

The Potential Impact of Nutrient Management Legislation on the U.S. Broiler Industry

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Abstract

Increasing numbers and concentration of broiler production has raised concern over waste disposal practices. This article uses a Bayesian Vector Autoregression to analyze the dynamics of the U.S. broiler industry and examine the impact of nutrient management legislation. Such legislation would increase production costs and impact production and wholesale prices.

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The U.S. broiler industry has seen far reaching structural changes in the last 50 years. Extensive improvement in technology and integration of various levels of production, processing and marketing have transformed the broiler industry from a disorganized group of small, independent farms, processors and distributors to a highly integrated, concentrated and efficient operation. Advances in breeding, nutrition, housing, equipment, and disease control have permitted large scale production of high quality meat and reduced real cost of production. Vertical integration has resulted in substantial investment in housing and equipment while reducing operating expenses. . These factors have lead to explosive growth in the number of broilers produced.

This growth in poultry production has not come without cost, however. Perhaps one of the largest concerns facing poultry growers today is how to dispose of poultry litter. Currently, much of the litter is land applied, and its application is largely unregulated. There is considerable potential for contamination of ground and surface water in areas near the land applications sites (Madison and Brunett; Council for Agriculture Science and Technology). These concerns have, in some cases, led to the imposition of State level nutrient management regulations on land application of manures (Carson and Smeltz). Agricultural economists have begun to examine the potential of litter for replacing inorganic nitrogen for crop production (Govindasamy, et al.).

The purpose of this paper is to examine the potential impacts to the U.S. poultry industry resulting from the imposition of nutrient management regulations on a national

basis. Potential regulation of the disposal of poultry wastes will have significant impacts on the industry. Such regulations will increase poultry production costs by increasing the amount of labor and management needed to dispose of litter. In order to examine how nutrient management regulations may impact the industry, we examine the dynamic interrelationships within the industry over time. This will be accomplished using a multiple-equation time-series model. In particular, we will model the U.S. poultry industry using a Bayesian vector-autoregressive approach.

Data and Model Specification

The data were obtained from U.S. Egg and Poultry statistics for 1978-1992 (USDA-ERS). Monthly time series data for total U.S. consumption (1000 lbs.), production cost on a liveweight basis (cents/lb.), 12-city composite wholesale price (cents/lb.), total ready-to-cook U.S. production (1000 lbs.) The selected data series summarize the aggregate dynamic characteristics of the broiler industry. The index of poultry and eggs prices received by farmers was used to deflate production cost and wholesale price.

Preliminary tests of nonstationarity

If the data are deemed to be stationary, then analysis with a vector autoregressive (VAR) model is appropriate. If the data rejects the null hypothesis of stationarity then a vector error correction (VEC) model is called for. Here we perform two tests for non-stationarity, tests for the existence of unit roots and for the presence of cointegration.

The unit root test was based on the "Augmented Dickey-Fuller" (ADF) test. All the variables had an ADF t-test statistic greater than the critical value at 0.10 level. Therefore, the null hypothesis of no unit root was not rejected indicating that all the

variables are stationary in nature.

Though the individual series exhibited stationarity, the system of interrelated series may contain cointegrating vectors. Johansen's Full Information Maximum Likelihood approach is used to derive maximum likelihood estimators of the cointegration vectors for an autoregressive process. The null hypothesis that there are at most r cointegrating vectors in the system is tested using two likelihood ratio tests called the trace test and maximum eigenvalue test (Johansen and Juselius). The results of the cointegration test are presented in Table 1. The table shows the likelihood ratio trace test results for at the most r cointegrated vectors. At all the lag lengths tested, the computed trace test statistic for at most no cointegrating vectors was less than the corresponding 90% critical value ($trace_{r \leq 4, 90\%} = 49.925$). Therefore, we do not reject the null hypothesis of no evidence of cointegrating vectors in the system.

