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USDA Livestock Price Forecasts: A Comprehensive Evaluation

Dwight R. Sanders and Mark R. Manfredo

One-step-ahead forecasts of quarterly live cattle, live hog, and broiler prices are evaluated under two general approaches: accuracy-based measures and classification-based measures which test the ability to categorize price movements directionally or within a forecasted range. Results suggest U.S. Department of Agriculture (USDA) price forecasts are not optimal. Broiler price forecasts are biased, and all the forecast series tend to repeat errors. While the USDA forecasts are more accurate than those of a univariate AR(4) time-series model, evidence suggests the USDA live cattle forecasts could be improved with a composite forecast that includes a time-series alternative. Despite this, the USDA correctly identifies the direction of price change in at least 70% of its forecasts over the sample period. Furthermore, actual prices fall within the USDA's forecasted range 48% of the time for broilers, but only 35% for hogs. Finally, there is some evidence that the USDA's price forecasting accuracy has improved over time for broilers, but has gotten marginally worse for hogs.

Key words: forecast efficiency, forecast evaluation, livestock prices, USDA forecasts

Introduction

> *Tyson Foods, Inc., the world's largest producer, processor and marketer of chicken and poultry-based food products, today said that based on operating results through May, it continues to experience operating and margin pressures. These margin pressures are due to previous disruptions in the company's Russian market and to lower-than-expected prices received on its overall product mix....*
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> — Tyson Foods, Inc., Springdale, Arkansas
> Press Release, June 12, 1997

For agricultural producers and agribusinesses, commodity prices directly affect costs, revenues, and profitability. For example, agribusiness giant Tyson Foods is involved in the production and processing of the three major meats: chicken, beef, and pork. In its public announcements, Tyson Foods clearly indicates that fluctuating meat prices directly affect the company's corporate earnings. Furthermore, Tyson's earnings projections necessarily rely on "forward-looking statements" about market prices (Tyson Foods, Inc.). To provide meaningful guidance to industry analysts, it is important that Tyson—and similar firms—understand and evaluate available price forecasts. Likewise, for smaller agribusinesses, price forecasts are crucial for planning business operations and making investment decisions.

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Given the importance placed on agricultural prices, it is not surprising that commodity price forecasting, and the evaluation of forecasts, has long been an area of interest for economists [see, e.g., the early works of Green (1926) and Pettee (1936)]. In particular, forecasts provided by public agencies such as the U.S. Department of Agriculture's (USDA's) National Agricultural Statistics Service (NASS) are of interest. Producers, agribusinesses, and financial institutions use these forecasts to make production, marketing, and lending decisions (USDA/NASS). In fact, the objective of providing market outlook information is to enhance economic decision making, which leads to increased profits, utility, or social welfare (Freebairn). Accurate public forecasts for commodity prices can result in improved decision making by private forecasters, and also reduce market price variation (Smyth). Conversely, systematic errors in forecasts could lead to a misallocation of scarce resources (Stein). Thus, it is important that industry participants understand the uncertainty surrounding USDA price forecasts as well as any systematic biases or inefficiencies they may contain (Aaron).

Most research examining USDA forecasts focuses on the performance of USDA quantity or production forecasts in both crops (Irwin, Good, and Gomez) and livestock (Bailey and Brorsen). For example, as documented by Bailey and Brorsen, the USDA's annual beef and pork production forecasts, published in its "World Agricultural Supply and Demand Estimates" (WASDE) monthly report, are biased predictors over the entire 1982–1996 interval. Specifically, there is a tendency for the USDA to underestimate production over long horizons. Further, in a recent analysis of U.S. production forecasts for pork, beef, and broilers, Sanders and Manfredo found the USDA's one-quarter-ahead production forecasts are inefficient in that they are too extreme (i.e., they are not minimum variance forecasts).

The above findings, while specific to production forecasts, also lead one to question the efficiency of the USDA's price forecasts, which are also published in WASDE. It can be argued that these price forecasts are possibly more important than quantity forecasts. This is certainly the case for small firms, because aggregate quantity forecasts do not directly impact their businesses. Rather, it is the resulting price which determines their costs and revenues. In this sense, the present research is an important extension to the existing literature regarding the performance of USDA forecasts.

Despite their importance for agribusiness decision makers, USDA price forecasts have not been as closely scrutinized as production forecasts. An exception is an earlier study by Elam and Holder who evaluated the USDA's price forecasts for rice. They found the USDA's public forecasts compared favorably to those estimated by a univariate Box-Jenkins model. In related work, Kastens, Schroeder, and Plain concluded the USDA's livestock price forecasts were not as accurate as those provided by extension economists. While these studies' comparative findings are important, they do not provide a complete picture of the USDA's forecasting performance. In this context, USDA price forecasts have not received a thorough evaluation. Thus, the present research helps fill a void in the literature by providing a comprehensive examination of the USDA's livestock price forecasts.

The analysis provided here is comprehensive in the sense that it does not focus on a single aspect of forecast evaluation, such as traditional accuracy measures, but instead incorporates multiple tests of forecast performance. These multiple tests are separated into two general categories: accuracy-based tests and classification-based tests. The accuracy-based tests include: (*a*) traditional error measurements, (*b*) optimality as measured by bias and efficiency, (*c*) forecast encompassing with respect to time-series forecasts, and (*d*) forecast improvement through time. Accuracy-based tests are well established in the agricultural economics literature, and usually rely on a mean squared error loss function. The second category of evaluation, classification-based tests, includes: (*a*) directional accuracy or market timing, and (*b*) the probability that prices fall within a forecasted price range. Classification-based tests are binary in nature and gauge a forecast's ability to correctly categorize prices or price movements. USDA price forecasts have not previously been examined in this framework. Furthermore, in both the accuracy-based and classification-based approaches, statistics are calculated to test the USDA's performance versus a simple alternative.

Collectively, this array of testing procedures provides a complete evaluation of the USDA's ability to forecast livestock and broiler prices and represents a methodological extension over prior research. The results presented here should allow industry participants to more efficiently utilize the USDA's outlook information, ultimately increasing the efficiency and accuracy of their economic decisions.

Data

In evaluating the performance of USDA livestock price forecasts, this study analyzes the performance of one-quarter-ahead price forecasts for slaughter cattle, hogs, and broilers published in the WASDE reports. The price forecasts are for 1,100–1,300 pound Nebraska slaughter cattle (direct trade), 51%–52% lean hog carcasses (live equivalent, national base), and 12-city average wholesale broiler prices.[1] Price forecasts are published as an expected range. For instance, the USDA's slaughter cattle forecast for the first quarter of calendar year 2002 is \$66–\$68 per hundredweight (cwt). The midpoint of the forecasted range (\$67) is used as the point forecast for the quarter.

