A compilation of research on the behavior of

Commodity Markets and Futures Prices

Raymond M. Leuthold, Editor

CHICAGO MERCANTILE EXCHANGE
International Monetary Market Associate Mercantile Market

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CME FELLOWSHIPS IN FUTURES SUBCOMMITTEE
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Introduction

In 1970 the Chicago Mercantile Exchange (CME) instituted a Fellowships in Futures program designed to provide opportunities for members of the academic community to study commodity futures markets. There are five categories in the program — the Graduate Student Research Fellowships, the Ph.D. Dissertation Fellowships, the Faculty Research Fellowships, the Visiting Professor Fellowships, and the Graduate Student Summer Intern Fellowships. More than $100,000 have now been disbursed through this program, allowing many scholars to conduct empirical commodity futures-market research.

This volume contains selected reports, not previously readily available, from the Faculty Research Fellowships category of the program. It is important that these papers be drawn to the attention of scholars and analysts as futures-market research tends to build upon itself. Most of the papers state and empirically test basic hypotheses relating to commodity futures markets. The empirical tests are conducted on those commodities traded on the Chicago Mercantile Exchange, either livestock or foreign currencies.

The studies vary widely in sophistication, technique, theoretical modeling, quality, and results, ranging from rewritten dissertation chapters to extension-type material for firm managers or traders. Most of these papers and fellowship requirements were completed prior to the task of organizing them into this volume, so they are printed here with only minor editing for consistency. No attempt was made to return manuscripts to authors for revision and many of the papers have never been subjected to peer review. However, the quality of these papers is similar to much of the research on futures markets currently being conducted and published.

There is a common element among all of the empirical tests and that is prices — price relationships, price behavior, and price performance. Since the Chicago Mercantile Exchange selects fellowship recipients from applicants, no attempt is made to cover all research areas. These fellowships are often short-run in nature, such as a summer research project, and with price data readily available, the tendency is to conduct a quick price-analysis study. Two of the papers do not directly involve the futures market, yet their contribution to understanding price behavior and analyzing market performance will be realized by the imaginative reader. Each paper serves as a complete study and many undertake novel ideas or approaches. As a group, they contribute to our overall knowledge and empirical understanding of the futures market.

This book is in four sections. Section 1 contains papers dealing with commodity-price behavior. Studies in Section 2 test the forward-pricing ability of futures markets, dealing mostly with the efficiency of exchange-rate markets. Section 3 contains one paper that illustrates the financial implications of a hedging program. Papers in Section 4 are concerned with price relationships, with one paper each on pricing over time, space, or form.

Comments at the beginning of each section provide a brief summary and attempt to link the papers in that section with other investigations. As will become apparent in Section 2, economists and financial analysts have developed a body of literature about the economic performance of forward-exchange and financial-instrument markets, quite parallel to some of the commodity futures-market literature. Unfortunately, these two bodies of literature have not been fully linked, and this volume will help in that endeavor.

For the student who is just beginning to study the futures market and desires some theoretical background and empirical understanding beyond the references cited within each paper included in this volume, the following works may be helpful. Holbrook Working is credited for much of the original theoretical and empirical contributions to the economics of futures markets, and selections from his writings appear in *Selected Writings of Holbrook Working* (1977). Further and more recent theoretical and empirical contributions to our base of understanding by others in the field appear in *Selected Writings on Futures Markets* (1977). For a review within one paper of the historical development of the economics of futures markets, see Gray and Rutledge (1971). One of the most popular textbooks describing the mechanics of futures trading and how commercial firms use the markets is by Hieronymus (1977). Another text with a substantial bibliography is by Teweles, Harlow, and Stone (1974). Library searches will uncover numerous additional works.

The Fellowships in Futures program of the Chicago Mercantile Exchange is a continuing event. At this writing, 12 Fellowships in Futures grants are being awarded for 1978. Topics for research include price analysis of both financial-instrument and livestock-futures contracts. For more information, contact the Chicago Mercantile Exchange.[1]

I wish to acknowledge the assistance on this volume of the following: Bill Sullivan, formerly Director of Education at the Chicago Mercantile

[1] For a listing of all past fellowships since 1970, see *Bibliography and Informational Source List* (1978).

