THE PRICING EFFICIENCY OF AGRICULTURAL FUTURES MARKETS: AN ANALYSIS OF PREVIOUS RESEARCH RESULTS

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Abstract

The analysis examines quantitatively the findings of previous studies of the pricing efficiency of various agricultural markets using a logit framework. The findings provide insight into the importance of commodity characteristics, uncertainty, and testing procedures used on the results of past research of pricing efficiency. The study also identifies several areas for further research.

Key words: agricultural commodities, pricing efficiency, meta-analysis.

The pricing efficiency of agricultural futures markets has long been a question of interest and concern. Various authors have recognized that futures markets generate information on forward prices which producers and marketing firms use in making production, marketing, and inventory decisions. If these prices do not appropriately reflect expectations of supply and demand conditions, a misallocation of resources may result in a reduction in economic surplus (Stein).

Numerous research efforts have examined the pricing efficiency of agricultural futures markets. However, many of the studies differ with respect to the commodities examined, the time period and method of analysis, and the type of data employed in the analysis. In addition, there is a wide range of variability in the conclusions drawn. As a result, definitive statements regarding the efficiency of futures trading are difficult to make despite the available theoretical base for evaluating market performance.

The aforementioned literature regarding the pricing efficiency of agricultural futures markets has been widely reviewed. Kamara, for example, provides a useful review of the literature based on the hypotheses tested in each analysis, and the issues and concerns related to pricing efficiency. Such reviews identify and provide qualitative insight regarding the factors which might affect the outcome of tests of market efficiency. In order to generate a more definitive understanding regarding the efficiency of futures markets, quantitative measures may be useful. Few, if any, attempts have been made to quantitatively synthesize the results of the studies on the pricing efficiency of agricultural futures markets.

The purpose of this inquiry is to examine past studies on pricing efficiency of agricultural futures markets in a quantitative manner. The literature is reviewed and classified with respect to factors hypothesized to influence the outcome of tests of market efficiency. A logit framework is then employed to generate measures regarding the impacts of these factors on the conclusions of market efficiency tests. The results of the inquiry provide information regarding the importance of the factors which influence the efficiency of agricultural futures markets, while suggesting future research directions.

The paper is organized as follows. Methodological issues are considered in the second section. The third section summarizes the data, methods, and empirical procedures. The results of the analysis are presented in section four. The paper concludes with a discussion of conclusions and implications for further research.

METHODOLOGICAL ISSUES

The lack of research attempting to synthesize quantitatively the results of previous studies on market efficiency may be in part attributable to the lack of well-defined methods for generating such comparisons. The problem is similar to that faced by social scientists conducting research involving small groups of subjects. In response to this problem, the technique of meta analysis, or the statistical

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analysis of results from individual studies for the purpose of drawing more comprehensive inferences, has evolved in the social science literature (Barrilleaux-Pizzolatto and Chhokar). By pooling the results of individual studies, social scientists have been able to draw general conclusions based on the aggregated results.

Consistent with this framework, the pricing efficiency of agricultural futures markets is examined. The research literature on futures market efficiency centers around the notions of empirical assessment of weak form, semi-strong form, and strong form efficiency advanced by Fama.[1] In Fama's framework, all futures markets can be expected to be equally efficient. Yet the application of efficiency tests to agricultural futures markets has produced mixed results.

Several factors have been identified as potentially influencing the efficiency of well-balanced agricultural futures markets, including: (1) differences in the characteristics of the commodities and their markets; (2) quality of information and uncertainty about economic conditions on supply and demand; (3) specific nature of the tests employed; and (4) type of data used in the analysis.[2] By combining the results of different efficiency studies, it may be possible to provide insight to our understanding of the degree to which the above factors influence the pricing efficiency of agricultural futures markets. Further, in conducting such an aggregate analysis, the potential sources of bias and inconsistency in the research results may be illuminated, thereby paving the way for additional and more comparable research efforts. Finally, by examining the accumulated knowledge gleaned from individual research efforts, it may be possible to generate conclusions regarding the overall efficiency of futures markets. As noted by practitioners of meta analysis, "a single study will not solve a major issue, and if done on a small sample it will not even solve a minor issue" (Hunter et al., p. 10). Combining the results of various studies may enhance our understanding of the foundations of science.

It should be noted that this initial investigation via meta analysis is somewhat limited by the reporting of results in published studies. Unlike the social science literature where detailed reporting of results is commonplace, the futures research literature tends to feature only selected results. Nonetheless, the classification of these studies in a consistent manner should provide useful information.