The USDA's WASDE report is published on a monthly basis, and is released between the 8th and the 14th of each month. Given the focus on quarterly forecasts, the price forecasts for cattle, hogs, and broilers are collected from the January, April, July, and October reports for each calendar quarter. For example, the forecasted price for the first calendar quarter is collected from the January report. This data collection process results in a series of non-overlapping, independent, rolling-event forecasts; thus, it negates the problem of inconsistent ordinary least squares (OLS) standard error estimates stemming from overlapping forecast horizons (Brown and Maital; Clements and Hendry, p. 57). The actual (realized) price levels are taken from subsequent releases of WASDE reports to assure they correctly match the prices the USDA is attempting to forecast. The sample period is from the third quarter of 1982 (1982.3) to the third quarter of 2002 (2002.3), resulting in 81 quarterly observations of one-step-ahead price forecasts and realized values.

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[1] Data definitions did change over the sample period. Live cattle prices were defined as follows: choice slaughter steers, Omaha, 900–1,100 pounds, 1982.3 to 1988.2; Omaha, 1,000–1,100 pounds, 1988.3 to 1991.1; Nebraska, direct, 1,100–1,300 pounds, 1991.2 to 2002.3. Live hog prices were defined as follows: barrows and gilts, seven-market average, 1982.3 to 1992.2; Iowa-S. Minnesota, No. 1-3, 1992.3 to 1999.1; Iowa-S. Minnesota, live equivalent, 51%–52% lean, 1999.2 to 1999.4; National Base, live equivalent, 51%–52% lean, 2001.1 to 2002.3. Broiler prices changed from a nine-city average to the 12-city average in 1983.2. Where data definitions changed, the USDA's predicted price changes are properly adjusted. In most instances, the new and old series used by the USDA closely correspond.

Livestock prices are known to demonstrate seasonal patterns as a result of natural fluctuations in production. For instance, hog prices tend to be higher in the summer, corresponding to the seasonal low in pork production. Therefore, the analysis focuses on seasonal differences defined as the log-relative price change from the same quarter of the prior year. Given this application, A_t is defined as the actual price level in quarter t, and F_t is the one-step-ahead price forecast for quarter t. The change in actual prices is defined as $AP_t = \ln(A_t/A_{t-4})$, and the forecasted price change is $FP_t = \ln(F_t/A_{t-4})$. Consequently, changes reflect the percentage change in the quarterly average price from the prior year. This framework is consistent with that used by most industry analysts (e.g., Hurt; Kastens, Schroeder, and Plain).[2,3]

Methodology and Results

The objective of this research is to fully evaluate the USDA's price forecasts for cattle, hogs, and broilers. In doing so, the USDA's forecasts are compared to those of a simple time-series model (Granger). Past research has shown that simple autoregressive integrated moving average (ARIMA) models perform comparably to more sophisticated vector autoregressive (VAR) style models (Brandt and Bessler). Therefore, $AP_t = \ln(A_t/A_{t-4})$ is modeled as an autoregressive process with four lags. This model was specified and estimated over the pre-sample data from 1970.1 through 1982.2. The AR(4) model fit the data well and the residual autocorrelation and partial autocorrelation functions were not statistically significant out to eight lags. The AR(4) model represents a simple, low-cost alternative to the USDA's forecasts. The AR(4) model yields a series of 81 one-quarter-ahead forecasts for AP_t from 1982.3 through 2002.3, which are used for comparison in the following tests.

Accuracy-Based Tests

The following tests all relate to the accuracy of the USDA's point forecasts of livestock prices. Point forecasts are assumed to be the midpoint of the forecasted range. The accuracy-based tests conducted are founded on well-established procedures in the literature, and in most cases rely either directly or indirectly on a mean squared error loss function.

Summary statistics for each series are presented in table 1. Means and standard deviations are measured as the percentage price change from the prior year. None of the mean actual price changes are statistically different from zero (5% level, two-tailed t-test). Furthermore, hog prices are the most volatile with a standard deviation of 21.8%, more than double the volatility of cattle prices (8.3%). The higher volatility of hog prices is consistent with the relatively high volatility displayed by pork production (Sanders and Manfredo).

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[2] The seasonally differenced prices, $AP_t = \ln(A_t/A_{t-4})$, and price forecasts, $FP_t = \ln(F_t/A_{t-4})$, are stationary series as judged using augmented Dickey-Fuller tests. The results are available from the authors upon request.

[3] In the evaluation of forecast errors, it does not matter if one uses year-over-year price changes, price changes over successive observations, or absolute errors. It is easily shown that $e_t = \ln(A_t/A_{t-4}) - \ln(F_t/A_{t-4}) = \ln(A_t/A_{t-1}) - \ln(F_t/A_{t-1}) = \ln(A_t) - \ln(F_t)$.

Table 1. Summary Statistics, 1982.3–2002.3

Description	Cattle	Hogs	Broilers
Actual Prices:			
Mean	0.0008	-0.0147	0.0092
Standard Deviation	0.0831	0.2183	0.1230
USDA Forecasts:			
Mean	0.0046	-0.0161	-0.0151
Standard Deviation	0.0615	0.1856	0.1032
AR(4) Forecasts:			
Mean	0.0177**	0.0156	0.0323**
Standard Deviation	0.0607	0.1768	0.0999

Notes: Double asterisks (**) denote statistically different from zero at the 5% level (two-tailed *t*-test). The values in the table are interpreted as percentages. For instance, the mean annual change in hog prices over the sample interval was -1.47% with a standard deviation of 21.83%.

Table 2. Forecast Accuracy Measures, 1982.3–2002.3

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
RMSE	0.0504	0.0882	0.0602
MAE	0.0392	0.0710	0.0456
Theil's U	0.6100	0.4059	0.4915
AR(4) Forecasts:			
RMSE	0.0648	0.1328	0.0758
MAE	0.0512	0.1059	0.0628
Theil's U	0.7841	0.6110	0.6188
RMSE MDM Test[a]	-2.496	-3.864	-2.267
MAE MDM Test[a]	-2.620	-4.662	-2.896

Notes: RMSE is the root mean squared error, and MAE is the mean absolute error.