Exchange, who initiated the project and provided considerable guidance and counsel; the Education Committee of the Chicago Mercantile Exchange who underwrote the project; and Pete Stubben, current Director of Education, who handled the many administrative tasks of publishing a book. Most important to me was the editorial and styling assistance and advice provided by Susan Hardwick, Karyl Wackerlin, and Keith Dublin.

July, 1978 Raymond M. Leuthold

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SECTION 1: PRICE BEHAVIOR

In this section there are three papers (Bear, Miller, and Meyer) that deal with price behavior; each conducts a specific test of a single behavioral aspect. Bear's paper is concerned with prices and the flow of information overnight; Miller's deals with the relationship between price volatility and contract maturity; and Meyer's tests trading rules on frozen pork-belly spreads.

The flow of information has always been a subject of concern to students of futures markets. Working (1958) was the first to develop a model hypothesizing that new information flows randomly. In futures market literature, this has led to a multitude of tests concerned with the stochastic nature of futures prices, many reviewed by Peck (1977, pp. 253-255). The most recent comprehensive tests have been conducted by Cargill and Rausser (1975), and Mann and Heifner (1976). Both find deviations from randomness.

The subject of information — how it flows from futures markets and the impact it has on current markets — has concerned many. Those who have recently contributed to this literature include: Hirshleifer (1975), Cox (1976), and Grossman (1977). The basic idea in these papers is that the existence of futures markets provides additional information to other markets, thereby improving price formation. The importance of information in markets, its effect on prices, and the costly nature of acquisition, continues to gain critical evaluation. The three studies in this volume contribute to our overall understanding and empirical knowledge of the use of information in markets and its effect on price behavior.

Bear uses the live-cattle and frozen pork-belly futures contracts as an empirical base from which to test hypotheses about information and traders' anticipation of and reaction to information. In a unique methodological application of examining overnight holdings and price changes of futures contracts, he finds that information flows at a steady rate through time, and that traders appear to properly anticipate these flows. These markets seem highly competitive and efficient in the short run, yet traders react slowly and appear averse to risk when anticipating information which may have considerable price impact.

Miller tests the hypothesis that volatility of futures prices increases as the futures contract nears maturity. Miller further develops the model set forth originally by Samuelson (1965) that variances are likely to change over time. She finds evidence from live-cattle futures contracts that there is some systematic volatility and accepts the above hypothesis. However, the model also characterizes spot prices, and evidence from these data is not clear as to whether or not the increased return variability on futures contracts, as maturity approaches, can be attributed to the process generating spot prices.

More recently, Rutledge (1976) has also tested the hypothesis that volatility of futures prices increases in the period immediately prior to contract expiration. Two of four commodities tested provide support for this notion. Samuelson (1976), responding to this paper, implied that an analysis of price changes over a few months is an inadequate test of the basic hypothesis.

Meyer constructs and tests three sets of mechanical trading rules designed to reduce the risk exposure of an investor in commodity futures contracts. Utilizing frozen pork-bellies data, all of the rules employ spread trades. These trades involve the simultaneous sale of a distant futures contract and the purchase of a nearby contract when the premium of the distant over the nearby is of a specific magnitude. Most applications of the strategies generated positive returns which exceeded any negative returns. In fact, in some instances, only positive returns were reported. Unfortunately, generalization of these results to guarantee positive investor returns in the future is not possible.

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Risk and Return Patterns on Overnight Holdings of Livestock Futures

Robert M. Bear

Although a large number of futures traders are in and out of their positions within a few days, often within minutes, most studies on the behavior of forward markets concern price behavior over longer periods. This can be rationalized to an extent; it is more difficult to obtain and work with data on an intraday or interday basis than it is to consider weekly, monthly, or yearly observations. However, as traders know, where work is most tedious, rewards tend to be greater. This study has analyzed short-run price behavior of livestock futures using an approach that this author believes has no precedent in the study of competitive markets. Information — its flow, anticipation, and utilization by traders — is the critical variable of interest.

