TOWARD A PERFORMANCE EVALUATION OF THE CARCASS BEEF MARKET — WEAK FORM TEST OF THE EFFICIENT MARKETS MODEL

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Concern has been expressed by many people, from producers to consumers, regarding the adequacy and accuracy of reported wholesale carcass beef prices and their use in pricing slaughter cattle and beef. The controversy has generated numerous government investigations and lawsuits beginning at least as early as the mid-1960s (General Accounting Office, 1977, 1978; National Commission on Food Marketing). Despite the decade and a half of criticisms about cattle and beef pricing and price reporting, and the importance of the carcass beef market to the cattle and beef subsector, agricultural economists have devoted surprisingly few resources to analyzing carcass beef market performance.

This article reports on initial effort to evaluate performance of the carcass beef market by applying weak form tests of the efficient markets model to the market for carcass beef. Results suggest more research is needed for full appraisal of carcass beef market performance. Therefore, a secondary objective of the article is to encourage further research, theoretical and applied, by agricultural economists in the area of marketing and pricing performance.

PROBLEM AND IMPORTANCE

Carlot carcass beef sales were an estimated 48.6 percent of all steer and heifer carcass sales for a one-month study period in 1977 (Packers and Stockyards Program, 1978). An estimated 14.8 percent of carlot steer and heifer carcass sales was reportable to one of the three price reporting services, i.e. two private price reporting firms and one public agency (Agricultural Marketing Service, U.S. Department of Agriculture).[1] Only a portion of reportable sales were actually reported by any of the three reporting services, however. Reported steer and heifer carcass prices represented an estimated 1.7, 1.6, and 4.6 percent of all federally inspected steer and heifer slaughter for the two private and one public price reporting services, respectively, during the period studied.

The carcass beef market therefore is a thinly reported market (Hayenga et al.). Expressed concerns about cattle and beef pricing and price reporting are related to implications of thin market characteristics. The two primary concerns are whether reported prices accurately reflect supply and demand conditions and whether reported prices are manipulatable at the expense of cattle producers and beef consumers.

One private price reporting firm (The National Provisioner, Inc.) reports carlot carcass beef prices daily and is a near-monopolist. Unlike prices reported by the other two price reporting services, The National Provisioner's reported prices serve as a basis for formula pricing all classes of carcass beef (Ward). Packers and Stockyards Program (1978) found an estimated 70.0 percent of carlot steer and heifer carcasses were priced by formula, with price tied to a future reported price by The National Provisioner's *Daily Market & News Service*, the so-called "Yellow Sheet." Carlot carcass beef prices reported by The National Provisioner also serve as a starting point for meatpackers in developing a daily pricing policy or strategy for procuring live cattle (Ward). Reported carlot carcass prices for steers, heifers, and cows serve as base prices for specific types of cattle (sex, weight, quality grade, and yield grade), as well as a basis for determining differences from the base price for cattle of other sex, weight, quality grade, and yield grade. Reported prices have a potential direct one-to-one effect on meatpackers' pricing policies, and thus a significant effect on bids to cattle producers and transaction prices for cattle traded.

EFFICIENT MARKETS MODEL

Fama (1970) states, "A market in which prices always 'fully reflect' available information is called 'efficient'." Empirical tests of the efficient markets hypothesis (that prices fully reflect all available information) are categorized into weak form, semistrong form, and strong form tests, each utilizing a different

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[1]The subclass of reportable trades omits carcasses not priced by private negotiation, carcasses not USDA quality graded, carcasses priced higher because of special trim, delivery, or selection, and carcasses priced lower because of carcass damage (Packers and Stockyards Program, 1978).

information set. Each is progressively more rigorous and aids in determining the level of information at which the efficient markets hypothesis is rejected.

Weak form tests employ historical prices as the information set and much of the previous empirical work involved testing the random walk hypothesis. Bachelier in 1900 first stated and tested the random walk hypothesis, assuming successive stock price changes were independent and normally distributed. Empirical work focused on testing the independence and distribution assumptions.

Tests of the efficient markets hypothesis require specification of the price formation process. Working (1959) argues that prices are formed by market participants searching for available public and private information to guide them in making decisions which ultimately result in market prices. The price formation process for the price expected in the next period begins with the current price because in an efficient, competitive market the current price reflects information from events which occurred in the past and which are expected to occur in the future (Fama, 1965; Working, 1959). New information affects future prices to the extent that the new information differs from what was previously expected. Next period's price adjusts to the influx of new information that affects the current price and has entered the market since the current price was formed.

