Forecasting Accuracy, Rational Expectations, and Market Efficiency in the US Beef Cattle Industry

By

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Abstract

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Recent studies have tested whether futures prices respond to U.S. Department of Agriculture inventory reports in accordance with the efficient markets hypothesis. These studies use survey forecasts to identify the anticipated and unanticipated information contained in a report. However, this approach implicitly assumes that survey forecasts be an unbiased and efficient predictor of the data in the USDA report. Furthermore, previous studies have not tested the bias and efficiency properties of USDA *preliminary* estimates as predictors of *final revised* USDA figures. This study introduces a framework for conducting tests of the efficient markets hypothesis in the presence of biased and inefficient survey forecasts, and preliminary USDA estimates that are biased and inefficient predictors of final revised figures. The approach is applied to the US beef cattle industry and results are quite different from those obtained using conventional analysis.

1. Introduction

Several recent studies have used survey forecasts to distinguish between anticipated and unanticipated information contained in USDA inventory reports to investigate announcement effects and to test the efficient markets hypothesis (Barnhart, Colling and Irwin, Grunewald, McNulty, and Biere, and Colling, Irwin, and Zulauf). However, the true anticipated and unanticipated components of a government report are unobservable. The conventional approach introduced by Pearce and Roley, is to define anticipated information as a survey forecast conducted prior to the report's release, and unanticipated information as the difference between the actual report numbers and the pre-release survey forecast. This approach has led to very useful research analyzing whether USDA inventory reports fulfill their primary public policy objective of providing new information to market participants and testing whether the futures market's respond efficiently to information released in USDA reports. However, none of the existing studies have tested whether USDA preliminary estimates (i.e. the information released in the report) are rational forecasts of final revised numbers provided later, after more information has become available. If the USDA revises preliminary estimates in a predictable way, and/or if survey forecasts are not unbiased and efficient forecasts of the final revised USDA figures, then the convential tests of announcement effects and the efficient market hypothesis (EMH) may lead to incorrect inference. This is because, in these circumstances, the conventional approach fails to properly decompose information into components that can be predicted (anticipated) and another that cannot (unanticipated).

In this paper we make two contributions. First, we develop a procedure for testing announcement affects and market efficiency when *survey forecasts* are not unbiased, efficient, forecasts of *final revised* USDA numbers, and/or when USDA *preliminary estimates* are not unbiased, efficient, forecasts of *final revised* USDA numbers. Second, we show how private information, not publically available, can be included in the analysis and used to shed light on announcement effects and market efficiency. The procedures are illustrated by applying them to test for forecasting accuracy, announcement effects, and strong form market efficiency in the US beef cattle industry.

2. Conventional Approach

Consider the conventional model for testing the EMH applied to investigate the price response to the *Cattle on Feed* (*COF*) report . The model is as follows:

$$
\begin{aligned}
\ln p_{i+1,t} - \ln p_{i,t} = {} & b_0 + b_1\left(\ln F^{a}_{i,t} - \ln F^{e}_{i-2,t}\right) + b_2\left(\ln P^{a}_{i,t} - \ln P^{e}_{i-2,t}\right) + b_3\left(\ln M^{a}_{i,t} - \ln M^{e}_{i-2,t}\right) \\
& + b_4\left(\ln p_{i,t} - \ln p_{i-1,t}\right) + b_5 \ln F^{e}_{i-2,t} + b_6 \ln P^{e}_{i-2,t} + b_7 \ln M^{e}_{i-2,t} + v_{i+1,t}
\end{aligned}
\tag{1}
$$

