Multiple Horizons and Information in USDA Production Forecasts

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Practitioner's Abstract

USDA livestock production forecasts are evaluated for information across multiple horizons using the direct test developed by Vuchelen and Gutierrez. Forecasts are explicitly tested for rationality (unbiased and efficient) as well as for incremental information out to three quarters ahead. The results suggest that although the forecasts are often not rational, they typically do provide the forecast user with unique information at each horizon. Turkey and milk production forecasts tended to provide the most consistent performance, while beef production forecasts provided little information beyond the two quarter horizon.

Keywords: USDA forecasts, forecast consistency, efficiency

Introduction

USDA forecasts are widely used by "those in agribusiness who provide farmers with seeds, equipment, chemicals, and other goods and services, [who] study the reports when planning their marketing strategies" (National Agricultural Statistics Service, http://www.usda.gov/nass/nassinfo/importnt.htm). By their nature, these strategic decisions in agribusiness require relatively long-horizon forecasts. Moreover, producer's investment-decisions and marketing horizons often span a number of production cycles. The USDA accommodates this need by providing forecasts from one to three quarters ahead for most types of livestock production. In contrast to crops, where production forecasts generally span only one production cycle, livestock production forecasts can span a number of production cycles, especially in industries with relatively short biological lags such as poultry. Given the importance of long-horizons in strategic planning, it is important that both the USDA and forecast users understand the marginal information provided in multiple horizon forecasts.

Researchers have closely examined USDA forecasts in terms of accuracy (Kastens, Schroeder, and Plain; Garcia, Irwin, Leuthold, and Yang), information content (Carter and Galopin), and market impact (Sumner and Mueller). Notably, Bailey and Brorsen examine the accuracy of the USDA's monthly forecasts for annual beef and pork production in a fixed-event framework. They report that over the 1982-1996 sample period, the USDA forecasts are biased predictors, and furthermore, do not meet the conditions for optimality. In a similar vein, Sanders and Manfredo report that USDA one quarter-ahead production forecasts for beef, pork, and broilers are unbiased, but inefficient. Moreover, the USDA forecasts do not encompass simple time series models. Additional research by Sanders and Manfredo show that both USDA and Cooperative Extension Service forecasts by themselves are inferior to composite forecasts at longer-horizons. While these findings are important, they do not explicitly examine the informational content of the multiple horizon forecasts vis-à-vis their one step-ahead counterpart.

In this research, we specifically test the information provided by multiple horizon forecasts, using the method of Vuchelen and Gutierrez which directly tests if multiple horizon forecasts provide information beyond the one step-ahead forecast. For instance, in January of 2005, the USDA was forecasting a 4.5% year-over-year increase in broiler production one-quarter ahead, a 3.1% increase two quarters ahead, followed by a 3.3% increase in the third quarter: Does the forecasted 3.1% increase two quarters hence really provide any useful information beyond 4.5% increase forecasted for the next quarter? Moreover, does the 3.3% increase forecast for three quarters ahead provide any incremental information over the 3.1% two quarter ahead forecasts? In general, do the forecasts beyond one period ahead incorporate additional information? Or, are they simply random adjustments to the one period ahead forecast? These questions form the crux of our inquiry.

The research question is addressed using quarterly livestock production forecasts published by the USDA in the *World Agricultural Supply and Demand Estimates* (*WASDE*). Importantly, a broad range of markets—beef, pork, broilers, turkey, eggs, and milk—are examined in order to contrast the results across different production cycles.

The value of multiple step-ahead forecasts is important for both forecast users and the USDA. If multiple step-ahead forecasts are essentially a random adjustment to the one step-ahead forecast, then the forecast user may be better served by simply extrapolating the one step-ahead forecast. Also, in this case, the USDA may be able to improve the forecast service by allocating resources differently across horizons or concentrating more on markets where the multiple step horizons add the most value. It is important to note that this approach differs from prior work because it specifically addresses the incremental value added by forecasts beyond one period-ahead. In that sense, it is not a "horse race" among competing models or forecasting methods. Rather, we pose the question: What is the incremental information, if any, is added at each horizon?