DATA

The results of 38 studies on futures market efficiency were reviewed and classified to facilitate identification of the aggregate impacts of commodity type, time period, method of analysis, choice of test, and type of data on the outcomes of the analyses. The studies were first divided by type of analysis, namely forecasting and nonforecasting. Studies used in this research were published or reprinted between 1970 and mid-1985 and were drawn primarily from academic journals, USDA reports, and Chicago Board of Trade publications. Theses and university research bulletins were not included. The studies were selected through a review of journal indices and from the references cited in published pieces. Due to the vastness of the literature, it is likely that there were oversights. Nonetheless, the studies used in the analysis represent the more commonly recognized works on futures market efficiency for agricultural commodities.[3] The studies used in the forecasting and nonforecasting analyses are summarized by commodity, time period, method of test, type of data, and general conclusion in Tables 1 and 2, respectively.

The conclusions reached by the studies examined were broken down and categorized as specifically as possible based on the published results.[4] The number of observations used in

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[1]Following Fama, a speculative market is efficient if the current price "fully reflects" all available information and is the "best estimate" of future price. Three degrees of market efficiency have been distinguished according to the type of information that is fully reflected in the market price. A market is weakly efficient if the current price always completely discounts the information contained in past market prices. The semi-strong form of efficiency widens the scope to include all publicly available information. The strong form efficiency occurs when the market accurately discounts all information, including that held only by a small number of market participants.

[2]Kofi also suggested that the degree of government market intervention can influence the performance of futures markets. Findings of Tomek and Gray suggest the influence of government market intervention may be limited.

[3]There is one notable omission. The work of Mann and Heifner which examines the weak form efficiency of several futures markets prior to 1973 was not included in the analysis because the authors later reported computational errors (Leuthold and Tomek).

[4]The objective of the classification scheme used here was to identify as closely as possible inferences about efficiency related to the commodity, temporal, and method effects. Summaries of the assessment made for each study and the data used in the analyses can be obtained from the authors upon request.

TABLE 1. SUMMARY CLASSIFICATION OF FORECASTING STUDIES

Authors	Observations	Commodity[a]	Time Period[b]	Form of Test	General Conclusion
Bigman et al.	72	CW, C, SB	Seventies	Weak	Mixed
Canarella and Pollard	15	CW, C, SB, SBM, SBO	Pre-1973	Semi-strong	Efficient
Giles and Goss	13	LC, W	Seventies	Semi-strong	Mixed
Just and Rausser	64	CW, C, SB, SBM, SBO LC, LH, C	Seventies	Semi-strong	Mixed
Kofi	66	CW, C, SB, P, CC, CF	Pre-1973	Weak	Efficient
Kolb and Gay	15	LC	Pre-1973	Weak	Efficient
Koppenhaver	6	LC	Seventies	Semi-strong	Mixed
Leath and Garcia	22	C	Pre-1973 and Seventies	Weak	Mixed
Leuthold (1974)	36	LC	Pre-1973	Weak	Mixed
Leuthold and Hartmann (1979)	6	LH	Seventies	Semi-strong	Inefficient
Leuthold and Hartmann (1981)	3	LC,LH, PB	Seventies	Semi-strong	Mixed
Martin and Garcia	16	LC, LH	Pre-1973	Weak	Inefficient
Rausser and Carter	24	SB, SBM, SBO	Seventies	Semi-strong	Mixed
Spriggs	4	C	Pre-1973	Weak	Mixed
Tomek and Gray	3	C, SB, P	Pre-1973	Weak	Mixed
Total Observations	365				

[a]Commodities are: C = corn; CC = Cocoa; CF = Coffee; CW = Chicago Wheat; LC = Live Cattle; LH = Live Hogs; P = Potatoes; PB = Pork Bellies; SB = Soybeans; SBM = Soybean Meal; SBO = Soybean Oil; W = Wool.

[b]Defined based on where majority of observations occurred. See text for a discussion of the observations used in the analysis.