In the case of a random walk market, the expected price in the next period, given the sequence of past prices (the information set), is the current price (Fama, 1965). Price changes only occur with the influx of new information. If the introduction of new information into the market is independent through time (random), then price changes are independent of preceding price changes (Moore). If new information enters the market frequently and in "small bits," successive price changes also will be normally distributed. In an efficient, competitive market, competition causes new information to be reflected instantaneously in current prices (Fama, 1965). Though current prices initially may over or under adjust to new information, the length of the lag period for complete adjustment is itself independent.

Semistrong form tests utilize an information set of other publicly available information and are concerned with the speed with which prices adjust to specific, public information. Individual tests examine the price adjustment to one kind of information-generating event (e.g., Leuthold and Hartmann; Miller).

"The strong form efficient markets model, in which prices are assumed to fully reflect all available information, is probably best viewed as a benchmark against which deviations from market efficiency (interpreted in its strictest sense) can be judged" (Fama, 1970). Strong form tests determine whether certain market participants have monopolistic access to information that is relevant to the price formation process.

PREVIOUS EMPIRICAL EVIDENCE

Studies applying any of the three types of tests to the efficient markets hypothesis are most numerous for capital markets (stocks and treasury bills; Fama, 1970) and commodity futures markets, primarily for agricultural commodities (e.g., Leuthold and Hartmann; Mann and Heifner; Miller). Tests of the efficient markets hypothesis for agricultural spot markets are few and are only of the weak form type.

Kendall in 1953 first tested the random walk hypothesis for an agricultural spot market. He constructed first differences of weekly and monthly Chicago spot wheat price series, arguing that the price change rather than the absolute price level was of primary concern in price formation. His analysis of serial correlations suggested that a series of speculative prices can be described by the random walk model. The distribution of first differences appeared approximately normally distributed but was somewhat leptokurtic, indicating a higher than expected proportion of large price changes.

Kendall's results for monthly New York spot cotton prices differed from results for spot wheat prices in that cotton price changes were serially correlated. Later study by Working (1960) and Alexander showed that Kendall's procedure of averaging daily prices to form a monthly price series introduced an element of serial dependence into the series. Working concluded that, after accounting for the averaging procedure, there was no clear evidence the two price series behaved differently.

Houthakker and Mandelbrot independently studied the logarithms of daily spot cotton price changes. Houthakker concluded from his work and that of others that the prices in speculative markets behave randomly. Both Houthakker and Mandelbrot found the distribution of logarithms of cotton price changes to be nonnormally distributed. Cotton price change distributions were found to be leptokurtic, having more very small and more very large price changes than are expected in a normal distribution.

EMPIRICAL ANALYSIS — CARCASS BEEF MARKET

Statistical tests were used to determine whether the daily changes of the logarithms of prices for selected carcass beef classes were serially independent, and whether the first difference series were normally distributed.[2] Data were the unweighted averages of daily closing carlot prices reported by The National Provisioner's *Daily Market & News Service* for 11 beef carcass classes from July 19, 1976 to November 16, 1979 (843 trading days). Carcass classes selected included eight combinations of weight, quality grade, and yield grade for steer and heifer carcasses and three quality grades for cow carcasses, thereby representing the most often traded beef carcass classes.

Test for Normality of the Distribution

The distribution of price changes is important because the distribution affects the applicability of certain statistical tools and the interpretation of test results of the efficient markets hypothesis (Fama, 1970). First differences of the natural logarithms of daily prices were constructed,

$$(1) \quad PD_{i,t} = LnP_{i,t} - LnP_{i,t-1}$$

where $PD_{i,t}$ is the price difference of the i^{th} carcass class in period t and $LnP_{i,t}$ and $LnP_{i,t-1}$ are the natural logarithmic transformation of prices of the i^{th} carcass class in periods t and $t-1$, respectively.

Two tests for kurtosis were applied to each first difference series. The first was a direct test (Snedecor and Cochran),

$$(2) \quad b_2 = \frac{M_4}{(M_2)^2}$$

where b_2 is the estimate of kurtosis and M_2 and M_4 are the second and fourth moments about the mean of the distribution, respectively. Expected value of b_2 assuming normality of the distribution is 3. Critical value of b_2 for a one-tailed test with 750 observations is 3.48 at the .01 significance level.

