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## **A Test of Forecast Consistency Using USDA Livestock Price Forecasts**

Dwight R. Sanders

and

Mark R. Manfredo\*

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\*Dwight R. Sanders is an Assistant Professor of Agribusiness Economics at Southern Illinois University, Carbondale, Illinois. Mark R. Manfredo is an Assistant Professor in the Morrison School of Agribusiness and Resource Management at Arizona State University, Mesa, Arizona.

# A Test of Forecast Consistency Using USDA Livestock Price Forecasts

## Practitioner's Abstract

*In traditional tests of forecast rationality, price forecasts are usually differenced to obtain stationarity. However, this data transformation may ignore important long-run information contained in forecasted price levels. Here, the concept of forecast consistency is paired with rationality concepts used in the market efficiency literature to develop a sequential testing procedure for forecast consistency and rationality. USDA quarterly livestock price forecasts do not demonstrate long-run consistency.*

**Keywords:** forecast evaluation, forecast consistency, efficiency

## Introduction

A barrage of tests exists for evaluating market price forecasts. The majority of forecast evaluations focus on absolute accuracy (Kastens, Schroeder, and Plain), bias and efficiency issues (Elam and Holder), encompassing and composite forecasts (Sanders and Manfredo), or directional accuracy (Pons, 2001). These evaluation procedures are important for determining forecast value and comparing alternative forecasting methods. However, for statistical reasons—usually to obtain stationarity in the time series data—these evaluation methods often focus on seasonal or first differences of the data series (e.g., Sanders and Manfredo). The focus on differenced data or forecasted price changes may neglect some information and desirable characteristics contained in the forecasted price level.

In regards to nonstationary data, Cheung and Chinn propose three criteria for “consistent” forecasts: the forecasted and actual series must (1) share the same order of integration, (2) be cointegrated, and (3) have a cointegrating vector that is consistent with long-run unitary elasticity. Ideally, a consistent forecast should have a one-to-one long-run relationship with underlying variable, and they should not drift “too far” apart over time. This evaluation structure is closely related to procedures used to test for efficiency in agricultural futures markets (Mckenzie and Holt) and forward exchange rates (Zivot).

The goal of this research is to extend the definition of consistency proposed by Cheung and Chinn using the cointegration and error correction methods proposed in market efficiency studies (Wang and Jones). Although some researchers have used cointegration techniques for examining forecast rationality (Grant and Thomas; Aggarwal, Mohanty, and Song), the applications have generally fallen short of presenting a unified approach. Moreover, cointegration techniques have been used to study efficiency in commodity futures markets (Yang and Leatham; Dequan and Holt), but they have not been widely applied to the evaluation of price forecasts made by public agencies or market experts.

The objective of this research is to refine Cheung and Chinn’s definition of a consistent forecast in a cointegration framework, and elaborate on the form of the error correction mechanism under

rational expectations (Grant and Thomas). The result is a sequential testing procedure for forecast rationality which is applied to USDA one-quarter ahead livestock price forecasts.

As a result of this study, academic researchers will be presented with a comprehensive and unified approach to examine consistency and efficiency of price forecasts. The USDA will gain insight as to the performance and consistency of their forecasting procedures. More importantly, practitioners will gain an understanding of the interaction between long-run consistency in forecasts and the short-run dynamics displayed by forecasts. The information should allow forecast users to better interpret, understand, and apply forecasts provided by the USDA. Collectively, the research should improve the overall forecasting process.

### **Methodology**

Traditionally, forecasts are subjected to the following regression (Granger and Newbold, p. 281):

$$(1) \quad P_t = a + bF_t + e_t .$$

Where,  $P_t$  equals the actual price level in quarter  $t$  and  $F_t$  equals the one step-ahead price forecast for quarter  $t$ . A rational and optimal forecast is unbiased ( $a=0$ ) and weakly efficient with  $b=1$  and  $e_t$  an i.i.d. error. Researchers have used variations of equation (1) to evaluate forecasts (Pons, 2000). But, the tests are primarily intended to circumvent statistical issues, and they do not represent a more general approach to testing rationality.