As a result of this study, the USDA will better understand the value of its multiple step-ahead forecasts across different industries. Based on these results, they may be able to better allocate forecasting resources. More importantly, practitioners will be better able to utilize USDA production forecasts, pin pointing those which provide the greatest incremental information across planning horizons and improving economic decision-making.

Methodology

The traditional Mincer and Zarnowitz definition of forecast efficiency has been tested with the following regression,

$$(1) \qquad A_{t+1} = \alpha + \beta F_t^{t+1} + u_{t+1}$$

where, A_{t+1} is the realized value at time t+1, F_t^{t+1} is the forecast for time t+1 made at time t, and u_{t+1} is the error term. Forecast rationality is tested under the joint null of a zero intercept (α=0) and unitary slope coefficient (β=1). Moreover, an efficient forecast is characterized by an i.i.d. error term.

Holden and Peel have shown that the traditional joint null hypothesis is a sufficient, but not necessary, condition for rationality. Therefore, a rejection of the null hypothesis in (1) does not lead to clear alternative statements about forecast properties. Granger and Newbold suggest researchers focus strictly on the error terms and a number of studies have employed these methods (see Pons; Sanders and Manfredo). These evaluations are important in determining the rationality properties of the forecasts. However, they provide little insight as to the informational content of the forecasts, especially at longer horizons.

Noting these issues, Vuchelen and Gutierrez build on (1) and develop a direct test for information content by writing forecasts as the sum of consecutive adjustments to the most recent observation. So, the one-quarter ahead forecast can be decomposed into the following components,

(2) $F_t^{t+1} = A_t + (F_t^{t+1} - A_t)$, and for the two step ahead forecast,

(3) $F_t^{t+2} = A_t + (F_t^{t+1} - A_t) + (F_t^{t+2} - F_t^{t+1})$.

From (2), it is clear that the one step ahead forecast can be expressed as a simple adjustment to the current level, A_t. That is, the one step ahead forecast, F_t^{t+1}, is equal to the current level, A_t, plus the expected change or adjustment from the current level, (F_t^{t+1}-A_t). Likewise, in (3), the two-step ahead forecast is equal to the current level, A_t, plus the forecasted change from the current level, F_t^{t+1} -A_t, plus the forecasted adjustment in the following period, (F_t^{t+2} - F_t^{t+1}).

Vuchelen and Gutierrez develop their direct test for information by substituting the decomposition from (2) into (1) to get the one-step ahead test,

(4) $A_{t+1} = \theta + \kappa A_t + \lambda(F_t^{t+1} - A_t) + u_t$.

In (4) we can see that A_{t+1} is equal to previous period's value, A_t, plus the forecasted change in value, (F_t^{t+1} -A_t). Note, this representation provides a wealth of information about the forecast's quality and information content. First, an unbiased and efficient forecast means θ=0 and λ=1, which results in (4) reducing to (1) under the null hypothesis of rationality. Second, a forecast that contains some information relative to the most recent observation (or the naïve "no change" forecast) only requires that $\lambda \neq 0$. So, under this methodology, the tests are more revealing in the sense that we can test for optimal properties and directly test for information content. The test for information content is perhaps more interesting in the case of multiple step-ahead forecasts.

The test equation for two step ahead forecast is developed by substituting equation (3) into equation (1),

(5) $A_{t+2} = \gamma + \delta A_t + \eta(F_t^{t+1} - A_t) + \varepsilon(F_t^{t+2} - F_t^{t+1}) + u_{t+2}$.

In (5), an unbiased and efficient forecast is tested under the null that γ=0, and $\delta=\eta=\varepsilon=1$. Again, under the null hypothesis, equation (5) simplifies to the two-step-ahead version of (1). Note, however, equation (5) tells us the amount of information that F_t^{t+2} provides relative to the most recent observation, A_t, and the one period ahead forecast, F_t^{t+1}. In the event that $\gamma=\varepsilon=0$ and $\delta=\eta=1$, then the forecaster may as well use the one step-ahead forecast. Moreover, if ε=0, then the two step ahead forecast is not providing any incremental information over the one step ahead forecast.