[a] The *t*-tests from the modified Diebold-Mariano (MDM) test for equality of prediction errors. The USDA's forecast RMSE and MAE are statistically smaller than those of the time-series forecasts at the 5% level.

Measures of Forecast Error

Traditional measures of forecast error are presented in table 2. The statistics reported are root mean squared error (RMSE), mean absolute error (MAE), and Theil's U.[4] By all measures, the USDA forecasts are more accurate than the time-series forecasts across the three sectors. However, Harvey, Leybourne, and Newbold (1997) suggest differences in accuracy measures should be tested with their modified version of the Diebold-Mariano test. Given two time series of one-step-ahead forecast errors (e_{1t}, e_{2t}), and a specified loss function $g(e)$, the null hypothesis of equal expected forecast performance using the modified Diebold-Mariano (MDM) test is $E[g(e_{1t}) - g(e_{2t})] = 0$. Specifically, the MDM test is based on the sample mean of d_t, where $d_t = g(e_{1t}) - g(e_{2t})$, with the test statistic having a *t*-distribution. The *t*-statistics from the MDM test are presented in the bottom two rows of table 2. Using this test, the RMSE and MAE produced by the USDA's

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[4] For n observations, the RMSE = $(\Sigma e^2/n)^{0.5}$, MAE = $\Sigma \mid e \mid / n$, and Theil's U = $[(\Sigma e^2)/(\Sigma AP^2)]^{0.5}$, where e is the forecast error.

forecasts are found to be statistically smaller (5% level) than those of the time-series model.

Similar to the RMSE, Theil's U relies on squared forecast errors, but normalizes the forecast errors by the volatility of the underlying series. Thus, Theil's U provides some basis of comparison across the three markets. Theil's U has a lower bound of zero for perfect forecasts, and it takes a value of unity for naïve "no-change" forecasts (Leuthold). As expected, both the USDA and time-series forecasts offer superior performance over a "no-change" forecast. Looking across the markets, Theil's U shows the most improvement over a "no-change" forecast occurs in hogs, suggesting much of the underlying volatility in hog prices is predictable.

Tests for Optimality—Bias and Efficiency

A forecast is optimal if it is unbiased and efficient (Diebold and Lopez). Granger and Newbold (p. 286) suggest efficiency tests should focus strictly on forecast errors, $e_t = AP_t - FP_t$, to avoid interpretive problems associated with the traditional linear regression-based test of forecast optimality (Holden and Peel). The following tests for bias and efficiency use the methodology demonstrated by Pons (2000), which incorporates the suggestion of Granger and Newbold.

The test for forecast bias relies on an OLS regression of forecast errors (e_t) on an intercept term (γ), where:

$$e_t = \gamma + \mu_t. \tag{1}$$

Given that optimal forecast errors should have a mean of zero (Diebold and Lopez), the null hypothesis of an unbiased forecast is $\gamma = 0$. This hypothesis is tested using a two-tailed *t*-test. The estimation results for expression (1) are presented in table 3.[5]

The USDA forecasts are unbiased for cattle and hog prices, but they consistently overestimate broiler prices ($\gamma < 0$). The bias in broiler price forecasts is a statistically significant −2.42%. In contrast, the time-series forecasts statistically underestimate all the price series ($\gamma > 0$). It is not clear why the time-series forecasts demonstrate this bias. The bias could result from a misspecification of the autoregressive process, structural changes in the livestock industry that are difficult to capture in time-series models, or the use of data from a period of rapid commodity inflation in the early 1970s.

To further explore the optimality conditions of these forecasts, tests for forecast efficiency are also conducted. Forecasts are weakly efficient if e_t is orthogonal to both the forecast as well as prior forecast errors (Nordhaus). Thus, weak efficiency is tested using the following regression framework (Pons 2000):

$$e_t = \alpha_1 + \beta FP_t + \mu_t \tag{2}$$

and

$$e_t = \alpha_2 + \rho e_{t-1} + \mu_t. \tag{3}$$

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[5] In this and all subsequent regression models, heteroskedasticity is tested using White's test, and serial correlation is tested using the Lagrange multiplier test. Heteroskedasticity is corrected using White's heteroskedastic consistent covariance estimator, and serial correlation using the covariance estimator of Newey and West (Hamilton, p. 218).

Table 3. Forecast Bias Test, $e_t = \gamma + \mu_t$, 1982.3–2002.3

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
Estimated γ	0.0038	-0.0014	-0.0242
(t-Statistic)	(0.56)[a]	(-0.14)	(-3.31)[a]
p-Value	0.5783	0.8855	0.0014
AR(4) Forecasts:			
Estimated γ	0.0169	0.0302	0.0231
(t-Statistic)	(2.42)	(2.09)	(2.86)
p-Value	0.0179	0.0396	0.0054

[a] Calculated using the Newey-West covariance estimator.

Table 4. Beta Efficiency Test, $e_t = \alpha_1 + \beta FP_t + \mu_t$, 1982.3–2002.3

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
Estimated β	-0.0744	-0.0027	-0.0650
(t-Statistic)	(-0.81)	(-1.45)	(-1.59)[a]
p-Value	0.4213	0.1505	0.1147
AR(4) Forecasts:			
Estimated β	0.1002	0.0092	0.0066
(t-Statistic)	(0.86)	(0.15)[a]	(0.08)
p-Value	0.3906	0.8807	0.9358

[a] Calculated using the Newey-West covariance estimator.

Table 5. Rho Efficiency Test, $e_t = \alpha_2 + \rho e_{t-1} + \mu_t$, 1982.3–2002.3

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
Estimated ρ	0.2465	0.1804	0.3161
(t-Statistic)	(2.26)	(1.63)	(3.03)
p-Value	0.0264	0.1078	0.0034
AR(4) Forecasts:			
Estimated ρ	0.0228	-0.2108	0.1745
(t-Statistic)	(0.20)	(-1.91)	(1.60)
p-Value	0.8388	0.0602	0.1146