Statistical concerns typically hinge on the (non) stationarity of the time series data. Indeed, equation (1) may not be “balanced” if  $P_t$  and  $F_t$  are not integrated of the same order, leading to estimation errors (Zivot) or non-stationary data series may generate spurious results (Zulauf, Irwin, Ropp, and Sberna). This has led researchers to examine forecasts in first differences or by looking at forecasted price changes. However, this approach puts potentially unnecessary restrictions on the short and long-run dynamics between the forecasts and realized prices (McKenzie, et al.). Given the potential problems associated with using one or the other of these approaches, it is important to develop a unified approach to testing forecast consistency and rationality (Cheung and Chinn).

In this research, we pull from the market efficiency literature (e.g., Zivot) and forecast evaluation studies (e.g., Aggarwal, Mohanty, and Song) to develop a unified approach to evaluating forecast rationality. The methodology initially relies on a sequence of tests proposed by Cheung and Chinn, and then proceeds to test rationality in the framework proposed by McKenzie, et al. An ordered testing approach is developed that lends itself to fully incorporating and understanding the long- and short-term dynamics of the forecasts.

The test moves along the following sequence. First,  $P_t$  and  $F_t$  must have the same order of integration, if not, the forecasts are inconsistent. If  $P_t$  and  $F_t$  are stationary in levels,  $I(0)$ , then equation (1) can be estimated in levels and the standard statistical tests are valid. Assuming that  $P_t$  and  $F_t$  are both stationary in first differences,  $I(1)$ , then consistency requires that  $P_t$  and  $F_t$  be cointegrated. Furthermore,  $P_t$  and  $F_t$  must have a cointegrating vector that is consistent with long-run unitary elasticity off expectations ( $a=0$ ,  $b=1$ ). Finally, for cointegrated  $P_t$  and  $F_t$ , short-

run efficiency is tested with restrictions on the error correction mechanism. The steps are outlined in Diagram 1.

Assuming that  $P_t$  and  $F_t$  are, in fact, cointegrated in levels, then the error correction mechanism (ECM) can be written as,

$$(2) \quad \Delta P_t = \lambda + \rho e_{t-1} + \beta \Delta F_t + \sum_{i=1}^m \beta_i \Delta F_{t-i} + \sum_{j=1}^k \theta_j \Delta P_{t-j} + v_t,$$

where,  $e_{t-1}$  equals the error correction term from equation (1),  $e_{t-1} = P_{t-1} - a - bF_{t-1}$ . Forecast rationality restrictions in equation (1) implies that  $\rho = -1$  and  $\beta = 1$  in equation (2). This can be seen by substituting,  $e_{t-1} = P_{t-1} - a - bF_{t-1}$  into (2) and simplifying.

$$(3) \quad P_t = \lambda - \rho a + (1 + \rho)P_{t-1} + \beta F_t - (\rho b + \beta)F_{t-1} + \sum_{i=1}^k \beta_i \Delta F_{t-i} + \sum_{i=1}^l \theta_i \Delta A_{t-i} + \varepsilon_t$$

Long-run consistency in (1) requires that  $a = 0$  and  $b = 1$ , which clearly implies that  $\rho = -1$  and  $\beta = 1$  in equation (3) and (2). Additionally, short-run rationality and efficiency requires that  $\rho = -1$ ,  $\beta = 1$ , and  $\beta_i = \theta_j = 0$  for all  $i$  and  $j$ . Note, the requirements that  $\rho = -1$  and  $\beta = 1$  in (2) have a very intuitive interpretation from a forecasting standpoint. Namely, the change in price,  $\Delta P_t$ , should equal the change in the forecast,  $\Delta F_t$ , adjusted for the forecast error (in levels) in the previous period,  $e_{t-1}$ .

The sequential testing procedure outlined above provides a general approach to testing forecast consistency and efficiency. Importantly, it allows for both long-term and short-run dynamics within the forecasts. In the following section we apply this methodology to USDA price forecasts in the livestock industry.

## Data and Empirical Results

### *Data*

The sequential testing methodology is applied to six USDA livestock price forecast series: Nebraska, direct, 1100-1300 pound slaughter cattle; national base, live equivalent, 51-52% lean hogs; wholesale, 12-city broilers; grade A, large, New York turkeys; and farm-level, all milk. A broad range of markets are examined in order to strengthen the empirical application and widely test for consistency. Specifically, one-quarter ahead price forecasts are collected from the *World Agriculture Supply and Demand Estimates (WASDE)*. The forecasts are issued between the 8<sup>th</sup> and 14<sup>th</sup> of the first month of each quarter (January, April, July, and October). Since data definitions did change over the sample period, the realized or actual prices are also collected from the *WASDE* reports to assure the correspondence between the forecasts and actual prices. In those instances where there were changes, the new and old data series corresponded very closely. The one-quarter ahead forecasts ( $F_t$ ) and realizations ( $P_t$ ) are collected from 1982.3 through 2004.3, resulting in 103 observations.