The following sections outline the findings that should be of particular interest to traders and students of livestock futures. The basic questions asked and the conclusions drawn from this study may be summarized as follows:

1. Is the amount of pertinent new information concerning a futures contract approximately constant between any two successive daily closing quotations? Information is found to flow at a steady rate. When a market is closed over a holiday or weekend, a greater amount of information occurs (on the average) in the interim than occurs between closings on successive weekdays.

2. Do traders act as if they correctly perceive and anticipate the amount of information forthcoming in the next 24 to 72 hours? Findings indicate that traders do properly anticipate information flows. However, there is some evidence to suggest that their reaction is not immediate.

3. What attitude towards risk is suggested by trader behavior in the short run? Position holders who are long in the market show a short-run aversion to risk, demanding a larger return over brief periods when a greater volume of information with potential price impact is anticipated.

Robert M. Bear is a faculty member at Pennsylvania State University. This paper was written in 1972.

The overall implication of these findings is that the Chicago Mercantile Exchange's livestock futures markets are highly competitive and efficiently operate in a short-run context.[1] Additional implications relevant to existing theoretical models of price behavior are discussed under *Further Evidence and Implications.*

All data, consisting of opening and closing daily prices of July pork bellies and June live cattle from 1965 to 1970, were obtained from CME yearbooks. The selection of one contract in each commodity is appropriate. Two livestock commodities were studied to insure that findings were representative of all livestock futures.

INFORMATION FLOWS

Many factors determine the value of livestock products and hence, livestock futures contracts. New information on any one or combination of factors will have a price effect on the futures. In an efficiently operating market, price effects will be immediate and unbiased. The timing of some new information such as governmental crop reports is known in advance, but most new information is more spontaneous. In either event, the release of new information is not limited to the period from 9 A.M. to 1 P.M. on trading days. The first question considered here is the rate of flow of new information to the market.

More information seems to become available at certain times of the day. For example, expect more information to become publicly available from 9 A.M. to 1 P.M. than from 9 P.M. to 1 A.M. This is not the issue raised here. Of interest is the relative amount of information that becomes available over periods (which vary in length) when the market remains closed. For example, on the average, does the same amount of information tend to become known from 1 P.M. to 9 A.M. on weekdays as becomes known from 1 P.M. on a Friday to 9 A.M. on the next Monday?[2] The former covers a time of 20 hours, while the latter covers 68 hours. If information flows are directly related to length of time, then more information will become known from close to open (or close to close) spanning weekends than during the week.

If information flows were directly related to time, there would be (on the average) larger price changes over weekends and holidays than between successive days of the week, due to the longer time intervals involved and the larger amount of information impacted in the price change within the interval. To test this, the variation in close-to-close

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[1] Other studies have come to this conclusion for the long run, notably Labys and Granger (1970).

[2] Theoretical studies have made the implicit assumption that this is true. See *Further Evidence and Implications.*

prices was measured by calculating the standard deviation of price change from the observed mean. A second, very similar measure was also calculated — the mean absolute deviation. This was done in recognition of the fact that the distribution of price changes may not exactly further the normal probability curve. Daily price differences were divided into two groups — the first spanning all successive weekday intervals, and the second containing all longer intervals (i.e., holidays, weekends, and holiday-plus-weekend combinations). By either measure of variation, there were larger price changes over weekends in both commodities. These results, summarized in Table 1, may be considered significant because the odds of observing a difference of such magnitude by chance in both commodities is very small.

TABLE 1
DISPERSION OF CLOSE-TO-CLOSE PRICE CHANGES IN JULY BELLIES AND JUNE LIVE CATTLE

Commodity and Time Interval	Number of Observations	Standard Deviation[a]	Mean Absolute Deviation[a]
July Bellies			
Weekday	915	.553	.404
Weekday and holiday	260	.594[b]	.451
June Cattle			
Weekday	1,029	.160	.112
Weekday and holiday	291	.201[b]	.148

[a] In cents per pound.
[b] Bartlett's test for homogeneity of variance indicates a significant difference between weekday and weekend observations at $\alpha = .15$ for bellies and $\alpha = .05$ for cattle.