where $\ln p_{i,t}$ is the natural log of the closing live cattle futures price on day *i*, the day which the report for month *t* is released; $\ln F^{a}_{i,t}, \ln P^{a}_{i,t}$ and $\ln M^{a}_{i,t}$ are the natural log of USDA preliminary estimates of cattle on-feed, placements and marketings, respectively, for month *t* released on day *i*; $\ln F^{e}_{i-2,t}, \ln P^{e}_{i-2,t}$ and $\ln M^{e}_{i-2,t}$ are the natural log of survey forecasts of cattle on-feed, placements and marketings, respectively, for month *t* released on day *i-2* (two days before the official report is released); and $v_{i+1,t}$ is a random error term uncorrelated with information known at the close of the trading day *i*. Model (1) is typically estimated in logarithms to minimize non-stationarity caused by increased price dispersion at higher price levels (Grunewald et al.). Model (1) implicitly assumes cattle on-feed survey forecasts are unbiased and efficient implying, $F^{e}_{i-2,t} = E\left(F^{a}_{i,t} \middle| f_{i-2,t}\right)$; where $f_{i-2,t}$ denotes all available information at the time the survey forecast is released two days before the *COF* report release. Likewise for placements and marketings survey forecasts. So, under the EMH b_4, b_5, b_6 and b_7 should all be zero and $v_{i+1,t}$ should be serially uncorrelated, because all available (anticipated) information, $f_{i-2,t}$, should already be reflected by day *i* prices. If the report contains new information, then at least one of b_1, b_2, b_3 should be different from zero. Model (1) is estimated separately using near-term, first-deferred, and second-deferred contract prices over the sample period February 1990 through December 1994. Cattle are on feed approximately four to five months so one would expect near-term contract price changes to have a positive relationship with unanticipated shocks to marketings, and deferred contract prices to have a negative relationship with unanticipated shocks to placements (more placements means more supply and lower prices in four to five months). Each variable was tested for stationarity, and no evidence of a unit root was detected. Residuals from model (1) were tested for heteroscedasticity including ARCH effects, and none was detected. Previous studies have estimated model (1) using the two-limit tobit model to account for limit price moves. Over our sample period, the near-term contract recorded just 4 limit moves, and the first- and second-deferred contracts recorded zero limit moves. The degree of inefficiency due to four limit price moves is expected to be negligible, thus model (1) is estimated using OLS for each contract horizon. Hypotheses test results for market efficiency appear in table (1). In general, results indicate failure to reject the EMH: survey forecasts are not useful for predicting price changes occurring one, two and three days following the release of the *COF* report for each contract horizon at conventional significance levels. Results indicate the only possible exception is a rejection for second-deferred price changes one day following the *COF* report release at the 10% level, but not at the 5% level. The conclusion is that prices do not respond to information already known when the *COF* report is released, which is consistent with the EMH.

Next we imposed the EMH, ($b_4 = b_5 = b_6 = b_7 = 0$), and tested for announcement effects ($b_1 = b_2 = b_3 = 0$). Hypotheses test results for announcement effects appear in table (2). Placements and marketings parameter estimates have expected signs and individual explanatory power. Results suggest the *COF* report does provide new information to the near-term and first-deferred contracts. For these contract prices we reject the null hypothesis below the 5% level, but not the 1% level. However, in the case of the second-deferred contract we reject the null hypothesis below the 10% level, but not the 5% level. The latter result suggests the *COF* report may provide less information relevant to longer term prices.

3. Limitations of the Existing Methodology

Model (1) may generate inefficient parameter estimates and incorrect inference if the following two conditions are not satisfied: $F_{i,t}^{a} = E\left(F_{i+n,t}^{*} \middle| f_{i,t}\right)$ and $F_{i-2,t}^{e} = E\left(F_{i+n,t}^{*} \middle| f_{i-2,t}\right)$, where $F^{*}_{i+n,t}$ is the final revised USDA estimate of cattle on-feed in month *t*, determined on day *i*+*n*. If preliminary estimates, $F^{a}_{i,t}$, do not satisfy the rationality condition, this implies USDA final revisions are made in a systematic way, implying they may not be optimal (minimum variance) forecasts of final revised figures. Likewise, if survey forecasts, $F^{e}_{i-2,t}$, are not rational, they may also not be minimum variance forecasts of final revised figures. We test USDA preliminary estimates and Knight-Ridder survey forecasts for rationality by conducting tests of unbiasedness and direct tests of efficiency relative to public and private information. We conclude USDA preliminary estimates and KR survey forecasts of cattle on-feed, placements and marketings may not be rational estimates of final revised numbers. One interesting aspect of our efficiency tests is the use of private data provided by Professional Cattle Consultants (PCC). PCC conducts a feedlot survey prior to the release of each monthly *COF* report, and returns compiled cattle on-feed, placements and marketings responses to each feedlot in a newsletter format approximately one week before the *COF* report release. Our sample of PCC data spans from January 1986 through December 1994. Over this sample period, the PCC survey represents between 1.3 and 2.2 million head of cattle each month; approximately 20 % of all cattle on-feed, placed and marketed from the seven largest cattle feeding states each month. The PCC data is divided by feedlot capacity to eliminate variation due to feedlots entering and exiting the survey over the sample period. Furthermore, no evidence of a unit root was detected in any of the data series.