Model Specification

Consider y_t , a $n \times 1$ vector of structural variables. The four structural variables considered are: total consumption of broiler meat (C), production cost per pound of meat produced (PC), wholesale producer price per pound (Pr), and total broiler meat produced (Pd).

Assume that the dynamic behavior of y_t is governed by the following structural model:

$$By_t = Cd_t + E(l)y_{t-1} + u_t, \quad (1)$$

$$V(u) = \Sigma.$$

where $E(l) = A(L)B$ and

- y_t = $n \times 1$ vector of variables observed at time t ,
- B, C = full rank $n \times n$ matrices of coefficients,
- $A(L)$ = matrix of polynomials of order n in the lag operator L that captures the

propagation mechanism of the broiler industry,
 d_t = $n \times 1$ vector of the deterministic component corresponding to y_t ,
 u_t = $n \times 1$ vector of structural disturbances,
 Σ = $n \times n$ covariance diagonal matrix of the structural innovations,

The u_t vector is also referred to as the innovation vector or vector of shocks. The vector of structural disturbances, u_t , is assumed to have a mean of zero and assumed to be serially uncorrelated, mutually orthogonal and have unit variance. A reduced-form representation of the structural model (1) that depends only on the observable variables of y_t can be obtained by premultiplying both sides of (1) by B^{-1} . The autoregressive representation for the n -vector y given by:

$$\begin{aligned} y_t &= B^{-1} C d_t + B^{-1} E(l) y_{t-1} + B^{-1} u_t, \\ y_t &= C^* d_t + F(l)^* y_t + v_t, \end{aligned} \quad (2)$$

here $\text{Cov}(v_t) = \Omega$. The v_t are mean zero, serially independent, one-step-ahead forecast errors. The reduced form in equation (2) summarizes the sample information about the joint process of y_t variables. $F(l)^*$ is a matrix of autoregressive parameters where $F_{ij}^*(l)$ is the i,j th element of the matrix.

In the unrestricted VAR model, each variable in the system depends on lagged values of itself and lagged values of all the other variables. A common order of lag length needs to be specified for the unrestricted VAR model. We start with a maximum lag length of 12 months to capture any yearly pattern in the broiler data.

The likelihood ratio test statistic (Tiao and Box) with the corresponding level of significance was estimated for all combinations of shorter versus longer lag lengths between one and 12. The results of this estimation is presented in Table 2. If the

estimated χ^2 value had a significance level lesser than 95 percent, the null hypothesis was not rejected and the shorter lag length k_1 was chosen. Lags longer than 12 were not considered because they would result in a large number of estimated parameters and reduce the degrees of freedom. Shorter lag lengths such as 1, and 2, were not considered because they fail to reach back far enough to summarize important information. The remaining lag lengths were tested against each other to determine the appropriate lag length. Lag 10 was shown to be preferred to lag 11, however it was rejected by lag 9. Lag 9 rejected all the lag lengths between 4 and 8. Therefore, the lag length was set at 9.

Litterman developed a systematic method for specifying priors for a BVAR. He suggested using the Bayesian prior distribution on parameters of a VAR, which centers on a simple random walk process for each individual series. This is based on the assumption that the behavior of most economic variables can be approximated as a random-walk around an unknown, deterministic drift.

The construction of a BVAR model proceeds with the specification of multi-variate normal prior distribution over the coefficients $F_{ij}^*(l)$. Litterman's prior specifies all coefficients in $F_{ij}^*(l)$ to have zero means, except for the first lag of the dependent variable which has a mean of one. The initial own lag coefficients F_{ii}^* , are equal to one for the series specified in logs. The $F_{ij}^*(l)$ are uncorrelated across all i and j .

The random-walk prior is supplemented with additional assumptions on the form of the distribution of the prior means. Variable lags further in the past have less explanatory power than the more recent lags, thus the standard deviations decrease as the lag lengthens. The parameter λ represents the overall tightness of the prior or how close all

of the coefficients are to their prior mean. Low values of λ imply a tight prior in which the distributions of the estimated coefficients are tightly spiked around the prior means.