More information seems to become known over a weekend than during a corresponding close-to-close interval during the week. The following sections concern evidence on the way traders react to this situation.

RISK, RETURN, AND TRADER EXPECTATIONS

To a position holder, be he long or short, the liquidity of his position is somewhat less when the market is closed than when it is open. When open, the trader may respond immediately to new information. When closed, the trader must wait until the market opens again to react to information. In the ensuing interval, additional information may become available and/or a fuller assessment of existing information may be made, both possibly to the detriment of the trader's position. Thus, the lack of liquidity is an element in the risk that is borne in a position when the market is closed. Consider the following set of assumptions:

1. Greater price variation occurs over weekends. This was verified in the preceding section.
2. Speculators are typically long position holders (net). This may quickly be verified by inspection of U.S. Department of Agriculture reports.[3]
3. Speculators correctly perceive relative liquidity risks resulting from the market being closed for intervals which vary in length.
4. In the short run, speculators exhibit risk aversion; that is, they demand a larger expected return in periods where risk is greater.
5. Traders' expectations are, on the average, realized.

Under this set of assumptions, we would find short-run (close-to-close) returns larger over a weekend than during the week.[4] The actual close-to-close returns are shown in Table 2. In both commodities, weekend returns were larger than weekday returns. The results are statistically significant, again indicating that the observed differences were not a chance occurrence.[5]

TABLE 2
CLOSE-TO-CLOSE RETURNS ON LONG POSITIONS[a]

Time Interval	July Bellies	June Cattle
Weekday	.0085	—.0050
Weekday and holiday	.0847[b]	.0510[c]

[a] Returns are in cents per pound. Because Bartlett's test for homogeneity of variance was significant (Table 1), the results of this comparison of returns must be interpreted cautiously.
[b] Significant difference between weekday and weekend means at $\alpha = .10$.
[c] Significant difference between weekday and weekend means at $\alpha = .05$.

Observance of larger returns over weekends and holidays is consistent with our assumptions regarding information flows and trader behavior. Two other issues of interest in the analysis of short-run price behavior will be examined. The first is the weekday adjustment mech-

[3] *Trading in Frozen Pork Belly Futures* (October, 1969) and *Trading in Live Beef Cattle Futures* (May, 1970), U.S. Department of Agriculture Commodity Exchange Authority. Also *Commitments of Traders in Commodity Futures* (monthly).

[4] Other combinations of assumptions substituted for assumptions 3-5 would provide the same results. The assumptions given are those most consistent with efficient market operation and also (fortuitously) most consistent with the findings of studies which have taken a longer-run perspective of market operation.

[5] If returns over the long run were positive to one side of the market or the other, adjustment would need to be made for the different time intervals involved. Since long-run return (normal accumulation rate) was about zero for both commodities, no adjustment was made and all return differences were assumed to be related to liquidity risk differentials. The normal accumulation rate adjustment is considered under *Further Evidence and Implications,* p. 19.

anism which accommodates larger weekend returns. The other, discussed in the final section, is the speed of price adjustment to weekend information.

To illustrate the question of how prices adjust during the week to provide larger weekend returns, we will consider an example where the current (and equilibrium) price of a future is 28.00 cents. In the absence of both new information and liquidity-risk differentials, an eight-day sequence of closing prices would be:

Day	Mon.		Tues.		Wed.		Thurs.		Fri.		Sat.		Sun.		Mon.
Price	28.00		28.00		28.00		28.00		28.00						28.00
Change		0		0		0		0				0			

Should liquidity risk adjustment be a constant (linear) factor, we might observe a pattern as follows:

Day	Mon.		Tues.		Wed.		Thurs.		Fri.		Sat.		Sun.		Mon.
Price	28.00		27.97		27.95		27.92		27.90						28.00
Change		−.03		−.02		−.03		−.02				+.10			

Since liquidity risk adjustment is very small in relation to both price changes resulting from new information and the minimum unit of price change (2½/100 cents/pound), most of the adjustment probably occurs on the trading day preceding the weekend. The pattern would then be:

Day	Mon.		Tues.		Wed.		Thurs.		Fri.		Sat.		Sun.		Mon.
Price	28.00		28.00		28.00		28.00		27.95						28.00
Change		0		0		0		−.05				+.05			

This latter hypothesis is consistent with the notion that some traders (net long) prefer to "even up" on a Friday rather than carry a position into the weekend. Breaking the weekday returns down by days of the week did not confirm this hypothesis for the pre-weekend daily return (generally a Thursday-to-Friday close-to-close) for all livestock futures. While pre-weekend return was less than daily return in bellies, the same was not true in cattle. Table 3 provides a summary of these results. However, evidence indicates that in both futures (ignoring transaction costs

TABLE 3
FURTHER BREAKDOWN OF CLOSE-TO-CLOSE RETURNS ON LONG POSITIONS

Time Interval	July Bellies	June Cattle
Weekday excluding pre-weekend	.0146	−.0080
Pre-weekend	−.0080	.0040
Weekend and holiday	.0847	.0510

and risk differentials) a trader who only bought near the close each Friday and sold near the close each Monday would have done markedly better than a trader who only bought each Thursday and sold each Friday.

SPEED OF THE ADJUSTMENT OF PRICES TO NEW INFORMATION

In an efficient market, price responds very quickly to new information. In the strictest definition of market efficiency, this adjustment must be both instantaneous and unbiased. Other studies of futures markets have found that almost all of the proper response to new information occurs sometime within the trading day when information first becomes known.[6] How quickly does a response occur within the trading day? Some evidence on this question can be obtained from our data.

If events occurring over a prolonged weekend closing are immediately reflected on the next trading day, all the results obtained so far using close-to-close price observations should also be evident using close-to-open observations. However, if the impact of new information works itself out sometime later in the first post-weekend trading day, higher risk and return observations will not be evident.

Using June cattle, Table 4 shows that weekend information is not immediately reflected in the opening quotations. Weekend risk and return measures were both very much smaller using close-to-open in place of close-to-close. This was also true of close-to-open measures during the week. Consistency was maintained with results using close-to-close in that both risk and return were significantly larger over weekends than during the week. These results suggest that news received over the weekend, while reflected in price levels by the close on Monday, is not fully acknowledged on the opening.[7] Limit orders and possibly a momentary

[6] Working (1956), Larson (1960), and Smidt (1968).

[7] An alternative explanation of these results is that very little information actually occurs outside of trading hours.

TABLE 4
RISK AND RETURN MEASURED FROM CLOSE-TO-OPEN
(JUNE CATTLE, 1965 to 1970)

Time Interval	Standard Deviation	Mean Absolute Deviation	Return
Weekday	.078	.0201	−.0006
Weekend and holiday	.117[a]	.0533	.0117[a]

[a] Significant difference in variance between weekday and weekend observations at $\alpha = .05$. Again, because population variances appear unequal, significance of difference between means must be interpreted cautiously.

"wait and see" attitude on the part of some traders may account for these results.

FURTHER EVIDENCE AND IMPLICATIONS

Corroborative Evidence under Conditions of Non-normality

Models viewing speculative prices as a stochastic process typically focus on the first differences, or their logarithmic counterparts, of day-to-day closing quotations.[8] Time intervals in such a series are not "fixed" in the sense implicitly assumed by these models: while trading time between successive observations is uniform, the length of time a market is closed and hence, the total time passing between observations, varies with the periodic occurrence of weekends and holidays. The purpose of this research has been to determine empirically if a weekend effect exists, what its pattern may be, and how it affects studies of market mechanisms involving distribution and dependence analysis of daily observations.

