Are Livestock Futures Prices Rational Forecasts?

J. S. Shonkwiler

A measure for evaluating whether live hog and cattle futures prices represent rational forecasts is presented. It is assumed that the mechanisms which generate rational price forecasts possess the same stochastic properties as the cash prices with which they are associated. Using empirical data, tests are constructed which suggest that for contracts more than two months from maturity the rationality hypothesis is generally rejected. These findings are related to other studies of futures performance and the livestock markets.

Key words: autoregressive models, forecasts, futures markets, livestock, rationality.

Recently several people have tested whether livestock futures markets are efficient and whether they are accurate in forecasting cash prices at contract maturity. A paper by Leuthold and Hartmann and comments by Pasour and Panton considered the efficiency issue. Papers by Leuthold, Just and Rausser, and Martin and Garcia addressed the forecasting issue. While these studies are valuable, they raised as many questions as they answered.

An additional question of performance with livestock futures is whether or not futures prices are rational forecasts. That is the topic of this paper. In general, a rational forecast is the best (in a mean square error sense) that can be made using all available information (Modigliani and Shiller). One way to test this rationality hypothesis is to find out if futures market prices have the same stochastic properties as the cash prices with which they are associated. Because the assumption of rationality automatically imbues agents with knowledge regarding the structure and operation of a market, it is important to consider whether this maintained hypothesis can be tested within the structural model which is used to perform the analysis. It may be more reasonable to carry out such testing in a reduced form rather than in a structural system. Lovell supports the view that direct testing of the rationality hypothesis in simple, disaggregated relationships is a worthwhile activity. For this reason a forecasting criterion is adopted.

To put this approach into perspective, the following section briefly reviews futures market efficiency tests and forecasting performance. Next, a rational forecasting mechanism is developed and empirical models presented for live hog and cattle markets. The discussion concludes with test results and possible implications.

Previous Studies

Tests of market efficiency (Leuthold and Hartmann) determine whether or not a market uses all available information in the price formation process. This requires a model of how market equilibrium is achieved. Fama identifies a major problem with this requirement:

Any test is simultaneously a test of efficiency and of assumptions about the characteristics of market equilibrium. If the test is successful—that is, if the hypothesis cannot be rejected—then this also implies that the assumptions about market equilibrium are not rejected. If the tests are unsuccessful, we face the problem of deciding whether this reflects a true violation of market efficiency . . . or poor assumptions about the nature of market equilibrium.

This criticism does not invalidate the work of
Leuthold and Hartmann, but it suggests that different models may produce different results. Because there is no general agreement about equilibrium models for determining market prices, results will not be uniform. Moreover, Leuthold and Hartmann generate no statistically testable hypotheses.

The price performance tests with futures markets may be divided into two approaches. One method regresses subsequent cash market prices on associated futures prices observed one or more periods previously. This approach generates tests of the regression’s intercept and slope coefficients to determine if they differ significantly from zero and one, respectively. If they do not, then the futures market price is said to be an unbiased and optimal forecast of the subsequent cash price (Martin and Garcia). Leuthold and Hartmann argue that such studies lack a norm for comparing performance results. Grossman (1977) regards as controversial the empirical issue of whether the futures price is an unbiased predictor of subsequent cash prices. Further, in a two-period model of a rational expectations market equilibrium, Danthine shows that the futures price is not an unbiased estimate of future cash prices.

The second price performance approach is to evaluate the mean square error of futures prices as forecasts of cash prices at maturity. This approach yields no statistically testable hypotheses, and results may be much affected by the forecast interval chosen. Dewbre even suggests that forecasting accuracy itself is a questionable performance criterion because forecasts of future cash prices are likely to be highly inaccurate for anything but the shortest time horizons due to the fact that information is randomly available to the market.

Rational Forecasts

The rational forecast concept stems from Muth’s notion of rational expectations requiring that all available information be taken into account when market participants make decisions. Rationality of expectations requires that

$$E[P_t - P_{t-1} | \Omega_{t-1}] = 0$$

where $E$ is the expectation operator, $P_{t-1}$ is the previous period’s expectation of the subsequently realized variable $P_t$, and $\Omega_{t-1}$ is the information available when the expectation was formed.

Expectations are typically unobservable, so a model of a market’s operation is required to generate the rational expectations. Modigliani and Shiller suggest a means to determine whether observed expectations or forecasts, e.g., futures market prices, are rational. They maintain that if forecasts are rational (or economically rational in the sense of Feige and Pearce), they should be generated by the same stochastic process as the underlying series. For example, let the best one-period-ahead forecast of a stochastic series be denoted by

$$\hat{P}_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + \ldots + a_k P_{t-k}.$$ 

Here the coefficients, the $a_i$'s, are selected to minimize the square of the expected forecast error. The distributed lag on past prices arises quite naturally if $P_t$ is being generated by an infinite moving-average error process (Box and Jenkins).

