relationship between BSB and WOG market prices. A dynamic multiplier of 0.73 with respect to LQ also indicates that this dark meat cut is price-sensitive to BSB price shocks, although the response is



**Figure 1.** Impulse Responses of WOG and Chicken Cuts to BSB Shock

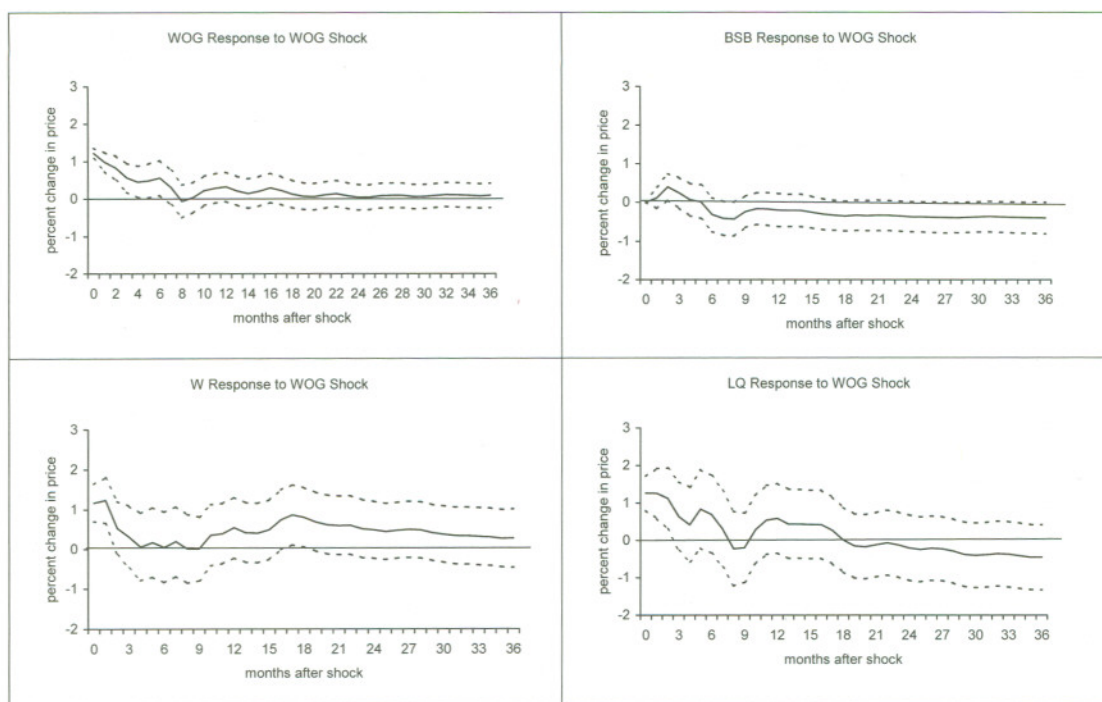
noticeably smaller than for WOG price or for W (a quasi-white meat) price. Also, the absence of any significant impulse responses in BN price to a BSB price shock—which results in a zero-response multiplier—highlights the fact that BN is essentially a by-product and hence does not react to price changes in the white meat market.

Examining the impulse response functions generated by a WOG price shock (and displayed in the panels of Figure 2), one notices that the patterns are similar to the BSB price shock-induced impulse response patterns presented in the panels of Figure 1. An initial 1.2% change in WOG price leads to significant own-price responses for a 7-month period. This price shock is transmitted across all wholesale broiler part markets, although BSB price response is relatively small. Dynamic response multipliers show BSB price changes by only 0.10% for each percent change in WOG price. In contrast, particularly large price responses of almost 0.90% for each percent change in WOG price are recorded for LQ and BN markets. W price also has a substantial positive response to WOG price shock with a

dynamic multiplier of 0.60. The dynamics of the BN response are of a longer duration than for the other markets, taking as long as 13 months before returning to preshock levels. This result would also be consistent with the fact that BN is a by-product; hence, BN price adjustments, although large in magnitude (in percentage terms), are absorbed very slowly. Response times for BSB price (1 month), W price (2 months), and LQ price (3 months) are much shorter. The results are consistent with FEVD results and show that WOG price influences prices in other wholesale broiler markets.