The decay parameter γ_1 determines the rate at which the standard deviations decrease on coefficients in the lag distributions. This implies that as the standard deviations become tighter around the mean on the coefficients, lags farther back in time receive less weight. The parameter γ_2 represents the relative tightness of standard deviations of own lags of dependent variables compared to lags of other variables in the system. Standard deviations on other variables in the system can be made tighter than own-lag distribution according to this parameter. Own lags of the dependent variables typically carry a weight of 1.0. Other variables would be assigned weights ranging from 0.0 to 1.0. A value near zero suggests that the prior mean is correct does not allow the data to have much influence on resulting models. When other variables receive the same weight in each equation, the prior type is known as symmetric prior. The weights can be more finely tuned to each individual equation using a general prior $\gamma_2(i,j)$. $\gamma_2(i,j)$ reflects tightness information on coefficients of variable j in the i th equation of the VAR. Values on $\gamma_2(i,j)$ range from 0 to 1.

Given the parameters $(\lambda, \gamma_1, \gamma_2)$, the Litterman prior for the standard deviation of coefficient i, j at lag l is given by:

$$\delta_{ij}^l = - \begin{cases} \frac{\lambda}{1^{\gamma_1}} & \text{if } i = j, \\ \frac{\lambda \gamma_2 \hat{\sigma}_i}{1^{\gamma_1} \hat{\sigma}_j} & \text{if } i \neq j, \end{cases} \quad (4)$$

In the prior, $\hat{\sigma}_i$ is the standard error of the residuals from the univariate autoregressions

for variable i of the lag length chosen for the VAR. The priors are scaled by a ratio of standard errors from the univariate autoregressions. The scaling is necessary so that the units in which the variables of the original series are measured do not bias the specification of the BVAR.

In this study a symmetric prior was specified, where the tightness parameters for the coefficients of variable i in equation j are the same for all i and j . Next, a grid search for choosing the appropriate values of the hyperparameters $(\lambda, \gamma_1, \gamma_2)$ was conducted based on data over the period January 1978 through December 1983. In this search the value of λ ranged from 0.1 to 1.00; γ_1 ranged from 0.001 to 1.0; and γ_2 took values such as 0, 1 and 2. Out-of-sample forecasts are generated for each combination of parameter settings for the period January 1984 through December 1992. The one-step ahead forecast performance statistic as given by the Theil's U-values was calculated for each combination of parameter settings. The combination parameter setting for $(\lambda = 0.3, \gamma_1 = 0.0, \gamma_2 = 0.4)$ was determined to provide the minimum Theil's U over the out-of-sample period. This combination of parameter settings was used to specify the BVAR model.

A BVAR can be further analyzed to study the structural dynamics of the system. Sims termed such an analysis "innovation accounting." Innovation accounting involves obtaining the impulse response functions.

Impulse Response Functions

Consider two variables y_t and z_t . Let the time path of y_t be affected by the current and past realizations of the z_t . The time path of z_t is also affected by the current and past realizations of the y_t . Let this bivariate system be represented by:

$$y_t = b_{10} - b_{12}z_t + \gamma_{11}y_{t-1} + \gamma_{12}z_{t-1} + \epsilon_{yt} , \quad (5)$$

$$z_t = b_{20} - b_{21}y_t + \gamma_{21}z_{t-1} + \gamma_{22}y_{t-1} + \epsilon_{zt} , \quad (6)$$

where it is assumed that both y_t and z_t are stationary. It is also assumed that ϵ_{yt} and ϵ_{zt} are uncorrelated white noise disturbances with standard deviations of σ_y and σ_z , respectively. Since y_t and z_t are allowed to affect each other, b_{ij} and γ_{ij} are its coefficients that allow the structure of the system to incorporate feedback. Equation (5) and (6) constitute a first-order VAR where the structure of the system allows y_t and z_t to affect each other. The fact that the y_t and z_t can effect each other allows us to trace out the time path of the various shocks on the variables contained in the VAR system. Plotting the impulse response functions from the system is a practical way to visually represent the behavior of the y_t and z_t series in response to the various shocks.