A condition for efficiency is that $\beta = 0$ in (2) and $\rho = 0$ in (3). These hypotheses are tested using a two-tailed t-test on the estimated parameters. The results of estimating equation (2) are presented in table 4. For the USDA forecasts, the null hypothesis of weak efficiency ($\beta = 0$) is not rejected at the 5% level for any of the price forecasts. Therefore, the price forecasts efficiently incorporate the utilized information set, in contrast to the inefficiency of USDA livestock production forecasts documented by Sanders and Manfredo. The time-series forecasts also fail to reject the null of efficiency. Furthermore, the results from estimating equation (3), reported in table 5, show there is a consistent tendency across the three markets for the USDA to repeat like errors—i.e., the estimated ρ is positive for all forecast series, and is statistically significant (5% level) for cattle and broilers. This pattern suggests past forecast errors have some tendency to be repeated. For example, the estimated ρ for cattle is 0.2465. If the previous quarter's forecast error is 5%, then the current quarter's forecast should be adjusted by subtracting 1.2325% ($0.2465 \times 0.05 = 0.012325$). This positive serial correlation in the forecast errors ($\rho > 0$) could be caused by difficulty in modeling structural changes, or by slowly evolving price cycles in the livestock industry (Aadland and Bailey). Interestingly, the USDA's tendency to repeat price forecasting errors is consistent with the positive correlation in livestock production forecast errors reported by Sanders and Manfredo. By contrast, there is no statistically significant error repetition in the time-series models.

Forecast Encompassing

If a preferred forecast encompasses an alternative forecast, then the alternative forecast provides no useful information beyond that provided in the preferred forecast (Harvey, Leybourne, and Newbold 1998). In essence, there is no linear combination between the preferred and alternative forecasts which could produce a mean squared error smaller than that produced by the preferred forecast (Mills and Pepper). Forecast encompassing is tested using the following OLS regression framework:

$$(4) \qquad e_{1t} = \alpha_3 + \lambda(e_{1t} - e_{2t}) + \varepsilon_t.$$

In equation (4), e_{1t} represents the forecast error series of the preferred forecasts, while e_{2t} is the forecast error series of the competing forecast. The estimated λ is the weight placed on the competing forecast, and $1 - \lambda$ is the weight placed on the preferred forecast in forming the optimal composite predictor. The null hypothesis that the covariance between e_{1t} and $(e_{1t} - e_{2t})$ is zero (i.e., $\lambda = 0$) is tested against the single-tailed alternative, $\lambda > 0$ (Harvey, Leybourne, and Newbold 1998).

Harvey, Leybourne, and Newbold show the traditional regression-based test in equation (4) is oversized in small samples when the forecast errors are not bivariate normal. They note that heavy tails are a common occurrence in the distribution of price forecast errors, and recommend a modified Diebold and Mariano type test (the MDM test) to account for this. The traditional Diebold and Mariano test statistic is computed as the ratio of the sample mean of the series, $d_t = (e_{1t} - e_{2t})e_{1t}$, divided by its sample standard error. With the MDM statistic, Harvey, Leybourne, and Newbold modify the traditional Diebold and Mariano test statistic by multiplying it by $n^{-1/2}[n + 1 - 2h + n^{-1}h(h - 1)]^{1/2}$, where n is the number of observations and h is number of steps ahead for the forecasts. The MDM statistic is tested as a t-distribution with $n - 1$ degrees of freedom under the null hypothesis that $d_t = 0$, versus a single-tailed alternative. The results of the MDM test are presented in table 6, with the regression-based test in equation (4), to verify the statistical results.[6]

The USDA forecasts serve as the preferred models in the forecast-encompassing tests. Using the regression-based test, equation (4), the null hypothesis that the "preferred"

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[6] Note, the regression-based test in equation (4) is still necessary to estimate optimal weights assigned to the preferred ($1 - \lambda$) and competing (λ) forecasts. In the event of nonnormal errors, the parameter estimates are not biased. Instead, the estimated standard errors are inconsistent, leading to the oversizing of the encompassing tests (Harvey, Leybourne, and Newbold 1998). The MDM statistic essentially provides an alternative test statistic for the null hypothesis that $\lambda = 0$ in the regression-based test.

Table 6. Forecast Encompassing Test, $e_{1t} = \alpha_3 + \lambda(e_{1t} - e_{2t}) + \varepsilon_t$, 1982.3–2002.3

	USDA Encompassing Time Series		
Description	Cattle	Hogs	Broilers
Estimated λ	0.1986	-0.0190	0.0973
(t-Statistic)	(1.93)[a]	(-0.15)[b]	(1.12)[a]
p-Value	0.0286	0.4425	0.1330
MDM Statistic[c]	1.6600	-0.1460	0.9287
p-Value	0.0650	0.4615	0.1779

[a] Calculated using the Newey-West covariance estimator.

[b] Calculated using White's covariance estimator.

[c] The t-statistic from the modified Diebold-Mariano test for forecast encompassing.

USDA forecast encompasses the "competing" time-series forecast is rejected at the 5% level only for cattle. The MDM test rejects the null that the USDA price forecasts encompass the time-series forecasts at the 10% level for cattle. The MDM results generally confirm that regression-based tests of forecast encompassing may be oversized. Collectively, the evidence suggests USDA forecasts for hog and broiler prices appear to capture the information contained in time-series forecasts, whereas USDA cattle forecasts do not. Based on these findings, practitioners who utilize the USDA forecasts for cattle may want to supplement them with time-series forecasts, and the USDA may want to incorporate time-series techniques into its forecasting procedures.

Forecast Improvement

To test if the forecasts have improved over time, an approach similar to the methodology used by Bailey and Brorsen is incorporated.[7] In this test, the absolute value of the forecast errors is regressed on a time trend:

$$(5) \qquad |e_t| = \theta_1 + \theta_2 Trend_t + \mu_t.$$

If $\theta_2 = 0$, then there is no systematic increase or decrease in the absolute value of the forecast error, $|e_t|$, over time. Rejection of this null hypothesis would suggest forecasts either improved ($\theta_2 < 0$) or worsened ($\theta_2 > 0$) over time. This hypothesis is tested using a two-tailed t-test, with results presented in table 7.

The estimated θ_2 is less than zero, and is statistically significant at the 5% level for broilers, indicating the absolute forecast errors have become smaller over time. In contrast, USDA hog forecasts show a modest decline in accuracy through time; however, the estimated θ_2 is not significant at conventional levels.[8] Because the AR(4) model

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[7] Tests for structural change were conducted for the bias, efficiency, and encompassing tests [equations (1), (2), (3), and (4)] using the Chow breakpoint test. Roughly splitting the sample in half, the third quarter of 1992 is used as the breakpoint. The null hypothesis of no change in the parameter estimates between the two samples cannot be rejected at conventional levels.