Impulse response results for other broiler cut markets are presented in Figures 3 and 4. Perhaps the most noteworthy result is the lack of any response in BSB and WOG prices to price shocks generated in other broiler cut markets. The shocks were 2.6 and 2.5% for wings and leg quarters, respectively, in the two figures. Figure 3 illustrates that, apart from an own-price response lasting approximately 8 months, only WOG price shows any significant response to a W price shock, and in this case, the response is small in terms of





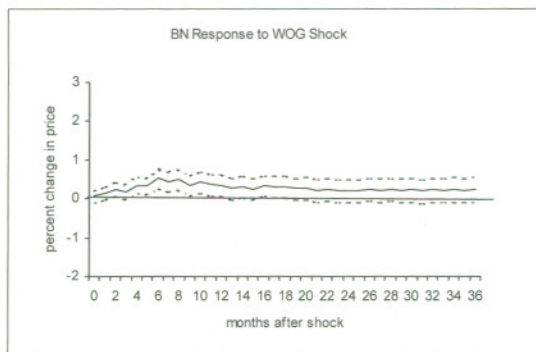
**Figure 2.** Impulse Responses of WOG and Chicken Cuts to WOG Shock

both size and duration. A small dynamic response multiplier shows WOG price only increases 0.03% for each percent change in W price, and the response takes place in a single month (the second month after the shock).

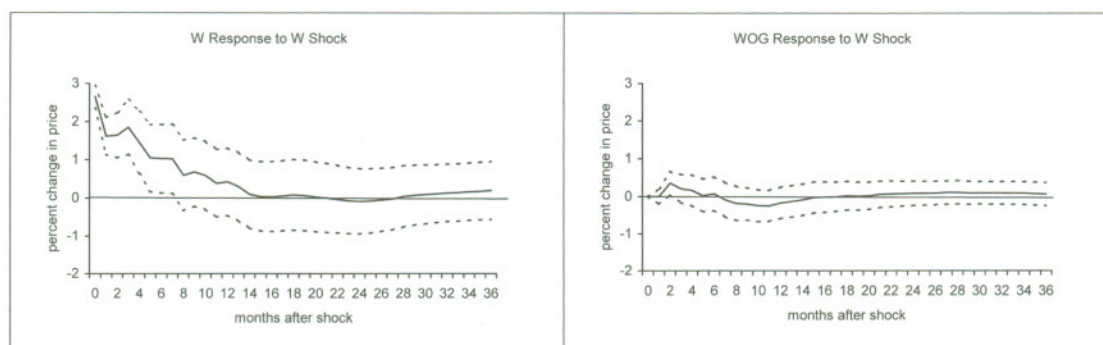
A shock in LQ results in own-price responses lasting 8 months and W and BN responses lasting 8 and 6 months, respectively (note the BN response occurs only in month 6). In terms of dynamic response multipliers, the strength of the responses to LQ price shocks is small. W price increases 0.18% and

BN price increases 0.02% for each percent change in LQ price. These results are also consistent with FEVD results, in which LQ was shown to have some explanatory power in W and BN markets. A shock in BN price elicits no significant price response in any of the other wholesale broiler markets, which again confirms its status as a by-product with no influence on other prices within the chicken complex.

The modal conclusions that can be drawn from the impulse response analyses are as follows. First, BSB plays a dominant role in driving WOG prices and, to a lesser extent, influencing W and LQ prices. Second, WOG price shocks play an important role in transmitting price signals (probably emanating primarily from WOG supply shocks) across all wholesale broiler markets. Third, impulse responses generated in BSB and WOG markets are relatively long in duration (consistent with FEVD results) and highlight the importance of marketing contracts in the broiler industry. Fourth, there is ample evidence to suggest that dark meat cuts induce either no or very little price response in either BSB or WOG mar-