The second test for kurtosis was a modified

TABLE 1. RESULTS OF TESTS FOR KURTOSIS AND SERIAL DEPENDENCE OF THE FIRST DIFFERENCES OF THE NATURAL LOGARITHMS OF DAILY PRICES FOR ELEVEN CARCASS BEEF CLASSES, JULY 19, 1976 - NOVEMBER 16, 1979

TABLE 1. RESULTS OF TESTS FOR KURTOSIS AND SERIAL DEPENDENCE OF THE FIRST DIFFERENCES OF THE NATURAL LOGARITHMS OF DAILY PRICES FOR ELEVEN CARCASS BEEF CLASSES, JULY 19, 1976 - NOVEMBER 16, 1979

Carcass Class	Observations	Tests for Kurtosis		Tests for Serial Dependence						
				Turning Point Test			Phase Length Test			
		Direct Test (b_2 value)[a]	Modified Kolmogorov-Smirnov D Statistic (D value)[b]	Number of Turning Points: Observed	Number of Turning Points: Expected	Computed Test Statistic (χ_1^2)[c]	Phase Length	Number of Phases: Observed	Number of Phases: Expected	Computed Test Statistic (χ_2^2)[d]
Steer beef										
Choice quality grade, Yield grade 3, 600-700 lbs.	791	4.31	0.23	368	526	141.66	1	149	328	185.68
							2	103	144	
							≥3	115	52	
Choice quality grade, Yield grade 3, 700-800 lbs.	788	4.09	0.22	379	524	140.76	1	166	327	170.94
							2	97	144	
							≥3	115	52	
Choice quality grade, Yield grade 4, 700-800 lbs.	807	5.31	0.26	354	537	186.40	1	158	335	211.30
							2	80	147	
							≥3	121	53	
Good quality grade (top half), 600-700 lbs.	769	6.57	0.35	291	511	282.31	1	119	319	223.82
							2	66	140	
							≥3	106	51	
Holstein, 600-700 lbs.	726	11.51	0.42	212	483	454.28	1	96	301	262.27
							2	26	132	
							≥3	89	47	
Heifer beef										
Choice quality grade, Yield grade 3, 600-700 lbs.	804	6.15	0.27	378	535	137.70	1	163	334	194.63
							2	93	147	
							≥3	121	53	
Choice quality grade, Yield grade 4, 600-700 lbs.	796	6.24	0.31	324	529	236.84	1	135	330	283.74
							2	62	145	
							≥3	126	49	
Good quality grade (top half), 500-700 lbs.	782	5.52	0.30	320	520	229.60	1	141	324	208.16
							2	68	144	
							≥3	110	52	
Cow beef										
Utility quality grade, breaking type	701	6.01	0.41	178	466	530.94	1	73	291	310.66
							2	13	128	
							≥3	91	46	
Utility quality grade, boning type	771	5.09	0.30	332	513	190.84	1	158	320	186.88
							2	65	141	
							≥3	108	51	
Canner and Cutter quality grades	750	5.43	0.31	291	499	229.07	1	136	311	212.04
							2	50	137	
							≥3	104	50	

[a] Critical values of b_2 at the .01 significance level for n = 701 and 826, respectively, are 3.50 and 3.45.

[b] Modified D values were significant at the .01 level.

[c] Critical value of χ_1^2 at the .01 significance level is 6.6.

[d] Critical value of $\chi_{2\frac{1}{2}}^2$ at the .01 significance level is 6.3.

[2] Use of changes in the logarithms of prices is common in the random walk literature (Fama, 1970). Osborne based the rationale for using natural logarithms on the statistical precept that an equal interval of the independent variable should have equal psychological significance to be most meaningful. An example paralleling one given by him is that a change in the carcass beef price from $40 to $41 per cwt will be nearly equal in psychological significance to a price change from $80 to $82 per cwt because each is a 2.5 percent change.

Kolmogorov-Smirnov D statistic (Hoel; Stephens),

$$\text{(3)} \quad D_n = \max | F(x) - S_n(x) |$$

where D_n is the maximum value of an upper and lower step function of an ordered sample (x), F(x) is the known distribution function, and S_n (x) is the sample distribution function.

All 11 first difference series exhibited leptokurtosis with either of the two statistical tests, thus indicating they do not conform to the normal probability distribution (Table 1). Both tests were statistically significant for all carcass classes at the .01 significance level.