[8] To test the robustness of these results, a Chow breakpoint test was also administered for equation (5) with the third quarter of 1992 serving as the breakpoint. There was not a statistically significant difference in the estimated parameters before and after 1992.3. Equation (5) was also estimated with quarterly intercept shifters to test for systematically higher or lower $|e_t|$ in particular quarters. The null hypothesis of equal parameter estimates for θ_1 across quarters could not be rejected with a standard F-test (5% level). There is no evidence that livestock price forecasting is more or less difficult in a particular quarter.

Table 7. Time Improvement Test, $|e_t| = \theta_1 + \theta_2 Trend_t + \mu_t$, 1982.3–2002.3

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
Estimated $\theta_2 \times 10^2$	-0.0085	0.0377	-0.0462
(t-Statistic)	(-0.56)	(1.52)	(-2.53)[a]
p-Value	0.5789	0.1328	0.0133
AR(4) Forecasts:			
Estimated $\theta_2 \times 10^2$	-0.0284	0.0933	-0.0603
(t-Statistic)	(-1.51)	(2.28)[a]	(-3.13)
p-Value	0.1344	0.0254	0.0025

[a] Calculated using White's covariance estimator.

parameters are estimated with greater precision as the estimation sample increases, one might expect the time-series forecast errors to decline through time. However, this is not the case. Instead, the time-series estimates of θ_2 have the same signs as those estimated for the USDA forecasts. Specifically, the time-series forecast errors for hog prices also increased over the sample, and broiler price forecasting errors declined. The persistent changes in forecast error over time may suggest that the underlying cause of the changes in forecast performance resides in the structure of the industry and not with the forecasting method employed (see Barkema, Drabenstott, and Novack). These trends are visually apparent in the time-series plots of $|e_t|$ in figure 1.

Conducting these accuracy-based tests is necessary, and provides considerable insight into the overall efficiency of the USDA livestock price forecasts. The size of the forecast error is clearly important, especially when the forecast user's loss function is assumed to be represented by squared errors. However, many decision makers may be concerned with the ability of a forecast to predict price direction in addition to its point accuracy. Therefore, simple binary classifications, such as the direction of price, are also important to decision makers. Indeed, in order to provide a truly complete assessment of the USDA livestock price forecasts, directional accuracy must also be assessed.

Classification-Based Tests

In many applications, it is important to know the direction of price change. In other words, are prices expected to move up or down relative to some base period? A speculator in the livestock futures markets would certainly benefit from knowing if prices will be higher or lower in the next quarter. Likewise, a food service firm may need to know if prices in the upcoming quarter will be higher or lower than the previous year for planning and budgeting purposes. In fact, Henriksson and Merton demonstrate it is only necessary for a forecast to have directional accuracy to provide value to a decision maker. Similarly, McIntosh and Dorfman note that the ability to predict the direction of price changes is nontrivial and is often just as important as forecasting price levels. Therefore, we examine the directional accuracy of the forecasts using Henriksson and Merton's nonparametric approach. This is followed by an assessment of the USDA's ability to accurately categorize realized prices within the forecasted range.

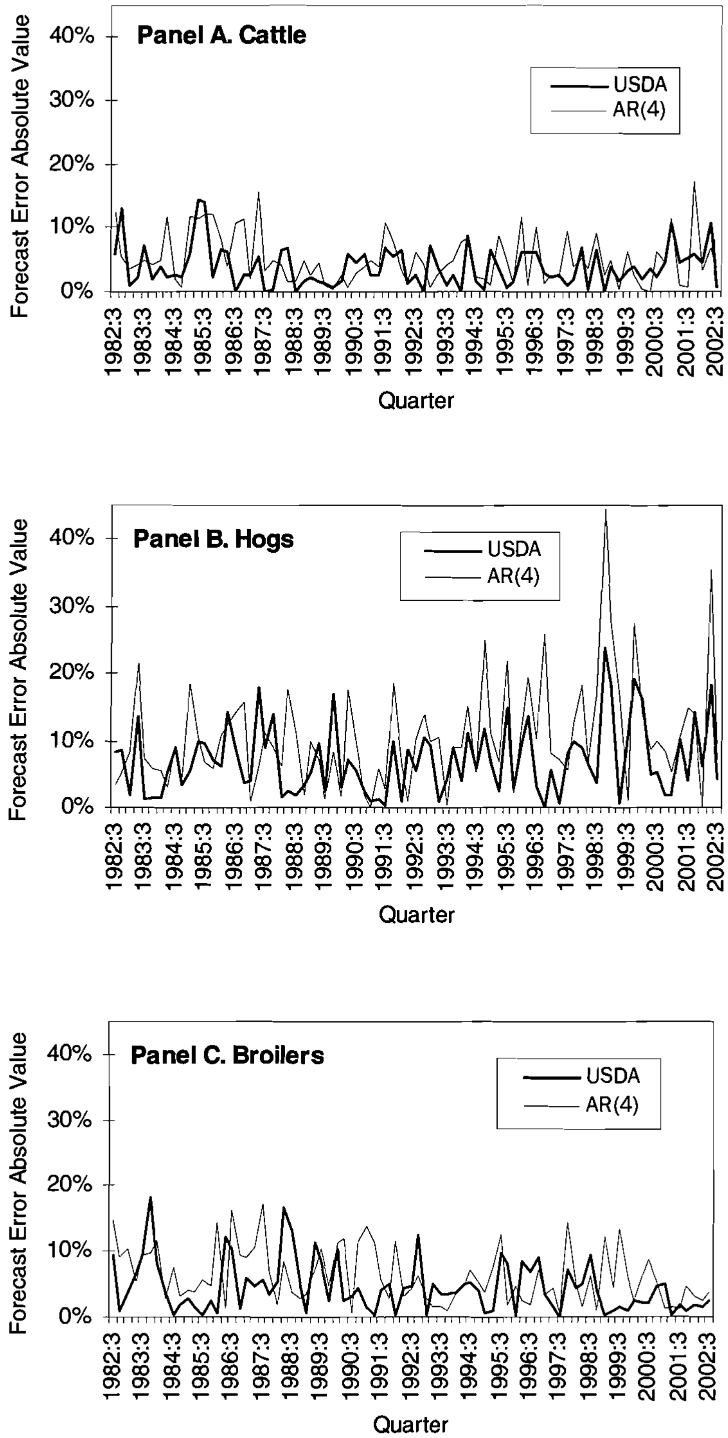

Figure 1. Absolute value of forecast errors, $|e_t|$, 1982.3–2002.3

Directional Accuracy

McIntosh and Dorfman endorse the timing test proposed by Henriksson and Merton to qualitatively evaluate forecast performance. As demonstrated by Pesaran and Timmermann, Henriksson and Merton's hypergeometric test is asymptotically equivalent to a chi-squared test for independence in a $\{2 \times 2\}$ contingency table (see table 8). In table 8, ΔF is the forecasted direction of change, ΔA is the actual direction of change, and n is the number of observations in each cell of the table. Perfect directional forecasting would be represented by $n_{21} = n_{12} = 0$, or equivalently, $n_{11} = N_1$ and $n_{22} = N_2$.