### ***Unit Root Tests***

Keeping with the sequence presented in Diagram 1, the first step is to test for stationarity of the time series. In this and all subsequent tests, we work with the natural log of the price series to reduce heteroskedasticity in the data. We follow Rapach and use the augmented Dickey-Fuller (ADF) test which has a null hypothesis of nonstationarity (unit root), as well as the KPSS test which has a null hypothesis of stationarity or no unit root (Kwiatkowski, et al.). Using tests with different null hypothesis helps to serve as a cross-check on the results.

The results for both the ADF and KPSS are shown in Table 1. There are two important questions to address from the unit root tests. First, are the forecasts consistent? That is, do  $F_t$  and  $P_t$  have the same order of integration? Second, what is the order of integration?

In levels (Table 1, Panel A), the ADF test provides conflicting stationarity results only for turkeys, where we reject the existence of a unit root in  $P_t$ , but not in  $F_t$ . In contrast, the KPSS test shows that the turkey  $P_t$  and  $F_t$  both contain a unit root. The only lack of consistency in the KPSS tests is with cattle, where the null hypothesis of no unit root is rejected for  $P_t$  but not  $F_t$ . For no set of forecasts do both the ADF and KPSS tests both show inconsistency (different orders of integration) for  $P_t$  and  $F_t$ . Therefore, we conclude that the forecasts are, in fact, consistent in this sense.

It is more difficult to draw conclusions concerning the order of integration for each market from the results presented in Table 1. The results clearly indicate that turkey, egg, and milk prices (and forecasts) are stationary,  $I(0)$ , in levels. Likewise, it is pretty clear that cattle prices are non-stationary in levels,  $I(1)$ . However, the results for broilers and hogs are in direct conflict. For instance, with hogs, the ADF test shows that the price series is stationary in levels; whereas, the KPSS test rejects stationarity. To rectify this result, we further test the null hypothesis of no unit root using Johansen's procedure on broilers and hogs (results not presented). The Johhansen test fails to reject a unit root in broilers (p-value = 0.3514), but not in hogs (p-value = 0.0446).

Based on these results, we conclude that all of the forecasts are consistent in that they share the same order of integration with the actual price series. Furthermore, the hog, turkey, egg, and milk data are stationary in levels; therefore equation (1) can be estimated directly. Conversely, the broiler and cattle series are non-stationary in levels. Hence, these two series require testing for cointegration and estimating the error correction mechanism in (2).

### ***Rationality in $I(0)$ Series***

For those actual and forecast series that are stationary,  $I(0)$ , in levels, the next step is to estimate equation (1) and test for rationality:  $a=0$ ,  $b=1$ , and  $e_t$  is i.i.d. Equation (1) is first estimated with OLS. Then, the residuals are tested for heteroskedasticity using Whites's test. If the errors are heteroskedastic, then the equation is re-estimated using White's heteroskedastic consistent covariance estimator. Next, the residuals are tested for serial correlation using the LM test (results reported in the final column of Table 2). If the null of no serial correlation in the residuals is rejected, the equation is again re-estimated using the consistent Newey-West estimator. The final parameter estimates and hypothesis tests are presented in Table 2.

The null hypothesis of rationality in the forecasts states that  $a=0$ ,  $b=1$ , and  $e_t$  is i.i.d. error. A joint test of the parameter restrictions,  $a=0$  and  $b=1$ , is rejected at near the 10% level for hogs, turkeys, eggs, and milk. This suggests that the forecasts are not fully rational. Looking more closely at the individual parameter estimates reveals that the forecasts for hogs, turkeys, and milk are downward biased ( $a>0$ ). The estimated slope coefficients are statistically less than one for hogs, turkeys, and milk, indicating that the USDA forecasts are “too extreme.” This tendency is displayed in Figure 1, where turkey price forecasts are clearly more extreme than actual prices in the late 1980’s and early 1990’s. Notable in Table 2, the USDA egg forecasts appear to be the most rational in terms of bias ( $a=0$ ) and optimality ( $b=1$ ). However, the egg forecasts, along with hogs and milk, are inefficient in that the error term is serially correlated.