Test for Serial Independence

Use of nonparametric statistical tests for subsequent tests on the first difference series was appropriate because price change distributions deviated from the Gaussian (normal) distribution. Two tests were applied to the 11 first difference series to test for serial dependence in successive price changes. The first test compared the number of observed turning points (peaks and troughs) with the number expected in a random series (Kendall and Stuart). A peak is a value greater than the preceding and succeeding values in a series and a trough is a value smaller than the preceding and succeeding values in a series. The expected number of turning points in a random series is

$$\text{(4)} \quad E(p) = 2/3\,(n-2)$$

where E is the expected value operator, p is the number of turning points, and n is the number of observations in the price change series. As n increases, expected number of turning points increases.

The second test was a phase length test, comparing the observed distribution of phases of length d with the distribution expected in a random series (Kendall and Stuart). A phase length is the length of the interval (number of price changes) between two turning points. The expected number of phases of length d is

$$\text{(5)} \quad E(N_d) = \frac{2(n-3-2)\,(d^2+3d+1)}{(d+3)!}$$

where E is the expected value operator, N_d is the number of phases N of length d, and n is the number of price change observations. Kendall and Stuart suggest testing the observed versus expected number of phases with a three-way classification of phases of lengths one, two, and greater than or equal to three. The test statistic is a χ^2 with 2.5 degrees of freedom.

Turning point and phase length tests indicate successive price changes are serially dependent (Table 1). Observed turning points are in excess of three standard deviations fewer than the number expected for each carcass class. Observed turning points range from 38.2 to 72.3 percent of the number expected. The hypothesis of independence is rejected for each first difference series.

Phase length test results are similar. Phases of lengths one and two occur less frequently than the number expected in a random series (Table 1), and phases of length three or more occur more frequently than expected. Observed phases of length one range from 25.1 to 50.8 percent of the number expected; phases of length two, 10.2 to 71.5 percent; and phases of length three or more, 189.4 to 257.1 percent. Maximum observed phases of lengths 14 to 34 are found for the 11 price change series but, given the number of observations, phases of length five are the maximum expected in a random series. The hypothesis of serial independence for each first difference series is rejected.

EVALUATION AND IMPLICATIONS

First difference series for carcass beef classes could be expected (*a priori*) to behave randomly on the basis of previous studies of speculative spot agricultural commodity prices by Kendall, Working (1960), Alexander, and Houthakker. The distribution of first differences could be expected to be nonnormal on the basis of studies by Kendall, Houthakker, and Mandelbrot.

Evidence reported here rejects the random walk hypothesis. Carcass beef price changes exhibit serial dependence, unlike results of previous studies of spot agricultural commodity prices, and are nonnormally distributed, similar to previous findings.[3] Rejection of the random walk hypothesis, however, does not necessarily mean rejection of the efficient markets hypothesis (Fama, 1970; Samuelson). Results suggest some degree of market inefficiency in the carcass beef market and raise questions regarding market behavior.

The importance of whether a price series is normally distributed relates to the applicability of certain statistical price analysis tools to those data (Fama, 1970; Mann and Heifner). Failure of the data to conform to the assumption that data are normally distributed with finite variance requires researchers to make methodological adjustments, either transforming the data to approximate a normal distribution or employing nonparametric statistical tests as was done in this study.

[3] Test results are the same when untransformed price change data are used.

Nonnormality of the distribution carries an implication for market participants. A leptokurtic distribution usually has more small and more large price changes than are expected in a normal distribution. Thus, as Kendall noted, the best estimate of a price change in the next period is a zero price change. The probability of a zero daily price change for the 11 carcass beef classes examined ranges from .391 to .775.

The independence assumption is important because of the implications that can be drawn regarding market price behavior and the price formation process. Working (1949) indicated that the absence of objectionable error in expected prices requires random price changes.[4]

Serial dependence suggests some degree of predictability in price changes is possible. Bachelier noted a phenomenon in the stock market which Working (1959) discussed in his theory of price formation—that some market participants tend to follow the market rather than respond to supply and demand forces. This "market psychology" refers to market participants reacting in a way that exacerbates a given market situation rather than responding in the manner suggested by the laws of supply and demand. For example, assume price declines in the current period from the previous period. Some market participants will offer more rather than less for sale in the succeeding period, anticipating further declines, and causing price to decine further (*ceteris paribus*), contrary to the law of supply. Such market behavior causes a built-in dependence in price changes. Working assumes the presence of only a few inept market participants, and consequently relatively little of this type of behavior.