In this research, we will also evaluate three step-ahead forecasts with a similarly derived equation,

(6) $$A_{t+3} = \phi + \kappa A_t + \psi(F_t^{t+1} - A_t) + \omega(F_t^{t+2} - F_t^{t+1}) + \rho(F_t^{t+3} - F_t^{t+2}) + u_{t+3}$$

Similar to (5), the unbiased and efficient forecast is tested under the null hypothesis: ϕ=0, and $\kappa=\psi=\omega=\rho=1$. A number of conclusions are possible from the estimation results. For instance, if $\kappa=\psi=1$ and $\omega=\rho=0$, then multiple horizon forecasts are not adding information. Instead, they are simply random adjustments to the one step-ahead forecast. Likewise, if $\kappa=\psi=1$, $0<\omega<1$, and $\rho=0$, then F_t^{t+2} provides some information about A_{t+3}, but F_t^{t+3} has no information that improves upon that contained in the two step ahead forecast.

Equation (4) can be estimated using standard OLS procedures. However, equations (5) and (6) are characterized by overlapping forecast horizons, which will result in correlated forecast errors and subsequent biased and inconsistent standard errors. To correct this problem, we follow the lead of Brown and Maital and use the OLS coefficient estimates, but correct the variance-covariance matrix using the methods proposed by Hansen and used by Hansen and Hodrick.

Data

This study focuses on USDA production forecasts for beef, pork, broilers, turkeys, eggs, and milk published in the USDA's *World Agricultural Supply and Demand Estimates* (*WASDE*) reports. For beef and pork, the forecasts are for total commercial production during the calendar quarter. The broiler and turkey forecast is for federally inspected production on a ready-to-cook basis for the calendar quarter. Egg production is measured as millions of dozen of total eggs: table eggs plus hatching eggs. Milk production is billions of pounds of farm-level production.

The *WASDE* forecast is released between the 8th and 14th of each month. Thus, the forecasted level of production is collected from the January, April, July, and October *WASDE* reports for each calendar quarter. For instance, from the January issue, the forecasted meat production for the first calendar quarter (January, February, and March) is collected. Actual or final production levels are collected as reported in the USDA's *Livestock, Dairy, and Poultry* reports. The USDA began to consistently report three-quarter ahead forecasts in 1994. So, the data span from the first quarter of 1994 (1994.1) to the third quarter of 2005 (2005.3), resulting in 46, 45, and 44 one-, two-, and three-step ahead production forecasts and actual values, respectively.

In forming their forecasts, the USDA's approach is probably best described as a composite forecast (personal communication). The industry experts on the World Agricultural Outlook Board essentially put together an annual supply and use balance sheet for each industry. The annual forecasts are adjusted for seasonal tendencies within each industry. Then, using statistics provided by Economic Research Service and the National Agricultural Statistical Service—such as cattle on feed, hog inventory, and eggs in incubators—as well as recent production trends, the quarterly production estimates are fine tuned to reflect the available production indicators. Although some formal modeling is used, many adjustments are made based on the experience and knowledge of the Board members.

Vuchelen and Gutierrez's application of the direct tests focused on forecasted growth rates, and it is appropriate to do so here as well. Not surprisingly, the absolute level of meat production demonstrates strong seasonality. Therefore, the analysis focuses on seasonal differences defined as the log-relative change in production from the same quarter of the prior year. For example, let a_t

equal the level of production in quarter t and f_{t-1}^{t} equal the one-step ahead forecast of production for quarter t. The variables of interest are thus defined as the change in actual production, $A_t=\ln(a_t/a_{t-4})$, and the forecasted change in production, $F_{t-1}^{t}=\ln(f_{t-1}^{t}/a_{t-4})$, such that the actual and forecasts are essentially the percent change in quarterly meat production from the prior year. Organizing the data in this manner provides stationary time series that are consistent with those used by industry analysts (e.g. Hurt) and in prior research (e.g., Kastens, Schroeder, and Plain).