These results are consistent with Sanders and Manfredo, who also document extreme USDA price forecasts and positive serial correlation in forecasting errors. For these markets, hogs, turkeys, eggs, and milk, practitioners are well advised to appropriately scale USDA forecasts. For example, using the parameter estimates in Table 2, a USDA hog price forecast of \$40.00 should be adjusted to approximately \$40.87 ( $\exp(0.490 + 0.873 \cdot \ln(40))$ ). Likewise, the forecast user should be aware that the USDA repeats errors: over-estimates are followed by over-estimates. An understanding of these issues can help the practitioner make better use of the USDA forecasts that are stationary in levels. However, the issues of cointegration and error correction must be addressed to understand the rationality of non-stationary price forecasts.

### ***Rationality in I(1) Series***

The non-stationary series, cattle and broilers, must meet three requirements for rationality. First, they must be cointegrated. Second, the long-run cointegrating parameters must be  $a=0$  and  $b=1$  in Equation (1). Third, the error correction mechanism (equation 2) must be consistent with long-run rationality ( $\rho=-1$ ,  $\beta=1$ ) and short-run efficiency ( $\beta_i=\theta_j=0$ ).

Following McKenzie, et al., cointegration is tested using Johansen’s procedure. The unrestricted cointegration rank test fails to reject that the maximum eigenvalue is one (Table 3). Therefore, for both cattle and broilers, it appears that  $P_t$  and  $F_t$  are linked in the long-run and do not drift apart. However, the cointegrating regressions do not show a long-run unitary elasticity between  $P_t$  and  $F_t$ . That is, we reject the null hypothesis that  $a=0$  and  $b=1$ . For cattle, the long-run elasticity is statistically greater than unity at 1.227. This indicates that the forecasts are not “too extreme,” rather they are “too conservative.” Visually, this is confirmed in Figure 2, where the cattle price forecasts are too high at price cycle lows (e.g., 1985) and too low at price cycle highs (e.g., 2003). Moreover, the cattle forecasts are biased upward with the intercept statistically greater than zero. In contrast, the USDA broiler forecast must be scaled down ( $b < 1$ ) and it is biased downward ( $a > 0$ ). So for both broilers and cattle, the forecasts are consistent in the sense that they are cointegrated with the actual series, but they are not consistent in the sense that they do not have unitary long-run elasticities.

The error correction mechanism in (2) involves stationary data, and it estimated using OLS (McKenzie, et al.). The parameter estimates from (2) are provided in Table 4. Surprisingly, given the long-run cointegration results, the short-run forecast dynamics are mostly rational. Looking first at cattle, the short-run elasticity ( $\beta$ ) is not statistically different from one, and the error-correction parameter is statistically equal to a minus one. This suggests that the USDA

forecast behave rationally in the short-term, with the exception of not incorporating all of the information in past price changes and forecasts (reject,  $\beta_i=\theta_j=0$ ). Similarly, the broiler forecasts are rational and efficient in the short-run by all counts ( $\rho=-1$ ,  $\beta=1$ , and  $\beta_i=\theta_j=0$ ). Collectively, these results indicate that the USDA forecasts for non-stationary prices series are quite rational in the short-term—adjusting to recent price changes and deviations from the cointegrating relationship—but, the long-run relationship itself is not rational.

### **Summary and Conclusions**

Most forecast evaluations focus on forecasted price changes either in first or seasonal differences (e.g., Sanders and Manfredo). However, that focus may exclude some important information contained in the forecasted price levels. In this research, we propose a sequential testing procedure for forecast rationality based on the Cheung and Chinn's consistency concept. Specifically, the proposed methodology combines the idea of consistency with the rationality and efficiency tests commonly applied to futures markets (McKenzie, et al.) and foreign exchange markets (Zivot). Collectively, the methodology provides a comprehensive and systematic approach to evaluating forecast rationality.

The testing procedure is applied to one-quarter ahead USDA livestock price forecasts for cattle, hogs, broilers, turkeys, eggs, and milk. The breadth of markets provides ample opportunities for divergent testing methodologies. Indeed, we find that hog, turkey, egg, and milk prices and forecasts are stationary in levels; hence, the traditional regression approach to test rationality is statistically valid. Conversely, cattle and broiler prices and forecasts are non-stationary in levels; thus, the long-run cointegrating relationship and error correction mechanism must be estimated to provide valid statistical tests.