TABLE 2. SUMMARY CLASSIFICATION OF NONFORECASTING STUDIES

Authors	Observations	Commodity[a]	Time Period[b]	Type of Test	Type of Data	General Conclusion
Bigman and Goldfarb	3	CW, C, SB	Seventies	Non Distribution	Daily	Inefficient
Brinegar	6	CW, C, R	Pre-1973	Time Domain	Daily	Inefficient
Cargill and Rausser (1972)	21	CW, C, O, R SB, LC, PB	Pre-1973	Time, Frequency Domain	Daily	Mixed
Cargill and Rausser (1975)	24	CW, C, O, SB, LC, PB	Pre-1973	Time, Frequency Domain, Non Distribution	Daily	Mixed
Garrison	1	LC	Seventies	Time Domain	Daily	Efficient
Gordon	32	CW, C, RR, SB, LC, LH, CT, OJ	Eighties	Non Distribution	Daily	Mixed
Helms et al.	6	SB, SBM, SBO	Seventies	Non Distribution	Intraday, Daily	Inefficient
Helmuth	1	LC	Seventies	Non Distribution	Daily	Inefficient
Hunt	2	W	Pre-1973	Frequency Domain	Intraday, Daily	Inefficient
Labys and Granger	15	CO, P, E, CC, C, WF, L, SB, SBM, SBO, CT, R, O, WO, CW	Pre-1973	Frequency Domain	Monthly	Mixed
Labys and Granger	6	CO, CW, R, SB, SBO, SBM	Pre-1973	Frequency Domain	Monthly	Mixed
Labys and Granger	6	C, O, R, CW, L	Pre-1973	Frequency Domain	Weekly	Efficient
Labys and Granger	9	C, O, R, CW, S, RB, CT, CF, CC	Pre-1973	Frequency Domain	Daily	Mixed
Larson	4	C	Pre-1973	Time Domain	Daily	Efficient
Leuthold (1972)	1	LC	Pre-1973	Frequency Domain	Daily	Inefficient
Martell and Helms	21	CW, C, O, SB, SBO, SBM, IB	Seventies	Time Domain, Frequency Domain	Intraday	Inefficient
Martell and Phillippatos	2	CW, SB	Pre-1973	Non Distribution	Daily	Mixed
Peterson and Leuthold	1	LH	Seventies	Non Distribution	Daily	Inefficient
Pluhar et al.	1	LC	Seventies	Non Distribution	Daily	Inefficient
Smidt	3	R, SB	Pre-1973	Non Distribution	Daily	Mixed
Stevenson and Bear	6	CO, SB	Pre-1973	Time Domain, Non Distribution	Daily	Inefficient
Working (1977)	1	CW	Pre-1973	Time Domain	Intraday	Inefficient
Total Observations	172					

[a]Commodities are: C = Corn; CC = Cocoa; CO = Cottonseed Oil; CT = Cotton; CW = Chicago Wheat; E = Eggs; IB = Iced Broilers; L = Lard, LC = Live Cattle; LH = Live Hogs; O = Oats, OJ = Orange Juice, PB = Pork Bellies; R = Rye, RB = Rubber; RR = Rough Rice; S = Sugar; SB = Soybeans; SBM = Soybean Meal; SBO = Soybean Oil; W = Wool; WF = Winnepeg Flax; WO = Winnepeg Oats.

[b]Defined based on where majority of observations occurred. See text for a discussion of the observations used in the analysis.

the analysis from any study varied by the specifics reported. For example, the study by Tomek and Gary, which examined corn, soybeans, and potatoes, provides one conclusion on the forecasting efficiency for each commodity and therefore generated three observations for use in the analysis. Other studies reported results for varying forecast horizons and different tests employed. In general, each reported result that differed by one of the factors being examined in this study was treated as a separate observation. A total of 15 forecasting studies was examined which provided a total of 365 observations. The 23 nonforecasting studies generated a total of 172 observations. The number of observations in the forecasting studies exceeded the nonforecasting total primarily because of the forecast time to maturity dimension of this category and the tendency of the nonforecasting studies to report one conclusion for each commodity over the entire period of analysis.[5]

VARIABLE DEFINITIONS AND DISCUSSIONS

Qualitative variables were used to identify commodity groups, time periods, choice of test, methods of analysis, and type of data. The specific definitions of these variables are presented in Table 3. Four commodity groups were defined based on general commodity characteristics. Grain commodities were grouped together due to their common storability feature. Soybeans and related products (soybean meal and soybean oil) were separated from other grains because these markets tend to be thought of as more highly speculative (Peck). Livestock and livestock products were grouped together due to their limited storability and the expected differences in market performance associated with a lack of inventories. Commodities which did not fit into the grain, beans and products, or livestock categories were pooled in the "other" category. The most common feature of these commodities was their semi-storable nature.