The counterpart to the model in (1) is the revealed market expectation or forecast which may be related to previous realizations via

$$P_{t-1} = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 P_{t-2} + \ldots + \alpha_k P_{t-k} + u_t.$$ 

Modigliani and Shiller maintain that forecasts are rational if the revealed expectation, $\hat{P}_{t-1}$, is the best possible forecast of $P_t$ conditional on all information available at time $t - 1$. To determine whether the forecast takes into account information about the stochastic mechanism generating the realized series, they propose the test that the slope coefficients in (2) are not significantly different from the corresponding coefficients in (1). Hence, Modigliani and Shiller provide both a norm, i.e., rationality, and a test with which to analyze market forecasts.

To implement the test for rationality for forecasts a (univariate) distributed lag model which explains the evolution of the actual series under investigation must be specified. Fitting a distributed lag model can lead to “mining” the data (Pesando), thus the use of time-series procedures to identify a parsimonious autoregressive model appears to be a workable approach (Box and Jenkins).

A difficult conceptual problem with the autoregressive modeling approach is that the information set used to forecast appears artificially limited. Clearly, other information exists
which may improve the forecast. However, Shiller has shown that even if such additional information exists, the test of equality of slope coefficients between (1) and (2) is a necessary condition for rationality of forecasts. Pesando explains this point by stating that this result is due to the fact that all "other" information that is collinear with the realizations of the series will be incorporated into the distributed lag coefficients, while the uncorrelated remainder will represent—a purely stochastic error term.

A final technical consideration is that if other information besides lagged values is used by market participants to forecast $P_t$, then the model disturbances could be correlated with lagged $P_t$. Mishkin notes that under these circumstances the estimated regression coefficients are not consistent, but he points out that the restrictions imposed for the rationality test would still be valid because each set of coefficients would suffer from identical bias. In other words, the rationality assumption has implications only about the equality of the coefficients.

**Analyzing Livestock Futures Market Prices**

Having established the framework for evaluating forecast rationality, empirical tests of live hog and cattle futures market prices are now developed. Live hog and cattle futures have contract delivery dates of February, April, June, July (hogs), August, October, and December. Ignoring the July contract for hogs, these futures contracts may be considered as bimonthly expectations or forecasts of subsequent cash prices. Mid-month settlement prices for the six delivery months were hypothesized to reflect the same information as embodied in the corresponding monthly cash prices. Thus, bimonthly univariate autoregressive models are required for the associated cash series.

Seven-market barrow and gilt prices and Omaha choice steer prices were collected for the months associated with the six contract delivery dates above. That is, monthly averages for February, April, June, August, October, and December cash prices for both series were used. A total of seventy two observations from the October 1969 to the August 1981 period were available. The hog $(H)$ and cattle $(C)$ price series were first differenced to achieve stationarity, and the autocorrelation and partial autocorrelation functions for these series were analyzed. This latter function was particularly useful in determining appropriate lagged responses (Box and Jenkins, p. 175). Parsimonious models were selected and compared to "overfitted" models to test model adequacy. The estimated models are presented in table 1.

The simple autoregressive model in table 1 appears to fit the sample data well and is quite successful at generating uncorrelated residuals, as evidenced by the small Box-Pierce statistics. In order to satisfy the stationarity condition that permits representation of each series as an infinite moving-average error process, the complex roots associated with the polynomials in the lag operators must have moduli greater than one. Table 2 presents the derived roots and associated periodicities. It is interesting to note that for hogs there are several cycles of less than a year in duration and one cycle of 28.5 months (2.4 years) duration. This longer cycle corresponds closely to the 2.49 cycle discovered by Plain and Williams using weekly data from the 1970s and may further support the contention by some that the hog cycle has gotten shorter in recent years (Shonkwiler and Spreen). The cattle series reveals only annual and semiannual cycles, which appears reasonable considering that the period analyzed is too short to pick up the longer cattle production cycles.

It is now a straightforward matter to test the rationality postulate for one-period-ahead forecasts. However, in the case of two-period-ahead forecasts, the form of expression (2) must change because $P_{t-1}$ is not known. The appro-
Table 2. Roots of the Estimated Autoregressive Models and Implied Periodicities

<table>
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<tr>
<th></th>
<th>Roots</th>
<th>Moduli</th>
<th>Periodicities</th>
</tr>
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<tbody>
<tr>
<td>Hogs</td>
<td>.3002 ± 1.004i</td>
<td>1.05</td>
<td>9.82 mo</td>
</tr>
<tr>
<td></td>
<td>-5233 ± .9924i</td>
<td>1.12</td>
<td>6.11 mo</td>
</tr>
<tr>
<td></td>
<td>.9699 ± 4580i</td>
<td>1.07</td>
<td>28.5 mo</td>
</tr>
<tr>
<td></td>
<td>-1.287 ± 4201i</td>
<td>1.35</td>
<td>4.45 mo</td>
</tr>
<tr>
<td>Cattle</td>
<td>.7536 ± 1.268i</td>
<td>1.48</td>
<td>12.1 mo</td>
</tr>
<tr>
<td></td>
<td>-7536 ± 1.268i</td>
<td>1.48</td>
<td>5.96 mo</td>
</tr>
</tbody>
</table>