Working (1959) and Moore comment on another source of dependency—large price changes occur gradually. Gradualness results in limited short-run predictability in price changes. It occurs because of the time required for information to spread among all market participants, for them to assess its significance and react accordingly, and for market price to adjust appropriately. Both authors imply that large price changes should occur infrequently and small price changes should occur frequently. Carcass beef price series have more large and small price changes than are expected in a random series. Daily price changes are found to be greater than plus or minus 25 cents per cwt more than 50 percent of the time for only two carcass beef classes. Large daily price changes (more than three standard deviations of the mean) range from plus or minus \$2 to \$6 per cwt for the 11 carcass classes.

The manner in which new information enters the market bears on whether prices fully reflect all information. Ward found private information to be significant in beef marketing and pricing decisions. Such information is not generally available to all market participants, and thus market prices (transaction prices and reported prices) may not reflect privately exchanged information. Some information may be introduced erroneously. Beef salespersons noted that information from private sources must be cross-checked for accuracy. Reaction to erroneous information may cause exaggerative bias in market expectations, a source of objectionable error (Working, 1949). This effect is especially important if reported prices are based on erroneous information and fail to reflect actual supply and demand conditions.

Some types of information (private and public) enter the market nonrandomly, e.g. The National Provisioner's *Daily Market & News Service* and the U.S. Department of Agriculture's daily livestock receipts at selected markets. Other types of information, especially privately exchanged information, enter the market more nearly as a random variable, e.g. the specific supply and demand positions of certain buyers or sellers. Information entering the market in a predictable manner and market participants reacting more to some information than to other both contribute to serial dependence. More reaction to information regarded as important and less reaction to small bits of information may explain why price changes for all carcass beef classes occurred more frequently in 50-cent per cwt than in 25-cent per cwt increments. This is similar to Osborne's lattice effect, implying that either market participants prefer to trade in 50-cent increments or that they react only to information sufficiently important to cause them to make a buying or selling change of at least 50 cents.[5]

The market structure of buyers and sellers for carcass beef differs from that assumed in either efficient markets or price formation theories. Instead of a large number of firms, no one of which can influence the total volume traded, the market structure is better characterized as an oligopoly facing an oligopsony (Marion et al.; Packers and Stockyards Program, 1979; Williams). The market structure may enable some firms to obtain market information and utilize it to their advantage before it becomes available to all market participants, thus causing market prices to reflect only information available to certain market participants.

The market structure, nature of how information enters the market, and serial dependence in carcass beef price changes combine to raise the question of whether some

[4]Objectionable error in market expectations is error in excess of "necessary inaccuracy" resulting from market participants responding to unpredictable changes in supply and demand.

[5]Price changes of plus or minus \$.50 and \$1 occur more frequently for each carcass class than price changes of plus or minus \$.25, \$.75, or \$1.25.

market participants can use information, especially historical price change behavior, to their advantage. Serial dependence and nonnormality imply that the application of technical trading tools may be appropriate for short-run price forecasting of carcass beef price changes because of a systematic element in historical price change data.

CONCLUSIONS

Statistical analysis rejects the hypothesis that carcass beef price changes behave as a random walk. Results suggest price changes do not fully reflect all available information entering the market since the preceding market period, but tests cannot show that the carcass beef market is inefficient. Several factors potentially explain why carcass beef price changes are found to be serially dependent, e.g. market psychology causing market participants to react contrary to the laws of supply and demand, gradual nature of large price changes, manner and predictability with which new information is disseminated and reflected in the market, and market structure of buyers and sellers.

Study results have implications for market participants and agricultural economists. For market participants, results indicate a relatively high probability of a zero or no more than 25-cent per cwt price change in the succeeding period. Systematic elements in historical price change series suggest technical trading tools may be applicable in forecasting daily price changes for carcass beef.

This study is an initial step toward evaluating performance of the carcass beef market. Thus further research is needed by agricultural economists for full evaluation of market performance. More study is required in several areas, e.g. frequency and randomness with which new information enters the market, dissemination of privately traded information, relative importance of and reaction to specific information by market participants, accuracy of reported prices, and market structure impacts on price behavior. Semistrong and strong form tests of the efficient markets model would aid in identifying market response to certain public information and in determining whether some market participants have monopolistic access to private market information. Finally, research is needed to determine the adequacy of efficient markets and price formation theories and alternative approaches to evaluating market performance.

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