Studies of daily prices have been concerned with statistical dependency, distribution properties, and filter analysis. They have in common the treatment of each daily close-to-close observation as being the expected equal of all others in its population parameters, and judgment of market efficiency is rendered in this context. As the first section of this report has shown, there are both theoretical and empirical bases for denying this treatment. Measurement of risk and return were made with standard (parametric) statistical techniques which presume distributions of daily differences to be normally distributed. Caution is required in interpreting these results due to possible non-normal characteristics of livestock futures price series, a condition well-documented in security prices and grain futures.[9] Sufficiently strong non-normality may negate the conclusions drawn from parametric procedures. Various applications of the Kolmogorov-Smirnov test, a non-parametric measure of overall difference between distributions without regard to the contribution of individual parameters to this difference, were conducted to determine the answers to the following questions:[10]

1. Are the distributions of livestock futures in homogeneous groupings (i.e., weekday, pre-weekend, and weekend) normal?
2. Do the significant results obtained in the first section remain significant under the observed degree of non-normality?
3. Is the non-normality consistent with the stable Paretian hypothesis?

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[8] Examples are numerous. The literature through 1963 is well-reviewed in Cootner (1964). An updated survey has recently been provided by Fama (1970).

[9] Cootner (1964), Fama (1963), Larson (1960), and Stevenson and Bear (1970).

[10] Siegel (1956).

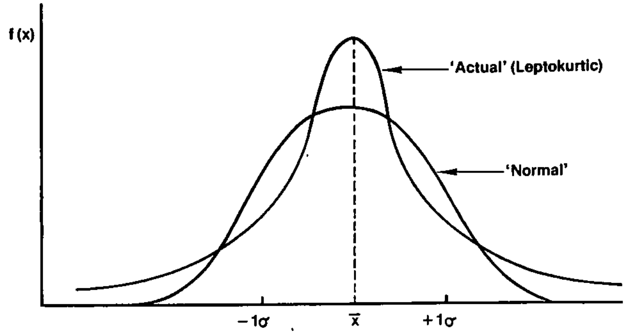

FIGURE 1. THEORETICAL (NORMAL) AND ACTUAL DISTRIBUTIONS OF PRICE CHANGES IN FUTURES MARKETS

In response to the first question, evidence shows that, owing to differing lower moments, aggregate distributions of all daily changes appear more leptokurtic than do their individual summands (see Figure 1). However, does recognizing weekend variation suggest that the distributions are normal (i.e., nonstationary Gaussian)? The one-sample Kolmogorov-Smirnov test against a normal curve indicates that weekday, pre-weekend, and weekend price changes remain too leptokurtic to be considered drawn from a normally distributed population. Thus we must consider the stable Paretian hypothesis as a description of these distributions.

In response to the second question above, a two-sample application of the Kolmogorov-Smirnov test found that the combined disparity in location and dispersion parameters of weekend observations was significantly different from those of weekday and pre-weekend observations. This finding using non-parametric techniques confirms the results of our prior parametric measurements.

A third distribution measurement was made. While leptokurtosis and differences in location and dispersion are consistent with a stable Paretian hypothesis, differences in skewness and characteristic exponents are not.[11] The Kolmogorov-Smirnov test was run on standardized distributions (using the mean absolute deviation as a measure of dispersion) to test consistency in form. Here D values were insignificant, indicating no intraweek shifting of form parameters.

Measurement of Daily Return and Price Dependency

The observation that dispersion, and possibly return, varies in cyclical fashion on an intraweek basis, to the extent that it is motivated by in-

[11]Fama (1963).

formational and liquidity preference factors, is of course completely consistent with the notion of an efficiently operating market.[12] It also suggests that measurements of serial correlation and run analysis (on a daily basis) should evidence some tendency toward reversal rather than the strict statistical independence expected in a time-information homogeneous world. There is another reason to expect negative dependence, namely a measurement bias caused by improper treatment of trend in these algorithms. The bias results from treating trend as a per observation concept, which generally creates an overadjustment across weekday intervals and underadjustment over weekend intervals.

As an example of the above problem, we will consider a simple random-walk model:

$$P_{t+k} = \beta P_t + \epsilon_{t+k} \tag{1}$$

where P_t is a closing price observation, ϵ_{t+k} is a random variable with $E(\epsilon_{t+k}) = 0$ and $r(\epsilon_t, \epsilon_{t+k}) = 0$ for all $K \neq 0$.