Empirical Results

Accuracy Measures

Forecast accuracy is evaluated with two traditional measures: mean absolute error (MAE) and Theil's U. The results are presented in table 1. Since the forecasts are in log-relative changes, the MAE can be interpreted as the average absolute error in percent. For instance, the MAE for beef production forecasts is 2.32% for one-quarter ahead forecasts. Comparing across markets, the beef, pork, and turkey production forecasts all have MAE's in excess of 2%, while egg and milk MAE's are near 1%. All of the forecasts, except eggs, show a tendency for accuracy to decline as the horizon lengthens. The MAE for beef production nearly doubles from 2.32% to 4.53% as the horizon lengthens from one to three quarters. The other markets show some level accuracy degradation across horizons. The lone exception is eggs. Oddly, egg production forecasts are more accurate at three quarters ahead than two quarters ahead. While the difference is relatively small, it is surprising and raises questions about the performance of the longer-horizon forecasts.

Theil's U essentially normalizes forecast errors by the volatility of "no change" forecast errors. Theil's U has a lower bound of zero for perfect forecasts, it takes a value of unity for naïve "no change" forecasts, and it has no upper bound (Leuthold). At the one quarter horizon, all of the forecasts provide performance superior to a "no change" naïve alternative, except for eggs. According to Theil's U, the one quarter ahead egg production forecasts result in a larger error variance than a "no change" forecast. Naturally, as the forecast horizon lengthens it should be easier to outperform the "no change" forecast with the addition of even modest information. Not surprisingly then, at the two quarter ahead forecast, all of the forecasts perform better than the naïve alternative. However, at the three quarter horizon, the beef production forecasts are nearly as inaccurate as the using the actual production growth from three quarters prior—i.e., the "no change" forecast. The relative slippage in the beef production forecasts may be due to the longer production cycle of cattle, which makes it more difficult to predict quarter-to-quarter changes in production.

Accuracy measures indicate that forecast precision declines at longer horizons, especially for beef. However, according to Theil's U, the forecasts generally perform better than a naïve "no change" forecast, the exceptions being eggs at the one-quarter horizon and beef at the three-quarter horizon. This casual comparison of forecast accuracy measures suggest that longer-horizon forecasts decline in accuracy, and there may particularly be performance issues with eggs and beef forecasts. Still, it is important to evaluate the longer-term forecasts in a statistical sense. We use the method proposed by Vuchelen and Gutierrez to explicitly evaluate the additional information provided by the USDA's longer-horizon forecasts.

Direct Tests for Information

The accuracy measures in table 1 suggest that the information contained in USDA production forecasts decline as the forecast horizon lengthens. However, accuracy measures alone do not tell the whole story. It is important to directly test the information contained at longer horizons versus the shorter term forecasts: Are the three quarter ahead forecasts providing information not contained in the one-quarter ahead forecasts? To start answering this question, equation (4) is estimated for all markets to test for information content versus a "no change" naïve forecast. The estimation results for equation (4) are presented in table 2.

In table 2, a rational one-step ahead forecast is tested under the null hypothesis of θ=0, κ=λ=1. While rationality is important in evaluating the optimality of forecasts, the thrust of this research is to gauge the information added at each horizon. In equation (4), an informative, but not necessarily rational, one-step ahead forecast simply requires rejection of the null hypothesis that λ=0.

One-step ahead pork, broiler, turkey and milk forecasts fail to reject the null rationality hypothesis. Examining the individual coefficients in these markets, we can see that the intercept, θ, is close to zero and the slope coefficients, κ and λ, are relatively close to one. Not surprisingly, in these four markets, the one-step ahead forecast provides information beyond the naïve forecast with $\lambda \neq 0$ and not statistically different from one. So, at least for pork, broilers, turkeys and milk, one-step ahead production forecasts appear to be rational and informative. Beef and egg forecasts provide quite different results.