The forecasts generally meet Cheung and Chinn's first two requirements for consistency. The forecasts and prices are integrated of the same order, and those that are non-stationary are cointegrated. However, except for the eggs, the stationary price forecasts generally are not rational in the sense that they are both biased and not correctly scaled. Moreover, forecast errors tend to be repeated. The non-stationary price forecasts, cattle and broilers, are also not rational (inconsistent) because their long-run elasticities are different from one, and they are also biased. Oddly, in the short-run, USDA forecasts quickly reflect recent price changes and adjust to deviations from the long-run relationship. Cattle price forecasts are not efficient, failing to incorporate the information contained in past prices and forecasts.

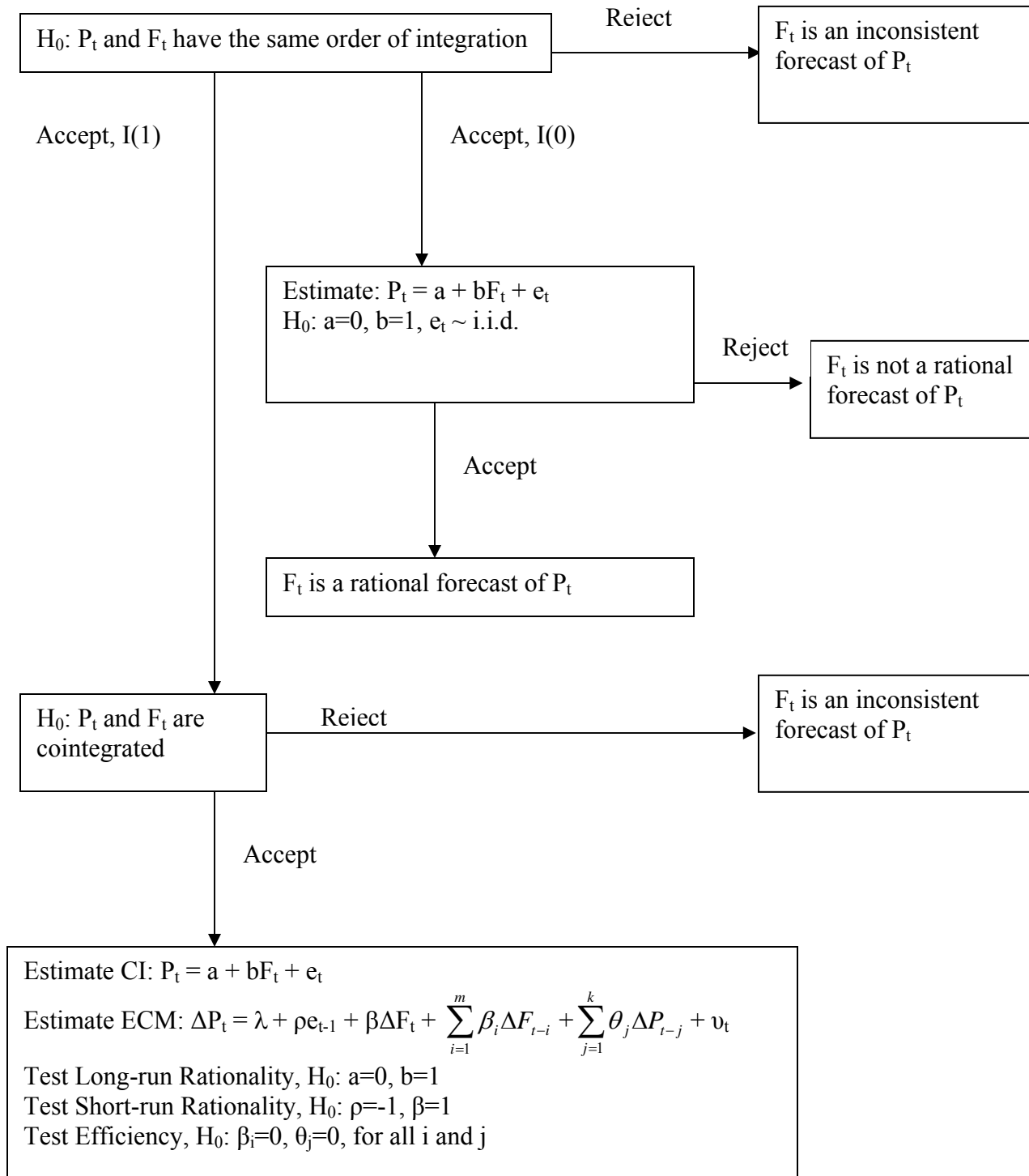
The results are consistent with those of other researchers who have shown a tendency for USDA prices to be incorrectly scaled and to repeat errors (Sanders and Manfredo). Practitioners are advised to adjust USDA forecasts correctly for bias and scale. The USDA may want to consider remedies to improve their forecasting. Make no mistake; forecasting is a daunting task, so effort should be directed towards those areas that are more easily remedied. Most obvious, the repetition of forecast errors found in hogs, eggs, and milk, is an error that can be fixed with simple adjustments. The bias and scale of forecasts are more difficult to address due to continuing shifts in the structure of the industry and potentially the price generating mechanisms. Indeed, it is much easier to provide a forecast diagnosis than a cure.