Results

The main component of production cost is feed cost. The major determinants of feed cost are corn and soybean meal prices. These input prices are influenced by factors external to broiler production (Chavas and Johnson). Thus, production costs were assumed to be exogenous while identifying the structural model. This exogeneity makes feed cost unresponsive to shocks from other variables in the system.

A production cost shock, however, has significant influence on the other variables included in this study. A positive shock to cost leads to a decrease in net returns to broiler production. The imposition of nutrient management legislation would cause a significant shock to production costs. Poultry producers would be required to take greater care in

the disposal of litter, much of which is currently land applied without great concern for application rates, or nutrient content of the litter. Most nutrient management plans would require a thorough analysis of the litter, an analysis of the soil upon which the litter is being applied, and an analysis of the nutrient requirements of the crop being grown on the land. In addition, more controlled processes of applying the manure would be required, in order to match the level of nutrients being applied to the needs of the crop. Figure 1 illustrates the decline in production due to a shock in production costs. A one standard deviation shock on feed cost led to a 0.12 percent decline in the first month. After 12 months, the production has decreased by 0.6 percent and it reaches the lowest of -0.77 percent after 27 months. When the impulse responses are extended up to 60 months the seasonal fluctuation dies out. The smoothing-out of the impulse responses by the end of 30 months indicate that the shock has only a temporary effect.

The shock to production costs also affect wholesale prices. During the drought of 1983-1984, production costs rose due to tight feed supplies. This situation limited production decisions which eventually resulted in high wholesale prices. Babula *et al.* attributed such price-increasing shocks to corn production in explaining poultry prices. The patterns of impulse responses parallel those expected where producers are price-takers in a perfectly competitive industry. Poultry producers having faced higher production costs, marketed birds early leading to price-depressing higher slaughter rate. More recently, increased corn price lead to an increase of farm poultry price. This is indicative of the change from an industry of many small, price taking producers to a vertically integrated industry where producers had the market power to pass on corn-based feed

cost increases to consumers.

Figure 2 shows a similar price response for a one percent standard deviation shock in production cost, to that found by Babula *et al.*. The impulse response shows an initial decline from 0.2 percent in the first month to -0.08 percent in the third month. This price behavior may be due initial lag in transmission of production cost shock. After the initial decline, the price response picks up in the consecutive months and tables after six months at 0.67 percent. Price remains positive until the 10th month after this period, the price response is negative and eventually dies out indicating stationarity.

The behavior of price in response to a production cost shock indicates an eventual increase in wholesale price. This suggests that the industry has the efficiency to transmit feed cost increases to consumers through increased prices. We can infer that the power over price transmission was made possible by the increased level of vertical integration.

Conclusions

It is clear from the impulse response functions that a production cost increasing policy such as the imposition of nutrient management legislation would have a negative impact on poultry production levels. This would, in turn, lead to higher wholesale broiler prices. These wholesale price impacts, however, appear to be transitory in nature. In the case of both the production level and wholesale price response, the impacts from the shock to production costs were quite small on a percentage basis. This tends to indicate that the impact of a cost-increasing event, such as the imposition of nutrient management legislation, would not cause major changes in poultry production, or wholesale prices.

Table 1. Testing for the number of cointegrating vectors at different lag lengths*.

Lag Length	$r = 0$	$r \leq 1$	$r \leq 2$
$p = 1$	33.217	16.582	3.110
$p = 6$	30.862	15.296	3.996
$p = 7$	30.472	15.459	5.808

* Critical value at 90 percent confidence is 49.925.