TABLE 3. VARIABLE DEFINITIONS

Variable	Description
Forecasting and Nonforecasting Studies	
EFCONC	1 if authors concluded inefficiency; 0 otherwise
GRAINS	1 for grains, including corn, wheat, rye, oats, and flax; 0 otherwise
BEANS	1 for soybeans and products; 0 otherwise
LIVESTOCK	1 for livestock and products; 0 otherwise
OTHER	1 for other commodities (mostly semi-storable), including wool, lard, shell eggs, cotton, cocoa, coffee, cotton oil, potatoes, and sugar
PRE-SEVENTIES	1 if data period was pre-1973; 0 otherwise
SEVENTIES	1 if data period was 1973 through 1979; 0 otherwise
Nonforecasting Studies Only	
EIGHTIES	1 if data period was 1980 to 1985; 0 otherwise
FREQDOMN	1 if method of test was frequency domain; 0 otherwise
TIMEDOMN	1 if method of test was time domain; 0 otherwise
OTHERTEST	1 if method of test was not time or frequency domain (these included filter rules and nonparametric tests); 0 otherwise
DAILY	1 if the data analyzed were daily or intraday price observations; 0 otherwise
Forecasting Studies Only	
WEAKFORM	1 if type of test was a weak form test; 0 otherwise
SEMISTRONG	1 if type of test was a semi-strong form test; 0 otherwise
HORIZON	length of forecast horizon in weeks

[5]As suggested by a reviewer, this classification procedure can result in the findings being influenced by a few studies with a large number of observations. To minimize this effect, it is important to examine the distribution of the data across categories. Preliminary inspection of the data suggested a sufficiently balanced distribution of the findings for the categories specified. See footnote 8 for a discussion of the effect of an uneven data distribution.

The temporal aspects of the analysis of agricultural futures markets measure the behavior of these markets during periods of varying volatility and their forecasting accuracy as maturity approaches. Three time periods were defined based on expectations regarding market volatility and its impact on the measures of market efficiency. Specifically, it was hypothesized that markets were relatively efficient prior to 1973. The increased turbulence during the 1970s was expected to provide increased incidence of market inefficiency from 1973 through 1979. The period from 1980 to present was hypothesized to be more efficient than the 1973 through 1979 period.[6] For the forecasting studies, a continuous variable representing the forecast horizon was specified. The horizon variable was defined in terms of the number of weeks in the future for which the forecasts were made. This should account for the fact that the forecasting performance of futures markets may vary as the delivery month approaches and as traders have a greater degree of certainty about subsequent supply and demand.

The type of test and method of analysis may influence the results of market efficiency studies. As indicated, assessments of pricing efficiency commonly have been divided into weak, semi-strong, and strong form tests. Within this framework, the evaluations also may be classified into nonforecasting and forecasting categories according to the specific dimensions of the market examined (Kamara). Nonforecasting tests are concerned with the search for nonrandom characteristics of futures prices and are weak form in that only data from the particular series itself are used in the analysis. Forecasting studies evaluate the predictive accuracy of futures markets and may be either weak form or semi-strong form tests, depending upon the analytical approach and data used. Weak form forecasting tests assess the ability of past futures prices to predict subsequent cash prices, while semi-strong form tests compare the predictive accuracy of futures relative to some forecasting model which incorporates relevant public information.

Examination of the literature reveals a concern over the sensitivity of the findings to specific tests used in the analyses. This concern is manifested as much by the propensity of authors to use various approaches as by their discussion and interpretation of results (Kamara). As indicated, all of the nonforecasting studies involved weak-form tests. However, several different testing methods were used in the nonforecasting studies. Three method-of-test variables were defined to examine the impacts of frequency domain tests, time domain tests, and nondistributional tests. The latter category includes primarily nonparametric and filter tests. For the forecasting studies, variables for weak form and semi-strong form tests were defined.

Finally, the type of data used in the analysis appears to impact the conclusions, particularly for weak form tests. Most randomness studies have used day-to-day closing prices in their analyses. Notable exceptions are the work by Martell and Helms which examined characteristics of prices using intraday data and Labys and Granger which used weekly and monthly data as well as daily data. With shorter intervals, the results suggest higher levels of series dependence. As a result, a daily variable was defined to separate interday and intraday analyses from analyses with longer (weekly and monthly) sampling intervals.