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**Diagram 1. Sequential Testing Procedure for Forecast Consistency and Rationality**



**Table 1. Unit Root Tests**

Panel A: Price Levels	ADF test <sup>a</sup>	ADF test	KPPS test <sup>b</sup>	KPPS test
	Actual, P <sub>t</sub>	Forecast, F <sub>t</sub>	Actual, P <sub>t</sub>	Forecast, F <sub>t</sub>
Cattle	-2.76	-1.81	0.379*	0.295
Hogs	-4.81***	-4.61***	0.468***	0.609**
Broilers	-3.24**	-2.69*	0.982***	1.072***
Turkeys	-2.93**	-2.16	0.086	0.207
Eggs	-4.75***	-3.26**	0.104	0.134
Milk	-5.07***	-5.55***	0.287	0.269

Panel B: First Differences	ADF test	ADF test	KPPS test	KPPS test
	Actual, P <sub>t</sub>	Forecast, F <sub>t</sub>	Actual, P <sub>t</sub>	Forecast, F <sub>t</sub>
Cattle	-9.75***	-10.85***	0.065	0.174
Hogs	-6.19***	-4.86***	0.114	0.191
Broilers	-6.74***	-8.23***	0.178	0.247
Turkeys	-6.31***	-7.16***	0.125	0.124
Eggs	-9.46***	-10.16***	0.284	0.230
Milk	-7.71***	-7.68***	0.041	0.191

<sup>a</sup>Augmented Dickey Fuller (ADF) test with a null hypothesis of non-stationarity (unit root). The reported t-statistics have critical values of -2.58 (10% level), -2.89 (5% level), and -3.51 (1% level).

<sup>b</sup>Kwiatkowski, Phillips, Schmidt, and Shin (KPPS) test with a null hypothesis of stationarity (no unit root). The reported LM statistics have critical values of 0.347 (10% level), 0.463 (5% level), and 0.739 (1% level).

\*\*\*Rejects null hypothesis at the 1% significance level.

\*\*Rejects null hypothesis at the 5% significance level.

\*Rejects the null hypothesis at the 10% significance level.

**Table 2. Efficiency Tests for I(0) Forecast Series:  $P_t = a + bF_t + e_t$** 

	Coefficient Estimates		Tested Restriction p-values			$e_t$ is i.i.d.
	a	b	a=0, b=1	a=0	b=1	
Hogs	0.490 (0.235) <sup>a</sup>	0.873 (0.061)	0.110 <sup>b</sup>	0.040 <sup>c</sup>	0.039 <sup>c</sup>	0.000 <sup>d</sup>
Turkeys	0.736 (0.246)	0.827 (0.059)	0.001	0.004	0.004	0.381
Eggs	0.321 (0.352)	0.929 (0.083)	0.101	0.364	0.400	0.000
Milk	0.329 (0.116)	0.877 (0.045)	0.000	0.006	0.008	0.025

<sup>a</sup>Standard error in parenthesis.

<sup>b</sup>P-value from F-test on stated restriction.

<sup>c</sup>P-value from a t-test (two-tailed) on stated restriction.

<sup>d</sup>P-value from LM test for serial correlation in  $e_t$ .