The appropriate model for representing the expected price is

\[ P_{t-2} = \gamma_0 + \gamma_1 P_{t-1-2} + \gamma_2 P_{t-2} + \ldots + \gamma_r P_{t-r} + v_t \]

where the futures price \( P_{t-1-2} \) is substituted for \( P_{t-1} \). This substitution simply recognizes the fact that if current and lagged realized prices have a given temporal relationship, this relationship should be followed by their associated forecasts if they are to be considered rational. In general, the \( j \)th period test is given by estimating the model

\[ P_{t-j} = \delta_0 + \delta_1 P_{t-1-j} + \delta_2 P_{t-2-j} + \ldots + \delta_r P_{t-r-j} + w_r. \]

The appropriate test is generated then by comparing the unrestricted sums of squared errors (SSE) for the models in (1) and (4) to the restricted SSE obtained by restricting corresponding parameters to be equal across equations (Chow). However, if the variances of the unrestricted models are different the \( F \)-test is affected (Toyoda). Thus, an iterative procedure was used to weight the individual regressions so their estimated variances were within one percent.

The Empirical Results

Table 3 presents the resulting \( F \)-statistics and associated probabilities calculated for futures price forecasts of up to ten months. Forecasts over eight months for hogs and over ten months for cattle were not evaluated because trading in the more distant contracts has not been very active, particularly during the early part of the sample period. For the case of the live hog futures market, it is quite apparent that forecasts of four or more months are not rational, i.e., they do not reflect the observed patterns of the original series. In the case of live cattle futures, the results are mixed. As the forecast horizon lengthens, cattle futures prices represent less rational forecasts except for the eight-month period. Here, the futures price eight months prior to maturity was found to have a large residual sum of squared errors, so imposition of the restrictions did not increase the SSE relatively.

Are live hog and cattle futures rational forecasting mechanisms? Certainly for forecasts two months from maturity the rationality of futures prices cannot be rejected at conventional probability levels. More distant contracts evidence strong departures from rationality for hogs. This may in part be due to the (complex) stochastic mechanism which generates hog prices. Recall that a number of price cycles were operating in this market. In the case of cattle, the evidence of departure from rationality is not uniform across contracts. The two- and eight-month contracts show that the rationality postulate can be rejected at the .141 and .126 levels, respectively. However, in terms of the much simpler stochastic model to which these futures had to correspond, perhaps such a stringent test is not necessary.

Implications

In terms of other studies, Martin and Garcia conclude that cattle and hog futures are suspect in their roles of rational price formation agencies. Though, again, the informational requirements needed for a rational expectations equilibrium need to be considered when evaluating rationality (Pesando; DeCanio).

Rational forecasts may not be feasible if the returns to market participants from allocating resources to collecting and analyzing market information are insufficient. Grossman (1981), however, provides a partial resolution. Speaking of the rationality condition, he indicates...
that the information requirements it makes on traders are no different than those of distributed lag models which only "... assume that traders know the stochastic process generating prices and use this knowledge in their decision process" (p. 545). He notes that in a rational expectations equilibrium traders do not necessarily need to know anything about the structural form of the market, rather they "need only to know the relationship between price and the stochastic factors which determine output" (p. 541). Such assumptions further establish that the approach taken provides an appropriate and useful framework for analyzing future prices.

Conclusions

Using recent data, it must be concluded that live cattle and hog futures prices do not serve uniform roles as rational forecasting agencies. The departures from rationality observed suggest that traders are ignoring certain types of information concerning the evolution of actual market prices. Given these departures, one is left with the question of what information is contained in the future prices. First and foremost, the series provides a forward price alternative to a market that is showing increasing evidence of thinness in the traditional cash markets (Williams, pp. 85–93). The hedger can assess these price levels against his cost and then judge the merits of the fixed forward price. Such decisions are made without concern for the expectation of latter prices. Second, the signals for the distant contracts must be judged with care since the underlying processes do not correspond with the cash series. Given the changes toward formula pricing, more direct buying, and fewer published cash prices, one must question whether the reported cash series are truly reflecting all market information. Thus, the test used may be without merit. However, the fact that monthly average cash prices were analyzed (as opposed to daily cash prices) weakens this criticism.

These findings further suggest irrationality under the maintained hypothesis that the market structure is stable. If, on the other hand, the market structure itself is evolving, then the conditions for rational forecasts cannot be met because past stochastic patterns will not necessarily be followed in future periods. For example, if the duration of the hog cycle or seasonality of hog slaughter are changing due to larger scale operations, farrow-to-finish enterprises, and confinement operations (Hayenga et al.; Shonkwiler and Spreen), then the value of imposing economically rational expectations diminishes.

The analysis assumed that the economical use of information requires knowledge of only the past behavior of the observed series. While this method provides a useful approach and easily tested hypotheses, the findings are not an end in themselves. Rather, the methodology presented should be used as a starting point and stimulus to the further analysis of futures market operations.

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References