METHODS AND EMPIRICAL PROCEDURES

Given the nature of the dependent variable, a conclusion of either efficiency or inefficiency, a qualitative choice model is used. Models of qualitative choice have been widely discussed in the literature.[7] Three qualitative choice models are available: the linear probability model, the probit model, and the logit model. The linear probability model is dismissed from consideration due to heteroskedasticity problems, the nonnormal distribution of the disturbance terms, and the potential for predicted probabilities outside the 0,1 interval (Capps and Kramer). The choice between the probit and logit models was based primarily on the concern that the normality assumption of the probit model is difficult to justify in econometric applications (Pindyck and Rubenfeld). Thus, the logit model was em-

[6]Studies were placed in the particular time period which most closely corresponded to the data used in the analyses. Limited work on the forecasting efficiency of futures markets has appeared in recent publications. Due to the lack of observations provided for the period beyond 1979, this time period is not considered in the forecasting analysis.

[7]See Capps and Kramer for a recent discussion and comparison of alternative qualitative choice models.

ployed in the analysis. In addition, research results suggest that "differences in empirical performance between the [probit and logit] models [are] indeed minimal" (Capps and Kramer, p. 58).

The logit models for the forecasting and nonforecasting studies were estimated using a maximum likelihood procedure with a convergence tolerance of .001. For both the forecasting and nonforecasting studies, one group in each category is dropped to avoid perfect collinearity. The categories which are dropped become the base against which comparisons are made. For both models, the grains are used as the base commodity group and the pre-1973 period is used as the base time period. The forecasting model uses the semi-strong form test as a base and also includes the horizon variable. The nonforecasting model uses the nondistributional tests and the non-daily data series as bases for the method of test and type of data, respectively.

Goodness-of-fit measures were calculated for each model, including Efron's R^2, MacFad-R^2, and the number of correct classifications. Efron's R^2 is simply the squared correlation coefficient between the observed dependent variable and the probabilities predicted by the fitted model. MacFadden's R^2 is computed as 1- $[L(B_{ML})/L(0)]$, where $L(B_{ML})$ is the maximum value of the log-likelihood function and L(0) is the value of the log-likelihood function subject to the constraint that all coefficients except the intercept are equal to zero. The number of correct classifications is computed using a 50-50 classification scheme (Amemiya).

EMPIRICAL RESULTS

The maximum likelihood estimates of the logit models, changes in probabilities, and summary statistics are presented in Tables 4 and 5 for the forecasting and nonforecasting studies, respectively.[8] The forecasting model satisfied the convergence criterion after four iterations. The likelihood ratio test indicates that a significant proportion of the variation in efficiency conclusions for forecasting studies is explained by the model. The model correctly classifies over 74 percent of the observations (Table 4).

TABLE 4. MAXIMUM LIKELIHOOD ESTIMATES AND SUMMARY STATISTICS FOR LOGIT MODELS, FORECASTING STUDIES

Variable	Parameter Estimates	Change in Probability[a]	t-Ratios
BEANS	.196	.006	.564
LIVESTOCK	2.233	.139	5.736
OTHER	−.136	−.006	−.266
SEVENTIES	3.488	.372	8.030
WEAKFORM	1.606	.074	3.960
HORIZON	.028		2.431
CONSTANT	−4.523		−6.013
Number of Iterations[b]	4		
Log of likelihood function	−181.533		
Likelihood Ratio Test[c]	141.822		
Sum of absolute errors	119.340		
McFadden's R^2	.281		
Efron's R^2	.347		
Studies correctly classified[d]	270 (73.98%)		

[a]Computed as the change in probability from the base (time horizon of 20 weeks). The sensitivity of the change in probability to varying time horizons is demonstrated in Figure 1.

[b]Convergence tolerance 0.001.

[c]Test for all slope coefficients equal to zero. The critical value is 12.59, a = .05, and 6 degrees of freedom.

[d]Based on a 50-50 classification scheme.

[8]A reviewer suggested the incorporation of a variable to ascertain the effect of post sample analysis on efficiency findings. Examination of this possible effect did not prove fruitful. Only one of the nonforecasting studies used a post sample assessment procedure. Inclusion of a zero-one variable in the forecasting analysis produced counterintuitive results. Inspection of the data revealed that the problem was related to an unbalanced distribution of the first sample variable across time periods, studies, and method of analysis. The finding emphasizes the need to obtain information from a range of representative studies for the issue under investigation.

The nonforecasting model also converged quickly, satisfying the convergence criterion after 5 iterations. The likelihood ratio test indicates that the model explains a significant portion of the variation in efficiency conclusions for the nonforecasting studies. The model correctly classifies over 84 percent of the observations (Table 5).