The one-step ahead beef forecasts reject the null rationality hypothesis, θ=0, κ=λ=1; however, the one-step ahead forecast is informative, by $\lambda \neq 0$. In fact, the λ estimate is not statistically different from one (p-value =0.573). The rejection of the rationality conditions stem from κ>1 (p-value = 0.025). Importantly, κ>1 and λ=1, implies that the one-step ahead beef production forecast, F_t^{t+1}, does not efficiently use the information contained in the current production growth, A_t. Hence, a rejection of the rational null hypothesis, even though the one-step ahead forecast is informative ($\lambda \neq 0$).

Contrast the beef results to that of eggs, and the advantage of the empirical methodology becomes clear. The one-step ahead forecasts for egg production also rejects the rational null hypothesis, but it also clearly indicates that the one-step ahead forecast is providing no information (λ=0) relative to just using the current quarters growth in production, A_t. This result is consistent with a Theil's U of 1.052 presented in table 1. The individual coefficient estimates for eggs suggest that θ>0, 0<κ<1, and λ=0. So, the egg production forecasts are downward bias (θ>0), fail to use all of the information in A_t (0<κ<1) and most telling, they provide no information beyond A_t (λ=0). A forecast user would not benefit from using F_t^{t+1} instead of A_t as a one-quarter ahead forecast of egg production.

The results for the two-quarter ahead forecasts in table 3 are fairly consistent with those in table 2. In particular, the null hypothesis of rationality, γ=0, and δ=η=ε=1, is again rejected for beef (p-value =0.001) and eggs (p-value = 0.054). Perhaps more importantly, for all markets, the two two-quarter ahead forecast provides some information relative to the one-quarter head forecast, i.e., $\varepsilon \neq 0$. For beef, 0<ε<1, while for all other markets, the null that ε=1 cannot be rejected. While it is useful to know about forecast rationality, the strength of the direct tests method is discovering that the USDA's two-quarter ahead forecasts are indeed providing useful information beyond that contained in the one-quarter ahead forecasts. For all of the two quarter ahead forecasts, the forecast user is will gain from using the USDA's forecast versus relying on a naïve forecast or just the one quarter ahead forecast.

The null hypothesis of no information content for three quarter ahead forecasts is rejected in pork, broilers, and milk at the 5% level and turkeys at the 10% level (Table 4). Only the beef production forecasts fail to reject the null hypothesis of no information (ρ=0). However, unlike the two-quarter ahead forecasts (Table 3), rationality (ϕ=0, and κ=ψ=ω=ρ=1) is rejected at the 10% level in all the markets except turkeys and milk. In both turkeys and milk, the three-quarter ahead forecast provides information, (ρ>0), and none of the slope coefficients are statistically different from one. Relative to the other markets, this is an impressive forecasting performance for a three-quarter horizon. The other markets, beef, pork, broilers, and eggs, reject rationality at the 10% level. Looking at the individual coefficients, beef has a ρ=0, so it is neither rational nor does it provide any information. On the other hand, at three-quarter ahead, pork forecasts do add information (ρ>0), but they are not fully rational (ρ=1).

In broilers and eggs, rejection of rationality conditions stems from both a bias in the intercept term and one or more of the slope coefficients statistically differing from one. Still, in both of these forecast series, the three-quarter ahead forecast is adding information beyond the one- and two-ahead forecasts ($\rho\neq0$). This is important information for a forecast user who may be more concerned about the informational content of the longer-horizon forecasts than the academic notion of rationality.