Henriksson and Merton show the null hypothesis of no timing ability is a test that the sum of the conditional probabilities of correct forecasts $(n_{11}/FN_1 + n_{22}/FN_2)$ equals one, and suggest a test based on the hypergeometric distribution of n_{22}. The test is equivalent to a test of independence in a $\{2 \times 2\}$ contingency table (Cumby and Modest), and can be tested with a standard chi-squared test (Stekler and Schnader; Pons 2001).

The definition of a forecasted price increase or decrease clearly depends on the base period of comparison. That is, a price change can be defined over successive time intervals (one quarter to the next) or year-over-year. Directional price changes from one quarter to the next might be important to a speculator or cash merchant, while year-over-year price changes might have greater importance to a corporate analyst whose budget is based on the previous year's prices. Therefore, it is useful to test the USDA's forecasts for directional accuracy in both cases (quarter-to-quarter and year-over-year price changes).

To test for quarter-to-quarter directional accuracy, we define the following variables: $\Delta F = 1$ if the price is forecasted to increase $(F_t > A_{t-1})$, and is zero otherwise, and $\Delta A = 1$ if actual prices increase $(A_t > A_{t-1})$, and is zero otherwise. The resulting numbers are tabulated and entered into a $\{2 \times 2\}$ contingency table. A chi-squared statistic is used to test the null hypothesis of no directional forecasting ability—i.e., independence in the $\{2 \times 2\}$ contingency table. Table 9 reports the percentage of directionally correct forecasts, the chi-squared statistic, and the p-values for both the USDA and AR(4) forecasts.

The USDA clearly demonstrates an ability to forecast quarter-to-quarter price direction. The USDA's price forecasts correctly predict price direction over 70% of the time for all three markets, and the results are statistically significant at the 1% level. The best directional forecasting is in live cattle, with over 76% correct forecasts. Only in the case of broilers does the AR(4) time-series model perform better (75.3% vs. 72.8%) than the USDA forecasts based on the ability to predict direction. Overall, the USDA's price forecasts show a relatively strong ability to forecast the direction of quarter-to-quarter price changes.

It is important to determine if the USDA's directional forecasting ability relative to the AR(4) alternative is statistically significant. To test this, we follow Chang, and use the normal distribution to approximate the mean and variance of Henriksson and Merton's original test based on the hypergeometric distribution of n_{22} in table 8. As shown by Chang, the parameters of the normal approximation to the hypergeometric distribution are the mean and standard deviation of the hypergeometric distribution: $E(n_{22}) = FN_2N_2/N$, and $\sigma^2(n_{22}) = [FN_2N_2(N - N_2)(N - FN_2)]/[N^2(N - 1)]$. Furthermore, the sampling distribution of the differences is also normally distributed and is given by $E(n_{22}^U - n_{22}^T) = E(n_{22}^U) - E(n_{22}^T)$, and $\sigma^2(n_{22}^U - n_{22}^T) = \sigma^2(n_{22}^U) + \sigma^2(n_{22}^T)$, where n_{22}^U and n_{22}^T are the number of correct forecasts for lower prices made by the USDA and the time-series

Table 8. Contingency Table to Forecast Market Direction

	Actual		
Forecast	$\Delta A > 0$	$\Delta A \leq 0$	Subtotal
$\Delta F > 0$	n_{11}	n_{12}	FN_1
$\Delta F \leq 0$	n_{21}	n_{22}	FN_2
Subtotal	N_1	N_2	N

Note: ΔF is the forecasted direction of change, ΔA is the actual direction of change, and $n_{i,j}$ is the number of observations in the i, j cell of the table.

Table 9. Directional Forecasting Ability versus Prior Quarter

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
% Correct	76.5	71.6	72.8
χ^2 Statistic	22.82	15.11	20.23
p-Value	0.0000	0.0001	0.0000
AR(4) Forecasts:			
% Correct	65.4	65.4	75.3
χ^2 Statistic	8.49	7.65	20.18
p-Value	0.0036	0.0057	0.0000
z-Score[a]	1.37	0.83	0.07

[a] The z-score testing the null hypothesis of equal directional forecasting ability between the USDA and the AR(4) models.

models, respectively.[9] The null hypothesis is that the two forecast series have equal timing ability. The z-score from the normal approximation is shown in the last row of table 9. Clearly, although the USDA does a relatively good job of forecasting price direction, its performance is not statistically better than the time-series forecasts at conventional levels.

Similar to the quarter-to-quarter evaluation, year-over-year directional accuracy evaluation uses the following variables: $\Delta F = 1$ if the forecasted price is greater than that of a year ago ($F_t > A_{t-4}$), and zero otherwise; $\Delta A = 1$ if actual prices are above the prior year ($A_t > A_{t-4}$), and zero otherwise. Again, these numbers are entered into a $\{2 \times 2\}$ contingency table and a chi-squared test for independence is performed, with results presented in table 10.

Given the USDA's ability to forecast quarter-to-quarter price changes, it is not surprising that these forecasts provide valuable information concerning year-over-year price changes as well. In fact, the USDA correctly forecasts year-over-year price changes over 80% of the time (statistically significant at the 1% level). USDA cattle, hog, and broiler forecasts are directionally correct more often than their time-series counterparts. Again, however, the difference is not statistically significant (z-score, 10% level). Collectively, over all three livestock markets, the Henriksson and Merton tests show that the

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[9] This test explicitly assumes the forecasts are generated independently. Given the time-series model's reliance strictly on past prices and the USDA's use of all available information, this is not an unreasonable assumption. If this is not true, then the test's standard errors are too large and any bias is in favor of the null hypothesis.