In Equation 1, β is a positive constant parameter specifying the level of expected return. If $\beta = 1$, the best estimate of the next closing price is the current closing price: there is no expected upward or downward drift in price through time. Let K represent any specified interval; $K = 1, 2, \ldots L$. Then $f(K)$ would represent the average percentage change in the value of P_t over the interval $(t, t + k)$. We express $f(K)$ in terms of β as:

$$\beta = 1 + f(K). \tag{2}$$

Testing Equation 1 by serial correlation involves the use of an algorithm where $f(K)$ is specified as:

$$f(K) = [(P_n - P_1)K]/P_1 n \tag{3}$$

where n is the number of daily closing price observations in the series $P_1, P_2 \ldots P_n$.

Formulation presumes a uniform interval of time between all observations. An alternative formulation which would correctly specify the accumulation rate recognizing variation in time intervals between closing observations would be:

$$g(K) = [(P_n - P_1)K]/P_1 m \tag{4}$$

where m is the total number of (calendar) days in the sample period —i.e., $m > n$.

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[12] That is, current price unbiasedly reflects all information such as that in a martingale context:

$E(Z_{J,\,t+1} \mid \phi_t) = 0$ implying Z_{Jt} is a "fair game" given the information set ϕ_t where

$Z_{J,\,t+1} = R_{J,\,t+1} - E(R_{J,\,t+1} \mid \phi_t)$. See Fama (1970).

TABLE 5

KOLMOGOROV-SMIRNOV TWO-SAMPLE TEST ON STANDARDIZED FUTURES DISTRIBUTIONS[a]

D Values

	Distribution 1:	Daily Except Pre-weekend	Daily	Pre-weekend
Futures	Distribution 2:	Pre-weekend	Weekend	Weekend
July Bellies		.045 (.101)	.079[c] (.096)	.051 (.121)
June Cattle		.067 (.095)	.109[b] (.090)	.071 (.114)

[a] Figures in parentheses indicate critical value for $\alpha = .05$.
[b] D value significant at $\alpha = .05$.
[c] D value significant at $\alpha = .20$.

In the case of daily observations, where $K = 1$, Equation 2 would take the form:

$$\beta = \begin{cases} 1 + g(1) \text{ for all daily } P_t, P_{t+1} \\ 1 + 2g(1) \text{ for all holidays between } P_t, P_{t+1} \\ 1 + 3g(1) \text{ for all weekends between } P_t, P_{t+1} \\ 1 + 4g(1) \text{ for all holidays plus weekends between } P_t, P_{t+1}. \end{cases}$$

Algorithms using Equations 2 and 3, thereby treating returns or a linear accumulation rate on an observation basis, systematically overstate weekday returns and understate weekend and holiday returns in markets where there is a positive return to risk-bearing. However, in markets where returns to one side of the market are very close to zero, the correction factor will be trivial. Returns to one side of the market in livestock futures are very close to zero over periods of several years, and we would expect a negligible effect.

Using Equations 4 and 5 instead of Equations 2 and 3 in calculating serial dependency for July bellies and June cattle had only a very minor effect on the correlation coefficient as Tables 5 and 6 indicate. In both

TABLE 6

UNCORRECTED AND CORRECTED SERIAL CORRELATION COEFFICIENTS, ONE-DAY LAG, (JULY BELLIES AND JUNE CATTLE, 1965-1970)

Category	July Bellies	June Cattle
Per Observation		
Accumulation rate (3)[a]	.025	.008
Daily accumulation rate (5)	.018	.005
Uncorrected r (1) (3)	−.029	.120
Corrected r (1) (5)	−.027	.122

[a] Numbers in parentheses refer to equations in this section.

cases the correction, although trivial, was in the expected direction of making the coefficient more positive (less negative). A greater difference between corrected and uncorrected correlations would result in markets and periods where trend is greater.

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The Relation Between Volatility and Maturity in Futures Contracts

Katherine Dusak Miller

Some students of futures markets believe that the volatility of futures prices increases as the futures contract nears maturity (see Telser, 1956; Segall, 1956; and Samuelson, 1965).