Forecasting Studies

The signs and size of the parameters, and the estimated probabilities provide an indication of the influence of the factors relative to the base described above. For example, the estimated coefficient for beans is positive, but not statistically significant, indicating that relative to grains no significant increase in the probability of finding inefficiency is associated with soybeans and soybean product markets. In contrast, the estimated coefficient for livestock is large, positive, and statistically significant. Relative to grains, the probability of finding inefficiency with forecasting tests increased by .14 when livestock and livestock product markets are examined.[9] The estimated coefficient for the other commodities group is negative but insignificant, suggesting no significant change in the relative probability of finding that inefficiency is associated with forecasting studies involving commodities in that group. These findings are consistent with expectations that livestock futures markets do not perform well as forecasting markets, and this may be the result of lack of storability and the potential for supply responses within the year (Purcell and Hudson).

The estimated coefficient for the time period from 1973 through 1979 is positive and significant. Relative to the pre-1973 period, the probability of identifying inefficiency through

TABLE 5. MAXIMUM LIKELIHOOD ESTIMATES AND SUMMARY STATISTICS FOR LOGIT MODELS, NONFORECASTING STUDIES

Variable	Parameter Estimates	Change in Probability[a]	t-Ratios
BEANS	.326	.079	.538
LIVESTOCK	1.218	.294	1.575
OTHER	−1.551	−.269	−2.272
SEVENTIES	1.633	.375	1.464
EIGHTIES	−3.904	−.380	−4.243
FREQDOMN	−.368	−.083	−.464
TIMEDOMN	−.228	−.053	−.272
DAILY	2.129	.453	3.322
CONSTANT	−.453		−.473
Number of Iterations[b]	5		
Log of likelihood function	−65.755		
Likelihood Ration Test[c]	96.572		
Sum of absolute errors	40.834		
McFadden's R^2	.423		
Efron's R^2	.495		
Studies correctly classified[d]	144 (83.73%)		

[a]Computed as the change in probability from the base.

[b]Convergence tolerance 0.001.

[c]Test for all slope coefficients equal to zero. The critical value is 15.51, α = .05, and 8 degrees of freedom.

[d]Based on a 50–50 classification scheme.

[9]In the forecasting case, the change in the probability is computed as a difference from the base (i.e., grains, pre-seventies, and semi-strong form test) for each qualitative variable separately at a forecast horizon of 20 weeks. In the nonforecasting case, the change in the probability simply reflects a difference from the base (i.e., grains, pre-seventies, nondaily data; and other test) associated with a particular qualitative variable.

forecasting tests increases by .37 when data from this period are used. This finding suggests that the period from 1973 through 1979 was characterized by futures markets which were poor forecasters. Such a result would be expected, given the changing nature of the agricultural markets during this time period, particularly the inflationary pressures (Irwin and Brorsen). As noted above there were no forecasting studies which covered the period from 1980–1985.

The weak form test variable is also positive and statistically significant. The probability of finding inefficiency through forecasting tests increases by .07 when weak form tests are used over semi-strong form tests. This finding was somewhat unexpected. Weak form tests generally are considered to be less stringent techniques for assessing efficiency. This result could suggest that weak form tests are less capable of distinguishing between necessary and objectionable error (Working, 1949). That is, during periods of uncertainty the futures market may fail the weak form forecasting test because of the necessary error associated with rapid and large changes in supply and demand. During these same periods, however, it also may be difficult to construct econometric models that "outperform" futures markets. Thus, the evidence may be suggesting that while futures markets appear to be inefficient forecasters from a weak form test perspective, their errors are more necessary than objectionable and that, on balance, these errors may be no more objectionable than available alternatives (Rausser and Just).

Finally, the horizon variable is positive and significant, indicating that as the forecast horizon is lengthened, the forecasting ability of the futures market declines. Sensitivity of a change in the forecast horizon is demonstrated in Figure 1. The positive relationship between the length of forecast horizon and inefficiency is consistent with previous research (e.g., Rausser and Just; Leath and Garcia).