Table 10. Directional Forecasting Ability versus Prior Year

Description	Cattle	Hogs	Broilers
USDA Forecasts:			
% Correct	85.2	87.7	80.2
χ^2 Statistic	40.10	46.06	31.17
p-Value	0.0000	0.0000	0.0000
AR(4) Forecasts:			
% Correct	80.2	77.8	75.3
χ^2 Statistic	30.52	24.95	25.10
p-Value	0.0000	0.0000	0.0000
z-Score[a]	0.67	1.26	0.50

[a] The *z*-score testing the null hypothesis of equal directional forecasting ability between the USDA and the AR(4) models.

USDA price forecasts provide valuable information to decision makers interested in the direction of price changes, but the USDA's forecasting performance is not statistically distinguishable from the capability of the AR(4) model.

Accuracy of Forecast Range

The USDA provides price forecasts as a range. For instance, the forecast for broiler prices in 2002.3 was \$57–\$59 per cwt. Thus far, the analysis has focused on using the midpoint of this range as the USDA's point forecast. However, the range itself may provide some forecasting information. In this section, we ask a simple question: How often does the realized price fall within the USDA's forecasted range? The forecast ranges for cattle, hogs, and broilers are illustrated in figure 2.[10]

To assess the value of the USDA's forecasted price range, we calculate the percentage of realized prices that fall within the forecasted range. Unlike the directional accuracy tests in the prior section, there is not a clear null hypothesis concerning how often the forecasted range should be correct by chance alone. Therefore, it is necessary to build a standard for comparison. A naïve range forecast is constructed using the previous quarter's price as the point forecast. Then, the forecast range width used in the subsequent quarter by the USDA is applied to this naïve point forecast. For example, the USDA's hog price range forecast for 1990.4 is \$51–\$55 per cwt. The previous quarter's (1990.3) actual price is \$57.67 per cwt. So, the naïve model's forecasted range for 1990.4 is \$55.67–\$59.67 per cwt. The proportion of times the realized price falls within the forecasted ranges is presented in table 11 (and plotted in figure 2).

Actual prices fall within the USDA's forecasted price ranges 40.7%, 34.6%, and 48.1% of the time for cattle, hogs, and broilers, respectively (first row, table 11). It is difficult to compare across markets due to their different levels of price volatility and the USDA's tendency to use the same range for each market. What is more important is how the USDA compares to the naïve alternative. As shown in the second row of table 11, the

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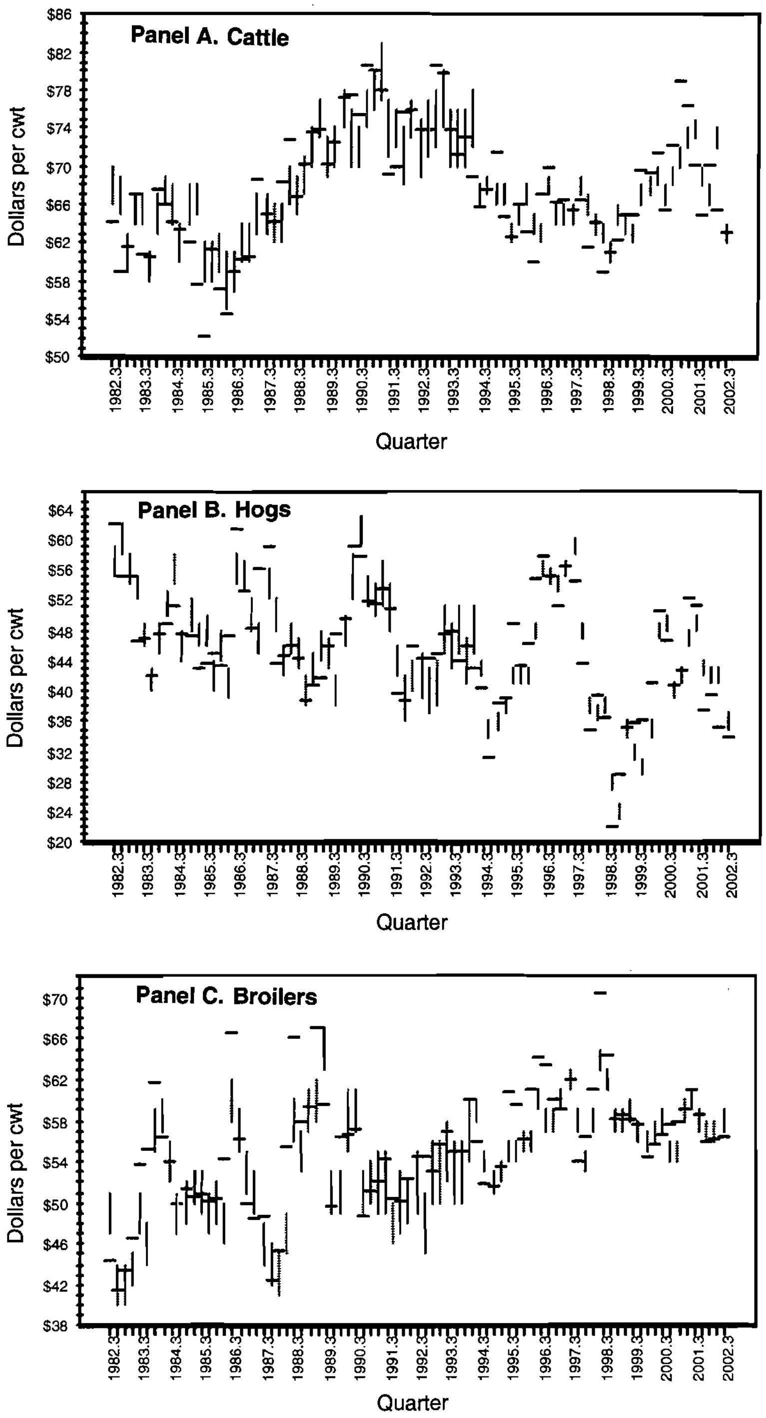
[10] The price range for livestock forecasts seems to be based more on institutional procedure as opposed to varying market conditions. For instance, the price ranges for cattle, hogs, and broilers were predominately \$3 or \$4 per cwt from 1982.3 through 1985.2. From 1985.3 through 1990.1, the range was typically \$4 per cwt. The range was expanded to \$6 per cwt from 1990.2 through 1994.2, after which the range has consistently been \$2 per cwt.



Note: The gray vertical bars represent the USDA's forecasted price range, and the black horizontal dashes denote the realized price.