**Figure 2.** (Continued)



**Figure 3.** Impulse Responses of WOG and Chicken Cuts to W Shock

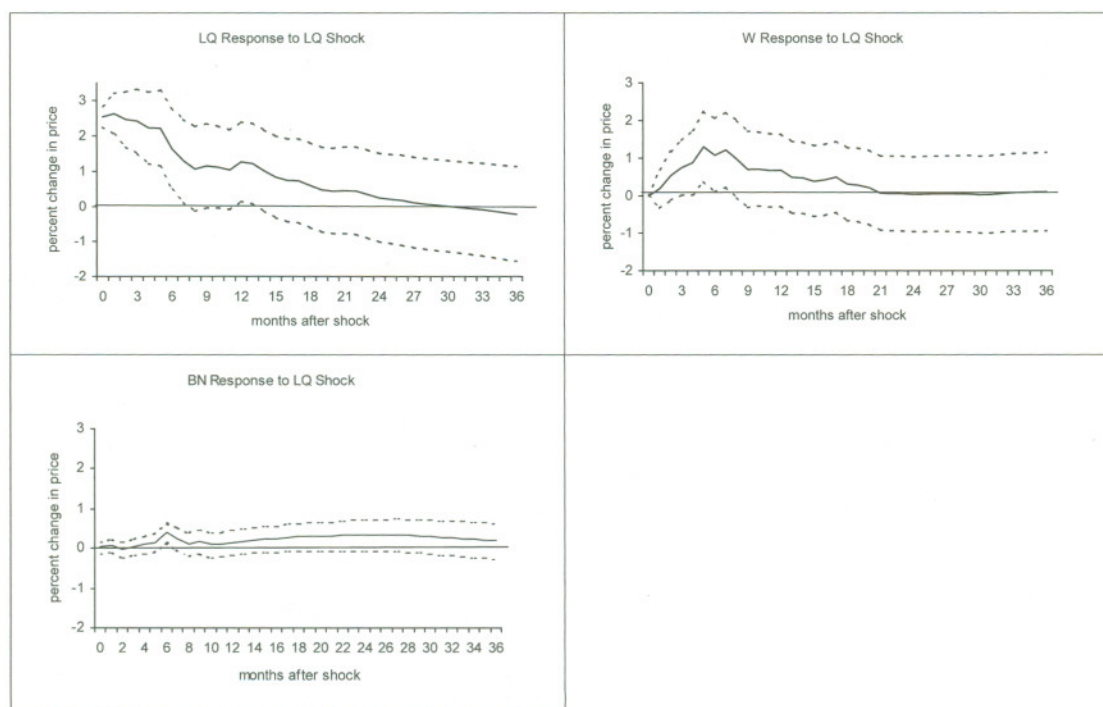
kets. Fifth, LQ price shocks are shown to induce small price responses in W and BN markets. Finally, BN price shocks are not transmitted to other wholesale broiler markets.

### Concluding Comments

This study assesses the importance of modeling price dynamics for broilers in different wholesale chicken markets. In these markets, price adjustments can occur not only from market demand and supply forces but can also

depend on both production and marketing strategies implemented by the integrators and food processors, as well as the fast food and grocery chains. A multimarket VAR model is applied to examine the effect of price shocks in one market on other markets.

The results show strong evidence of significant price relationships between BSB and WOG markets and, to a lesser extent, between BSB, WOG, and other broiler cut markets. In terms of price discovery, shocks in the BSB market have a greater effect on WOG market



**Figure 4.** Impulse Responses of WOG and Chicken Cuts to LQ Shock



prices compared with price shocks emanating in dark meat markets. This suggests that the BSB (white meat) market plays a more important role in transmitting pricing signals to WOG and other broiler cut markets than do the dark meat markets. Thus, our results confirm that BSB is the best part of the broiler. BSB price plays a dominant industry role in transmitting price signals across wholesale broiler markets, probably generated by consumer demand, whereas WOG price plays an important role in transmitting price signals, probably emanating from supply-side shocks, across wholesale broiler markets.

Prominence of BSB price with respect to other prices is consistent with white meat's importance in the broiler industry. BSB (and breast tenderloins when removed from the BSB in further processing) is the basic ingredient for the vast majority of value-added poultry food products. Processors have used these value-added products to diversify their product mix, thereby differentiating their products from those of other firms. This diversification and differentiation strategy has enabled the industry to smooth input and output price fluctuations and stabilize and expand their profits. It is expected that a similar pricing phenomenon will occur in dark meat markets as ethnic foods (primarily Hispanic and Asian) that lend themselves to greater use of dark meat continue to gain acceptance and market share in the United States. Also, as more and more of the volume of broiler meat goes into food service markets, an increasing importance will be placed on contracting for specific broiler cuts, both BSB and dark meat cuts.