Nonforecasting Studies

The signs of the parameter estimates for the nonforecasting studies are generally in line with expectations. For the commodity groups, beans and livestock are positive. Although neither is statistically significant, the latter in-

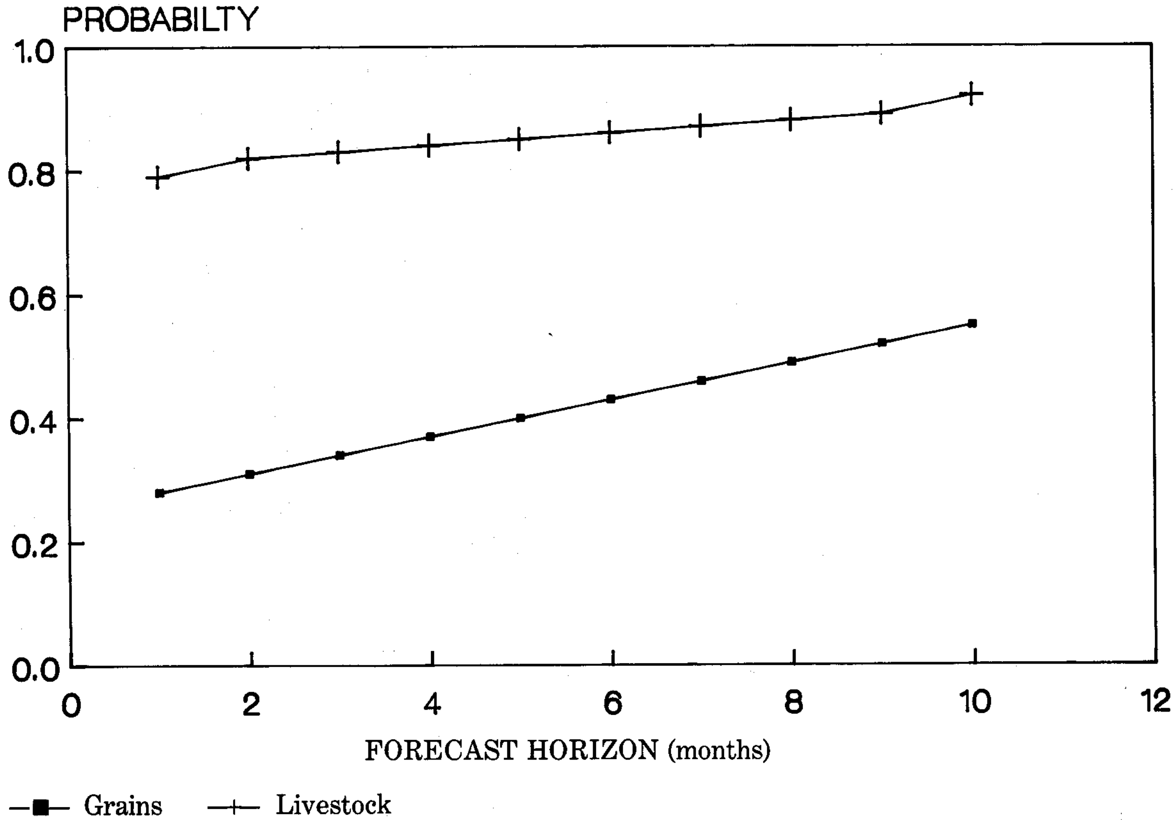

Figure 1. Estimated Probability of Finding Forecasting Inefficiency Using Semi-strong Form Tests in Grains and Livestock, 1973–1979.

dicates that relative to grains a .29 increase in the probability of identifying inefficiency is associated with nonforecasting evaluations of futures markets for livestock and livestock products. The sign on the other commodities group is negative and statistically significant, indicating that the relative probability of finding inefficiency declines by .27 when commodities in this group are evaluated in a nonforecasting context. While the commodities in this group are semi-storable, which may suggest increased efficiency relative to livestock, the result of increased efficiency relative to grains was somewhat unexpected. This result, in part, may be a function of the distribution of these observations over time. Many of the analyses in this group occur in the preseventies period, a period associated with less turbulent markets.

The coefficient for the time period from 1973 through 1979 is positive, although not statistically significant, and indicates a .38 increase in the probability of finding that inefficiency is associated with nonforecasting analyses of data during this time period versus the pre-1973 period. The 1980 to 1985 period is negative and significant, indicating that the probability relative to the pre-1973 period of finding that inefficiency is lower by .38 when data from this period are analyzed in a nonforecasting context. These results support the notion that the markets have become more efficient in the 1980s than they were in the 1970s. Such a result may in part explain the inability of researchers to generate trading profits during this period (e.g., Irwin and Brorsen).

The type of test variables are both negative but insignificant. The probabilities of identifying inefficiency with time and frequency domain tests are lowered by .05 and .08, respectively, when compared to nondistributional tests. The implications of this result are not clear. Perhaps the imposition of the normality assumption or the lack of ability to pick up nonlinearities limits that ability of these types of tests to detect inefficiencies which are picked up by the nondistributional tests.