Collectively, the results suggest that the USDA production forecasts are not always rational, but they usually provide important information at longer horizons. Turkey and milk production forecasts are especially good. At each forecast horizon, the forecasts are rational and provide incremental information not available in shorter-horizon forecasts. Egg and beef forecasts are particularly problematic. Rationality is rejected at the 10% level at each horizon for eggs and beef. One-quarter ahead egg production forecasts provide no information beyond the prior quarter's actual value. Likewise, the three-quarter ahead beef production forecasts fail to provide any incremental information. Pork and broiler production forecasts, while not rational at the three quarters ahead, provide new information at each horizon. So, except for eggs at the one quarter horizon and beef at the three quarter horizon, the USDA production forecasts are providing unique information at each interval over their multiple horizon forecasts.

Summary and Conclusions

Agribusinesses rely on longer-term and multiple horizon forecasts when making business plans and strategic decisions. To accommodate these needs, the USDA provides multiple horizon production forecasts for beef, pork, broilers, turkey, eggs, and milk. In this paper, we evaluate the informational content of the multiple horizon forecasts using the direct test proposed by Vuchelen and Gutierrez. The direct test establishes the contribution of longer-horizon forecasts relative to the information already contained in shorter-horizon forecasts.

The results largely indicate that the one, two, and three quarter ahead forecasts all add unique information to the overall forecast set. The exceptions are egg forecasts at the one quarter horizon and the three quarter ahead beef production forecasts. While forecasts beyond one quarter ahead are not always rational, they are generally informative, where each horizon forecast contains some unique information.

The results have some ramifications for agribusiness planners and USDA forecasters. First for the USDA, milk and turkey forecasts are quite good—both rational and informative—and the methodology should be maintained and perhaps replicated in other commodities. Conversely, egg production forecasts are generally not rational and contain little information at one quarter horizon. The USDA should review their forecasting procedures for eggs in an attempt to isolate the overall poor forecasting performance in this sector. Beef forecasts tend not to be rational, but they are informative at the one and two quarter horizons. It is possible that the longer production lags in the beef industry make forecasting beyond two quarters especially difficult. Although, there does not appear to be a strong correspondence between production cycles and performance as shown by good performance in a long production cycle (milk) and a short production cycle (turkeys).

Agribusiness managers who utilize USDA production estimates should take some comfort in the results: the USDA's multiple horizon forecasts generally do contain unique information. Although the forecasts are not always technically rational, they may contain important hints as to whether production in a particular industry is going to contract or expand. As agribusiness planners form expectations for future production levels, especially at longer horizons, the USDA forecasts clearly contain information that may improve those important business decisions.

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Table 1. Forecast Accuracy Measures, USDA Production Forecasts.

	MAE			Theil’s U		
Market	1-ahead	2-ahead	3-ahead	1-ahead	2-ahead	3-ahead
Beef	0.0232	0.0361	0.0453	0.749	0.883	0.999
Pork	0.0207	0.0242	0.0298	0.819	0.753	0.753
Broilers	0.0148	0.0194	0.0226	0.731	0.755	0.817
Turkeys	0.0209	0.0218	0.0256	0.681	0.604	0.665
Eggs	0.0104	0.0128	0.0126	1.052	0.852	0.716
Milk	0.0094	0.0117	0.0123	0.829	0.696	0.630

Note: For n observations, the MAE = $\sum|A_t-F^t_{t-k}|/n$, and Theil’s U = $(\sum(A_t-F^t_{t-k})^2/n)^{0.5}/(\sum(A_t-A_{t-k})^2)^{0.5}$, where A_t is the realized observation at time t, and F^t_{t-k} is the k-step ahead forecast for time t.

Table 2. One-Step Ahead Direct Tests, $A_{t+1} = \theta + \kappa A_t + \lambda(F_t^{t+1} - A_t) + u_t$.