4. An Alternative Approach

Next we consider whether a model of market efficiency can be specified which optimally reflects unanticipated and anticipated information. Following Mankiw et al., define the optimal linear (minimum variance) forecast of final revised cattle on-feed, $F^{*}_{i+n,t}$, conditional on information available at time (*i*,*t*), $\left\{F^{a}_{i,t}, F^{e}_{i-2,t}, F^{p}_{i-7,t}, P^{p}_{i-7,t}, M^{p}_{i-7,t}\right\}$, to be:

(2) $$F^{f}_{i,t} = \hat{b}_0 + \hat{b}_1 F^{a}_{i,t} + \hat{b}_2 F^{e}_{i-2,t} + \hat{b}_3 F^{p}_{i-7,t} + \hat{b}_4 P^{p}_{i-7,t} + \hat{b}_5 M^{p}_{i-7,t}$$

where $F^{p}_{i,t}, P^{p}_{i,t}$ and $M^{p}_{i,t}$ are PCC cattle on-feed, placements and marketings, respectively, and all variables have been defined previously. Model (2) is estimated over the period January 1986 through December 1988. To obtain optimal linear forecasts of final revised cattle on-feed figures conditional on information at time (*i*-2,*t*), $F^{\tilde{f}}_{i-2,t}$, model (2) was simply estimated without $F^{a}_{i,t}$.

The same procedure is used for placements and marketings. Define the optimal linear minimum variance forecasts of placements and marketings conditional on information available at time (*i*,*t*) as follows:

(3) $$P^{f}_{i,t} = \hat{b}_0 + \hat{b}_1 P^{a}_{i,t} + \hat{b}_2 P^{e}_{i-2,t} + \hat{b}_3 P^{p}_{i-7,t}$$

(4) $$M^{f}_{i,t} = \hat{b}_0 + \hat{b}_1 M^{a}_{i,t} + \hat{b}_2 M^{e}_{i-2,t} + \hat{b}_3 M^{p}_{i-7,t}$$

To obtain optimal linear forecasts of final revised placements and marketings figures conditional on information at time (i-2,t), $P^{\tilde{f}}_{i-2,t}$ and $M^{\tilde{f}}_{i-2,t}$, models (3) and (4) were simply estimated without $P^{a}_{i,t}$ and $M^{a}_{i,t}$, respectively. Parameter estimates from econometric models are presented in table (3). The parameter estimates from each model are used to predict cattle on-feed over the period February 1990 through December 1994, and placements and marketings over the period January 1990 through December 1994, using updated data. This approach was necessary because the USDA released final revised estimates for the period January 1984 through December 1988 in January 1990, and not again until January 1995. F-test results indicate the econometric models generate more efficient in-sample forecasts of cattle on-feed, placements and marketings than USDA preliminary estimates and Knight-Ridder survey forecasts of each over the period January 1986 through December 1988. Note that if auto-correlation is detected in any of the econometric models, it cannot be properly corrected because final revised data are not available at the time out-of-sample forecasts are made starting February 1990. Based on the durbin watson statistics we can conclude parameter estimates from the cattle on-feed econometric models conditional on information at time (i,t) and (i-2,t) are unbiased but inefficient. Thus, an agent can determine *ex-ante* that out-of-sample forecasts from both cattle on-feed models will not be minimum variance forecasts. However, econometric models for placements and marketings conditional on information at time (i,t) and (i-2,t) do not exhibit significant auto-correlation. T-tests from these models indicate PCC marketings data is useful for predicting final revised marketings at time (i,t) and (i-2,t), and that PCC placements data is useful for predicting final revised placements at time (i-2,t). We can reasonably conclude that a rational agent would use out-of-sample forecasts of final revised placements and marketings from the econometric models conditional on information at time (*i*,*t*) and (*i*-2,*t*). Based on these results it follows that unanticipated and anticipated placements and marketings, as defined in model (1) using USDA preliminary estimates and KR survey forecasts, may be non-optimal estimates of unanticipated and anticipated information. An optimal model of market efficiency is as follows:

$$
\begin{aligned}
(5)\quad \ln p_{i+1,t} - \ln p_{i,t} = {} & b_0 + b_1\left(\ln F_{i,t}^{a} - \ln F_{i-2,t}^{e}\right) + b_2\left(\ln P_{i,t}^{f} - \ln P_{i-2,t}^{\tilde{f}}\right) + b_3\left(\ln M_{i,t}^{f} - \ln M_{i-2,t}^{\tilde{f}}\right) \\
& + b_4\left(\ln p_{i,t} - \ln p_{i-1,t}\right) + b_5 \ln F_{i-2,t}^{e} + b_6 \ln P_{i-2,t}^{\tilde{f}} + b_7 \ln M_{i-2,t}^{\tilde{f}} + v_{i+1,t}
\end{aligned}
$$

where $\ln P_{i,t}^{f}$ and $\ln M_{i,t}^{f}$ are the natural log of optimal forecasts of final revised placements and marketings, respectively, *conditional only on available information at the time the COF report is released*; $\ln P_{i-2,t}^{\tilde{f}}$ and $\ln M_{i-2,t}^{\tilde{f}}$ are the natural log of optimal forecasts of final revised placements and marketings, respectively, *conditional only on available information at the time the KR survey forecasts are released*; and all other variables have been previously defined. Proceeding, model (5) is estimated to test for market efficiency in precisely the same manner as model (1). We test the null hypothesis that coefficients on available information, b_4, b_5, b_6 and b_7, are jointly equal to zero. Results appear in table (4). Two results stand out. First, we reject the EMH for near-term and first-deferred contract prices one day following the *COF* report release at the 10% level, but not the 5% level. Second, we reject the EMH for second-deferred contract prices one day following the *COF* report release at the 5% level, but not the 1% level. The latter result is consistent, yet stronger, than our result from model (1); it implies second-deferred price changes one day following the *COF* report release are not consistent with the strong form of the EMH. It is important to note that risk adjusted profits must be generated on the basis of the optimal forecasts of placements and marketings before we can definitively conclude the live cattle futures market is inefficient.

Next, we impose the EMH on model (5), $b_4 = b_5 = b_6 = b_7 = 0$, and test the null hypothesis that parameter estimates on unanticipated information, b_1, b_2 and b_3, are jointly equal to zero using near-term and first-deferred contract prices. In the case of second-deferred contract prices we test the same null hypothesis, but without imposing the EMH on model (5) since available information was found to be jointly significant for predicting these price changes. Failure to reject the null hypothesis indicates the *COF* report does not contain new information for market participants. Hypotheses test results for announcement effects appear in table (5). Two results are strikingly different than those found using the conventional approach; we fail to reject the null hypothesis that unanticipated information is not useful for the prediction of near-term and first-deferred contract prices. Finally, we reject the null hypothesis for second-deferred contract prices at the 10% level, but not the 5% level.

5. Conclusions

From these results we can reach two important conclusions. First, this evidence suggests the *COF* report may not provide new information to agents with optimal linear forecasts of final revised estimates of placements and marketings. Second, this evidence also suggests that agents with optimal forecasts of *COF* report numbers (which use PCC data and other data) may be able to predict some price movements after the *COF* report is released.

Table 1. Hypotheses test results for the Pearce and Roley semi-strong form efficiency test

	Tests for the first trading day after *Cattle on Feed* release	F-stat	P-value
Near-term	$H_0{:}b_4 = b_5 = b_6 = b_7 = 0$	1.28	0.29
First-deferred	$H_0{:}b_4 = b_5 = b_6 = b_7 = 0$	1.06	0.39
Second-deferred	$H_0{:}b_4 = b_5 = b_6 = b_7 = 0$	2.44	0.06
	Tests for the second trading day after *Cattle on Feed* release		
Near-term	$H_0{:}b_4 = b_5 = b_6 = b_7 = 0$	0.39	0.82
First-deferred	$H_0{:}b_4 = b_5 = b_6 = b_7 = 0$	1.28	0.29
Second-deferred	$H_0{:}b_4 = b_5 = b_6 = b_7 = 0$	1.14	0.35
	Tests for the third trading day after *Cattle on Feed* release		
Near-term [a]	$H_0{:}b_4 = b_5 = b_6 = b_7 = b_8 = 0$	1.72	0.15
First-deferred [a]	$H_0{:}b_4 = b_5 = b_6 = b_7 = b_8 = 0$	1.02	0.42
Second-deferred [a]	$H_0{:}b_4 = b_5 = b_6 = b_7 = b_8 = 0$	1.33	0.27

[a] Model was corrected for third order auto-correlation, and this parameter was additionally tested equal to zero.