**Table 3. Efficiency Tests for I(1) Forecast Series:  $P_t = a + bF_t + e_t$**

	<u>Coefficient Estimates</u>		<u>Tested Restriction p-values</u>				
	a	b	a=0, b=1	a=0	b=1	$e_t$ is i.i.d.	max k=1
Cattle	-0.959 (0.190) <sup>a</sup>	1.227 (0.045)	0.000 <sup>b</sup>	0.000 <sup>c</sup>	0.000 <sup>c</sup>	0.254 <sup>d</sup>	0.4609 <sup>e</sup>
Hogs							
Broilers	0.639 (0.222)	0.846 (0.055)	0.000	0.010	0.013	0.010	0.3514

<sup>a</sup>Standard error in parenthesis.

<sup>b</sup>P-value from F-test on stated restriction.

<sup>c</sup>P-value from a t-test (two-tailed) on stated restriction.

<sup>d</sup>P-value from LM test for serial correlation in  $e_t$ .

<sup>e</sup>P-value from the null hypothesis that the maximum eigenvalue is one (unrestricted cointegration rank test).

**Table 4. Efficiency Tests for I(1) Forecast Series, Error Correction Model:  $\Delta P_t = \lambda + \rho e_{t-1} +$**

$$\beta_1 \Delta F_t + \sum_{i=1}^m \beta_i \Delta F_{t-i} + \sum_{j=1}^k \theta_j \Delta P_{t-j} + v_t$$

	<u>Coefficient Estimates</u>			<u>Tested Restriction p-values</u>				
	$\lambda$	$\rho$	$\beta$	$\rho=-1$	$\beta=1$	$\rho=-1,$ $\beta=1$	$\beta_i=0,$ $\theta_i=0$	$v_t$ is i.i.d.
Cattle	0.001 (0.005) <sup>a</sup>	-1.434 (0.305)	1.064 (0.171)	0.159 <sup>b</sup>	0.709 <sup>b</sup>	0.352 <sup>c</sup>	0.010 <sup>c</sup>	0.717 <sup>d</sup>
Broilers	0.003 (0.006)	-0.883 (0.164)	1.008 (0.099)	0.475	0.937	0.709	0.589	0.937

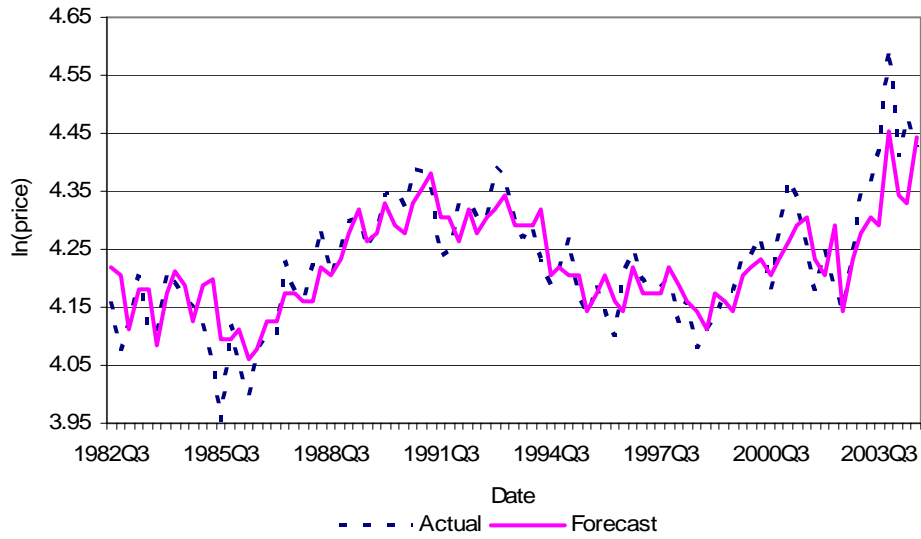
<sup>a</sup>Standard error in parenthesis.

<sup>b</sup>P-value from a t-test (two-tailed) on stated restriction.

<sup>c</sup>P-value from F-test on stated restriction.

<sup>d</sup>P-value from LM test for serial correlation in  $e_t$ .

**Figure 1. Turkey Prices and Forecasts, 1983.3 – 2004.3**



**Figure 2. Live Cattle Prices and Forecasts, 1983.3 – 2004.3**