Finally, the type of data appears to have a strong impact on the conclusions of nonforecasting tests. The daily variable is positive and significant, indicating a .45 increase in the probability of identifying that inefficiency is associated with intraday and daily data versus weekly and monthly data. This result supports the argument that price adjustments to new information may occur slowly, and therefore day-to-day price changes may appear dependent but when sampled over a longer interval will appear random (Lee and Leuthold).

CONCLUSIONS AND IMPLICATIONS FOR RESEARCH

The analysis presented here provides insight into the effects of commodity group, time period, type of test, type of data, and forecast horizon on the results of agricultural futures market efficiency. By using the findings of various studies, probabilistic estimates were developed regarding the impacts of each of these factors on the conclusions of efficiency studies. The results are generally consistent with theory and with our current state of knowledge regarding agricultural futures market efficiency. It is clear that test results are sensitive to the commodity and time period under study, as well as to the type of data and test being used. These results provide a synthesis of past research and suggest several avenues for continuing analysis of futures market efficiency.

In general terms, the findings suggest a characterization of agricultural commodity futures markets. Regarding the forecasting accuracy of subsequent cash prices, futures markets improve as the time horizon of the forecast shortens (i.e., the closer to maturity). In a relative sense, futures market prices for grains, soybeans, and other semi-storable commodities appear to be better forecasters than livestock market futures. As might be expected, during unstable periods, futures markets are not as effective in forecasting subsequent cash prices. However, evidence suggests that it is difficult to generate statistical models that "outperform" the market during these unstable periods.

In terms of the short-term price characteristics of futures, more systematic components are encountered in daily and intraday price changes as contrasted with weekly and monthly periods. In addition, more systematic changes in prices appear to exist in livestock markets relative to grains and other semi-storable commodities. Also, slightly higher levels of nonrandomness are detected with nonparametric tests and filter trading rules which are less stringent concerning the assumptions of the distributions examined and the nature of the existing nonrandomness. Perhaps, this suggests that more nonrandomness in prices is present than traditionally measured and that these dependencies may be nonlinear in nature. However, the most recent research during the 1980's indicates that daily price changes are becoming more random, difficult to predict, and hence less likely to generate short-term profits.

Regarding avenues of continued research, this study assists in identifying several areas. First, there appears to be a need for a comprehensive study of futures market efficiency using a common group of commodities, a common time period, common methods, and common types of data. Such a study would provide additional insight into the efficiency of futures markets. In particular, such a study could compare the 1970s to the 1980s and test the hypothesis that markets are more able to incorporate information in the 1980s.

Second, the findings regarding technique bias suggest the need to rethink the theory of price movements in commodity markets and the implications for efficiency. Specifically, it appears that we consistently find more inefficiency with weak form analyses, yet semi-strong form tests which incorporate additional information indicate the market is more efficient. Perhaps this suggests that the search for randomness in commodity markets has limited implications for market efficiency.

Third, further investigation of the differences in efficiency between commodity groups is needed, particularly in terms of forecast performance. Are the apparent biases in efficiency conclusions due primarily to commodity and institutional factors? How does trading volume in the efficient markets compare with trading volume in the inefficient markets? Do transactions costs differ? Are information flows similar?

Finally, our results suggest that some sources of bias exist in tests of market efficiency, but also that these appear explainable. Perhaps, then our interest should shift from simple analysis of whether price changes follow some theoretical pattern to a focus on whether these observed inefficiencies are detrimental, whether they lead to risk-adjusted profits in excess of the costs of identifying and implementing observed inefficiencies, and if they do, whether they can be corrected.

CONCLUDING REMARKS

Any analysis which attempts to aggregate results across time periods, methods, and studies is likely to be somewhat limited by the nature of the research design. However, in an effort to gain a greater understanding of theoretical concepts, such as market efficiency, and their relationship to real world events, such as futures trading, such approaches may be necessary. This seemingly "double-edged sword" problem should not preclude further efforts of this type. Similar studies could be generated where research findings are ample and the literature provides alternative hypotheses to be examined. Such work could facilitate literature reviews and expand our understanding of the issues in question.

The results presented here suggest that there are indeed consistencies with regard to conclusions about the pricing efficiency of futures markets reached in previous studies. Further, it would appear that research techniques, the time period of analysis, and other study specific features *do* impact the conclusions. It is time for a closer look at the theories upon which the research is based, with a focus on refinements which might account for these apparent inconsistencies. Perhaps this research effort can stimulate work in this important direction.

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