Table 2. Hypotheses test results for announcement effects from Pearce and Roley model

	Tests for first trading day after *Cattle on Feed* release	F-stat	P-value
Near-term	$H_0{:}b_1 = b_2 = b_3 = 0$	2.80	0.05
First-deferred	$H_0{:}b_1 = b_2 = b_3 = 0$	3.53	0.02
Second-deferred	$H_0{:}b_1 = b_2 = b_3 = 0$	2.45	0.07

Table 3. Parameter estimates and statistics from econometric forecasting models

Independent Variables	Econometric Models Conditional on Information (i,t)			Econometric Models Conditional on Information (i-2,t)		
	$F^*_{i+n,t}$	$P^*_{i+n,t}$	$M^*_{i+n,t}$	$F^*_{i+n,t}$	$P^*_{i+n,t}$	$M^*_{i+n,t}$
Constant	-24.11	21.54	13.83	862.89*	-19.79	283.75**
$s.e.$	(143.84)	(21.75)	(66.13)	(454.44)	(72.52)	(132.52)
$F^a_{i,t}$	1.12**					
$s.e.$	(0.063)					
$P^a_{i,t}$		0.96**				
$s.e.$		(0.052)				
$M^a_{i,t}$			0.93**			
$s.e.$			(0.085)			
$F^e_{i-2,t}$	-0.09			1.01**		
$s.e.$	(0.063)			(0.04)		
$P^e_{i-2,t}$		0.074			0.86**	
$s.e.$		(0.047)			(0.07)	
$M^e_{i-2,t}$			0.005			0.69**
$s.e.$			(0.08)			(0.11)
$F^p_{i-7,t}$	201.59			-641.99		
$s.e.$	(130.54)			(409.60)		
$P^p_{i-7,t}$	-390.04**	-302.75		1127.05**	1530.31**	
$s.e.$	(173.31)	(184.77)		(507.52)	521.55	
$M^p_{i-7,t}$	-61.29		547.63**	-1145.53		1189.18**
$s.e.$	(274.24)		(230.31)	(901.14)		(480.75)
$\overline{R}^2$	0.99	0.99	0.96	0.96	0.95	0.82
$F-stat$	1950.33	2389.58	269.66	207.61	304.06	73.84
$p-value$	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
DW	0.74	1.90	1.87	1.52	1.86	2.01

Table 4. Hypotheses test results for strong form efficiency test

	Tests for the first trading day after *Cattle on Feed* release	F-stat	P-value
Near-term	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = 0$	2.42	0.06
First-deferred	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = 0$	2.40	0.06
Second-deferred	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = 0$	3.23	0.02
	Tests for the second trading day after *Cattle on Feed* release		
Near-term	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = 0$	0.53	0.72
First-deferred	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = 0$	1.39	0.25
Second-deferred	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = 0$	1.68	0.17
	Tests for the third trading day after *Cattle on Feed* release		
Near-term [a]	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = b_8 = 0$	1.66	0.16
First-deferred [a]	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = b_8 = 0$	1.02	0.41
Second-deferred [a]	$H_0\!:\!b_4 = b_5 = b_6 = b_7 = b_8 = 0$	1.55	0.20

[a] Model was corrected for third order auto-correlation, and this parameter was additionally tested equal to zero.

Table 5. Hypotheses test results for announcement effects

	Tests for the first trading day after *Cattle on Feed* release	F-stat	P-value
Near-term	$H_0\!:\!b_1 = b_2 = b_3 = 0$	1.07	0.37
First-deferred	$H_0\!:\!b_1 = b_2 = b_3 = 0$	1.55	0.21
Second-deferred	$H_0\!:\!b_1 = b_2 = b_3 = 0$	2.67	0.06

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