Product developments pursued by integrators, food processors, and restaurant chains enable broiler product producers to not only diversify their output but also enhance the efficiency of the entire industry marketing system. Continuous product developments in consumer markets enable food processors and restaurant chains to utilize specific broiler cuts. Despite the saturated nature of the broiler market, integrators will search for and find segments in the market that create new market

boundaries to absorb excess supply of a particular broiler cut in the market.

Price fluctuations in related wholesale broiler markets are better managed if both the direction and the magnitude of the price relationships among markets are known. As both consumer and industry demand become more integrated through contracts, it is clear that players in the markets react strongly to BSB and WOG price shocks, which spill over into other broiler cut markets. Even though the physical products may not be delivered until a certain date specified in the contract, integrators are able to deduct the contingency selling of the dark meat in their accounting records (inventory). Buyers (food processors, groceries, or restaurant chains) are willing to commit to their future purchases on the basis of their future production planning, inventory, or sales forecasts. By doing so, both buyers and sellers of broiler cuts minimize future risks associated with price volatility.

This study has demonstrated that when statistical relationships are appropriately identified and modeled, results of such analyses can be useful for industry managers to efficiently plan and execute their strategies. Knowing the direction of price changes in one market (in particular, price changes in BSB and WOG markets) and the price sensitivities of other markets corresponding to these price changes can help decision makers at every level of the broiler industry to plan and execute their production, pricing, marketing, and inventory management strategies better. This improves risk management and thereby adds efficiency to the market, resulting in benefits to producers, integrators, retailers, and more importantly, to consumers.

[Received October 2001; Accepted March 2003.]

## References

- Babula, R.A. "Quarterly Dynamic Relationships Between the US Wheat Market and Wheat-Related Prices for Products Downstream." *Journal of International Food & Agribusiness Marketing* 11(2000):17-40.
- Babula, R.A., and D.A. Bessler. "The Corn-Egg Price Transmission Mechanism." *Southern*

- Journal of Agricultural Economics* 22(1990): 79–86.
- Babula, R.A., D.A. Bessler, and G.E. Schluter. "Poultry-Related Price Transmissions and Structural Change Since the 1950's." *Journal of Agricultural Economics Research* 42(1990):13–21.
- Bessler, D.A. "An Analysis of Dynamic Relationships: An Application to the U.S. Hog Market." *Canadian Journal of Agricultural Economics* 32(1984):108–24.
- Dickey, D., and W.A. Fuller. "Distribution of the Estimates for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74(1979):427–31.
- Dickey, D., W. Bell, and R. Miller. "Unit Roots in Time Series Models: Tests and Implications." *American Statistician* 40(1986):12–26.
- Featherstone, A.M., and T.G. Baker. "An Examination of Farm Sector Real Asset Dynamics: 1910–85." *American Journal of Agricultural Economics* 69(1987):532–46.
- Goodwin, B.K., and D.C. Harper. "Price Transmission, Threshold Behavior, and Asymmetric Adjustment in the U.S. Pork Sector." *Journal of Agricultural and Applied Economics* 32,3(December 2000):543–53.
- Goodwin, B.K., and M.K. Holt. "Price Transmission and Asymmetric Adjustment in the U.S. Beef Sector." *American Journal of Agricultural Economics* 81(August 1999):630–37.
- Goodwin, B.K., and T.C. Schroeder. "Price Dynamics in the International Markets." *Canadian Journal of Agricultural Economics* 39(1991): 237–54.
- Hahn, F.W. "Price Transmission Asymmetry in Pork and Beef Markets." *Journal of Agricultural Economics Research* 42(1990):21–30.
- Harris, R. *Using Cointegration Analysis in Economic Modeling*. New York: Prentice Hall, 1995.
- Kloek, T., and H. Van Dijk. "Bayesian Estimates of Equation System Parameters: An Application of Monte Carlo." *Econometrica* 46(1978):1–20.
- Sims, C. "Macroeconomics and Reality." *Econometrica* 48(1980):1–48.
- United States Department of Agriculture (USDA). *Poultry Yearbook: Supplement to Livestock, Dairy, and Poultry Situation and Outlook*. Washington, DC: U.S. Department of Agriculture, several issues.