Figure 1. Production Response to a One Standard Deviation Shock to Production Costs

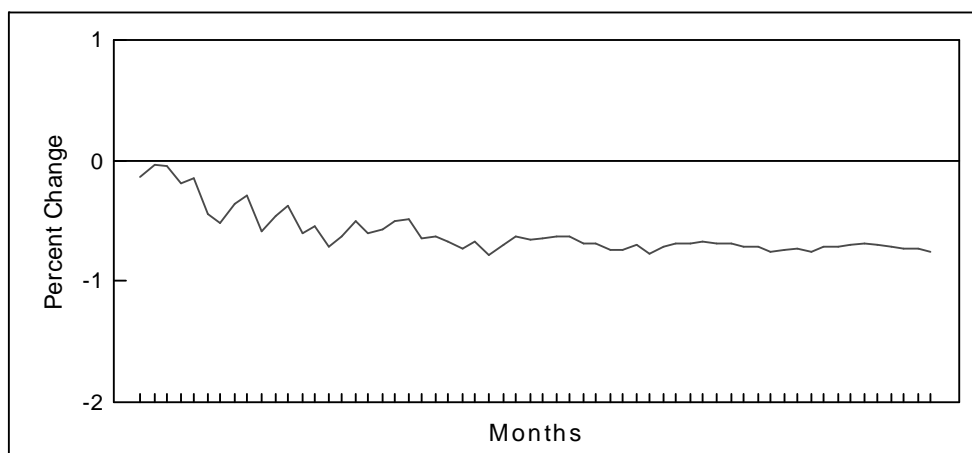
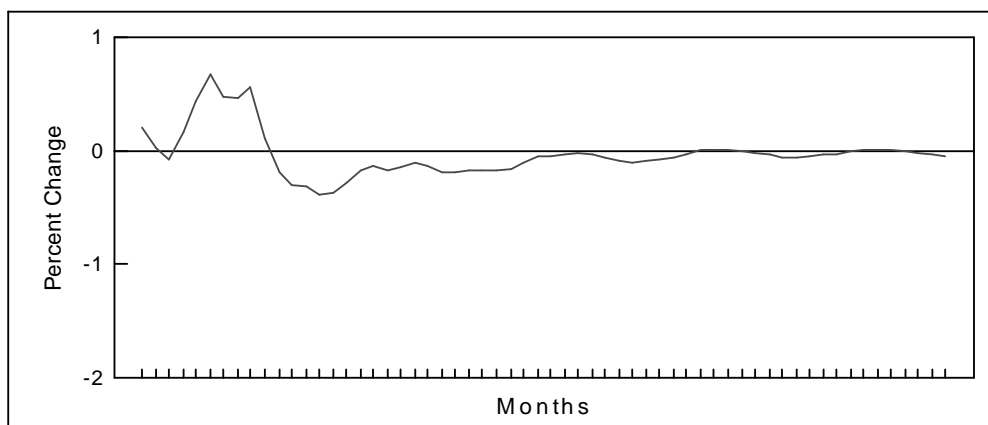


Table 2 Likelihood ratio test statistic for lag length in VAR models.

longer lag (k_2)	shorter lag (k_1)	$M(k_2, k_1)^*$	Levels of significance
2	1	122.99	0.00
3	2	86.28	0.00
4	3	37.91	0.00
5	4	18.21	0.31
6	5	12.6	0.70
7	6	51.94	0.00
8	7	51.44	0.00
9	8	90.18	0.00
10	9	7.08	0.97
11	10	24.87	0.07
12	11	33.70	0.01
9	7	139.57	0.00
9	6	188.60	0.00
9	5	200.62	0.00
9	4	215.81	0.00

* $M(k_2, k_1)$ is approximately distributed as a χ^2 with $m^2(k_2 - k_1)$ degrees of freedom.

Fig 2. Wholesale Price Response to a One Standard Deviation Shock in Production Costs



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