Figure 2. USDA forecast ranges with plotted points showing realized prices, 1982.3–2002.3

Table 11. Accuracy of Forecast Ranges

Description	Cattle	Hogs	Broilers
USDA Forecasts, % Correct:	40.7	34.6	48.1
Naïve Forecasts, % Correct:	29.6	34.6	40.7
z-Score[a]	1.48	0.00	0.95

[a] The *z*-score testing the null hypothesis of equal sample proportions between the USDA and the time-series model.

naïve forecast's range is correct 29.6% for cattle, 34.6% for hogs, and 40.7% for broilers. The USDA's forecasted price range performs better than that of the naïve model for cattle and broilers, but not for hogs.

Again, it is important to test if the performance of the USDA's forecasts relative to the naïve alternative is statistically significant. The test is the standard test for differences in sample proportions, which is normally distributed (Bender, Douglas, and Kramer, p. 70).[11] The *z*-scores are presented in the bottom row of table 11. In no market can the null hypothesis of equal sample proportions be rejected at the 10% level (two-tailed test). The results suggest the range forecasts provided by the USDA are not statistically better at categorizing realized prices than those produced by the naïve alternative.

Collectively, the classification-based tests confirm the USDA does a good job of categorizing prices. That is, it correctly forecasts quarter-to-quarter price changes at least 70% of the time, and year-over-year price changes at least 80% of the time. Likewise, the USDA's forecasted price range contains the realized price at least 35% of the time. Although these findings appear commendable, the performance of the USDA forecasts in this sample relative to the performance of the AR(4) and naïve model forecasts is not statistically significant at conventional levels.

Summary, Conclusions, and Discussion

This study examines the performance of the USDA's quarterly price forecasts for cattle, hogs, and broilers as reported in the WASDE. As a standard of comparison, forecasts are also generated from a univariate AR(4) time-series model. This research takes a comprehensive approach to forecast evaluation. Specifically, the USDA forecasts are examined incorporating both accuracy-based tests and classification-based tests.

Using accuracy-based tests, the USDA's price forecasts produce smaller mean squared errors than those generated by the time-series model, with the difference in forecast performance being statistically significant. Also, the USDA's price forecasts are found to be unbiased for cattle and hogs, but broiler prices are systematically overestimated by 2.42%. In contrast, the time-series model consistently underestimates prices in all three markets. The USDA forecasts are efficient in that they are neither too conservative nor too extreme; however, they are inefficient in that forecast errors tend to be repeated—i.e., positive errors are followed by positive errors, most notably in the cattle and broiler markets. The time-series forecasts did not display a consistent inefficiency.

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[11] This test assumes the forecasts are generated independently. A violation of this assumption biases the results toward a failure to reject the null.

Based on tests conducted for forecast encompassing, the USDA's hog and broiler price forecasts are conditionally efficient with respect to the time-series forecasts, but there is evidence suggesting the cattle forecasts do not encompass the time-series forecasts. Therefore, a forecaster may achieve greater accuracy, in a mean squared error framework, by combining the USDA cattle forecasts with those from a simple time-series model.

The data indicate broiler prices became easier to forecast over time, while hog prices have become more difficult to predict. The time-series models demonstrated the same increase or decrease in accuracy as shown by the USDA forecasts, suggesting that regardless of the forecast method, hog prices became more difficult to forecast and broiler prices easier to forecast. Indeed, over the sample period, the hog industry experienced the greatest structural changes, while the broiler industry was already fully integrated and the cattle sector has been slow to integrate (see Barkema, Drabenstott, and Novack). Structural shifts may partially explain the general decline in hog price forecast accuracy and the increase in accuracy for broiler price forecasts.

The classification-based tests evaluate both directional accuracy as well as the ability of the USDA's forecasted ranges to capture realized prices. Directional forecasts are evaluated both as market direction versus the prior quarter and versus the prior year using the test initially proposed by Henriksson and Merton. The USDA forecasts demonstrate the ability to correctly forecast quarter-to-quarter price direction at least 70% of the time, and year-over-year price direction with at least 80% accuracy across the three markets. Despite these generally favorable results, the superior market timing ability of the USDA relative to the time-series model is not statistically significant. Similarly, although the USDA's forecasted range captures realized prices at least 35% of the time, the performance relative to the naïve alternative is not statistically significant.

Across the three markets examined—cattle, hogs, and broilers—the USDA's broiler forecasts seem to demonstrate the most inadequacies. That is, the broiler price forecasts were biased and suboptimal. Even so, they showed consistent improvement, through smaller absolute errors, over the sample period. Indeed, the vertically integrated structure of the broiler industry may be driving this result. The controlled nature of production, the concentration of producers, and the relatively short production cycle may make prices increasingly easy to forecast. Even with accuracy improving, the USDA's broiler forecasts are not optimal, suggesting the USDA may want to consider changes in its forecasting procedures to correct the inefficiencies.

Collectively, the results of this analysis show that the USDA generally does an admirable job of forecasting livestock prices at a one-quarter horizon. Still, the agency may want to review its methods for producing livestock price forecasts. It may be possible for the USDA to take steps to remove some of the documented biases and inefficiencies—i.e., composite forecasts between its current methodology and simple time-series models could improve forecasting accuracy for cattle, or forecast ranges could be made more dynamic to reflect shifts in market volatility.

Despite some shortcomings, the USDA forecasts likely provide value to industry participants. For instance, practitioners may use them to improve existing private forecasts. More importantly, the forecasts may provide value to market participants who lack the expertise, time, or resources to generate their own forecasts. Specifically, the USDA forecasts certainly outperform a naïve "no-change" forecast. Hence, they may provide welfare enhancement through reduced price uncertainty (Irwin, Good, and Gomez).

Moreover, given the positive results of the directional accuracy tests, the USDA forecasts may prove useful to both traders and businesses alike who desire an indication of the direction of livestock price movements.

It is interesting to note that, aside from broilers, there is no improvement in the USDA's ability to forecast quarterly livestock prices over the sample period from 1982 through 2002. This lack of improvement is despite marked advances in computing power and statistical methods. Over the 20-year span, numerous academic articles have documented improved forecasting techniques in these markets (e.g., Goodwin). This raises an intriguing question as to whether or not the USDA and other forecasters are employing these new methodologies. If they are, do the methodological advances simply not provide improved performance in real-time forecasting? Are applied forecasters not receiving academic research results in a usable format? Are the new methods too costly to learn and implement? These questions are difficult to answer, but addressing them may be a crucial next step in improving the relevance of forecasting research (Brorsen and Irwin).

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