	Coefficient Estimates			Hypothesis Tests	
Market	θ	κ	λ	Θ=0, κ=λ=1	λ=0
Beef	-0.006	1.426	1.149		
	(0.004)[a]	(0.183)*	(0.262)	0.001[b]	0.000[c]
Pork	0.006	0.912	0.700		
	(0.004)	(0.110)	(0.168)	0.149	0.000
Broilers	0.006	0.876	0.812		
	(0.005)	(0.135)	(0.119)	0.406	0.000
Turkeys	0.000	0.911	0.768		
	(0.004)	(0.121)	(0.135)	0.374	0.000
Eggs	0.006	0.715	0.254		
	(0.002)*	(0.109)*	(0.217)*	0.003	0.248
Milk	-0.001	1.052	0.902		
	(0.002)	(0.126)	(0.258)	0.673	0.001

[a]Standard errors are in parenthesis.
[b]P-value from Chi-squared test for stated restriction.
[c]P-value from two-tailed t-test on stated restriction.
*Indicates θ estimate is statistically different from zero at the 5% level; κ or λ are statistically different from one at the 5% level.

Table 3. Two-Step Ahead Direct Tests, $A_{t+2} = \gamma + \delta A_t + \eta(F_t^{t+1} - A_t) + \varepsilon(F_t^{t+2} - F_t^{t+1}) + u_{t+2}$

	Coefficient Estimates				Hypothesis Tests	
Market	γ	δ	η	ε	γ=0, δ=η=ε=1	ε=0
Beef	0.003	1.161	1.030	0.398		
	(0.007)[a]	(0.251)	(0.285)	(0.192)*	0.001[b]	0.045[c]
Pork	0.007	0.957	0.794	0.760		
	(0.006)	(0.159)	(0.211)	(0.169)	0.303	0.000
Broilers	0.015	0.583	0.580	0.692		
	(0.011)	(0.244)	(0.285)	(0.293)	0.524	0.023
Turkeys	-0.005	0.974	1.079	0.939		
	(0.006)	(0.202)	(0.210)	(0.201)	0.749	0.000
Eggs	0.011	0.512	0.278	0.640		
	(0.005)*	(0.228)*	(0.272)*	(0.235)	0.054	0.009
Milk	-0.002	1.052	0.937	1.200		
	(0.005)	(0.285)	(0.381)	(0.319)	0.842	0.001

[a]Standard errors are in parenthesis.
[b]P-value from Chi-squared test for stated restriction.
[c]P-value from two-tailed t-test on stated restriction.
*Indicates γ estimate is statistically different from zero at the 5% level; δ, η, or ε are statistically different from one at the 5% level.

Table 4. Three-Step Ahead Direct Tests,
$A_{t+3} = \phi + \kappa A_t + \psi(F_t^{t+1} - A_t) + \omega(F_t^{t+2} - F_t^{t+1}) + \rho(F_t^{t+3} - F_t^{t+2}) + u_{t+3}$

	Coefficient Estimates					Hypothesis Tests	
Market	ϕ	κ	ψ	ω	ρ	ϕ=0, κ=ψ=ω=ρ=1	ρ=0
Beef	0.009	1.001	0.947	0.506	0.185		
	(0.011)[a]	(0.351)	(0.363)	(0.283)	(0.229)*	0.000[b]	0.406[c]
Pork	0.008	0.821	0.770	0.737	0.414		
	(0.009)	(0.237)	(0.287)	(0.215)	(0.155)*	0.007	0.011
Broilers	0.026	0.253	0.147	0.471	0.483		
	(0.012)*	(0.275)*	(0.317)*	(0.373)	(0.260)*	0.072	0.070
Turkeys	-0.009	1.021	0.885	0.923	0.910		
	(0.008)	(0.286)	(0.303)	(0.299)	(0.220)	0.711	0.000
Eggs	0.015	0.328	0.532	0.522	0.601		
	(0.005)*	(0.256)*	(0.301)	(0.246)	(0.190)*	0.063	0.003
Milk	-0.000	0.852	0.561	1.198	1.032		
	(0.007)	(0.401)	(0.459)	(0.384)	(0.290)	0.185	0.000

[a]Standard errors are in parenthesis.
[b]P-value from Chi-squared test for stated restriction.
[c]P-value from two-tailed t-test on stated restriction.
*Indicates ϕ estimate is statistically different from zero at the 5% level; κ, ψ, ω, or ρ are statistically different from one at the 5% level.