Samuelson offers an explanation for the existence of the variability effect as reviewed in Section 1 of the paper. His hypothesis about the behavior of futures prices requires that the stochastic process characterizing spot prices must be of a particular kind; other processes will yield different relations between the variability and maturity of futures contracts. Section 2 of the paper examines the behavior of a sample of futures returns for existence of a systematic volatility effect. Evidence, in this particular case, supports the view that such an effect exists. Section 3 examines the underlying spot-return series to see if its properties are consistent with the empirical results for the sample of futures returns examined in Section 2. Although the process generating the spot returns is consistent with the implications of Samuelson's hypothesis, there is a discrepancy between the observed pattern of futures return volatility and the pattern implied by the Samuelson relationship. Whether or not sampling variability could account for the discrepancy is discussed briefly at the end of the paper.

SECTION 1: RETURN VOLATILITY AS A FUNCTION OF CONTRACT MATURITY

As part of his demonstration that return volatility is related to contract maturity, Samuelson postulated that futures prices follow a martingale or "fair game" process. Mathematically, the martingale property can be represented as:

$$Y(T, t) = E_t[X(t + T)] \tag{1}$$

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where Y refers to futures prices, X to spot prices, T to the number of periods in which the futures contract will be outstanding, and t to the present time. Equation 1 states that the current futures price is equal to the spot price expected to prevail T periods hence.

The martingale property implies only that the first moment of the distribution of expected price changes is zero and says nothing about the second moment of the distribution. As Samuelson points out:

> Although the sequence $\{\Delta Y(T-n, t+n)\}$ has a zero first moment at all time periods $T-n$, there is no reason to suppose that the riskiness of holding a futures — in the sense of the second moment or variance as measured by $E[\{\Delta Y(T-n, t+n)\}^2]$ — should be the same when T is large and the terminal date far away as when $T-n$ is small and the futures contract about to expire. A well-known rule of thumb is that nearness to expiration date involves greater variability of riskiness per hour or per day or per month than does farness.... However, the present theory can contribute an elegant explanation of why we should expect far-distant futures to move more sluggishly than near ones [1965, pp.44-45].

The elegant explanation to which Samuelson refers assumes that futures prices follow a pure martingale but that spot prices are generated by the autoregressive model:

$$X_{t+1} = \alpha X_t + \{u_t\} \tag{2}$$

where α is assumed to be less than 1 and where X_{t+1} is the spot price that will prevail at time $t+1$, X_t is the current spot price and $\{u_t\}$ is a sequence of independent random drawings from a given distribution with mean 0 and variance $\sigma^2(u)$.[1]

If futures prices follow a martingale, the expected return from buying a T period futures contract at the beginning of time t and selling it one period later at the beginning of time $t+1$ should be zero.

Such a return may be represented as:

$$R(t, T) = E_{t+1}[X(t+T)] - E_t[X(t+T)]. \tag{3}$$

[1] The assumption that spot prices follow an autoregressive process would seem to imply that the spot-commodity market is inefficient. For many commodities, however, price changes do not measure the investor's total return; hence, behavior of the price series by itself implies nothing about market efficiency. For commodities such as live cattle, total return reflects both weight gain and price change over the holding period. If, for example, the relevant holding period is one month and the price of cattle is $20 per hundredweight at the beginning of the month as well as at the end of the month, the return computed simply as the price change would be zero. Allowing for normal weight gain of two pounds a day, the total dollar return taking weight gain into account would be $12 and not zero. Thus, without knowing the pattern of weight gain over a measurement interval, one cannot point to the existence of trends in the spot-price series as a priori evidence of spot-market inefficiency.

Equation 3 represents the forecast revision of the spot price expected to prevail at the time $t + T$ that is prompted by the receipt of new information occurring in the interval t to $t + 1$.

Since a specific process was assumed to be generating spot prices, $E_{t+1}[X(t + T)]$ and $E_t[X(t+T)]$ can be expressed in terms of the current spot price X_t and a sequence of disturbance terms $\{u_t\}$. It can be shown then that $R(t, T) = \alpha^{T-1}u_{t+1}$.[2] Of course $E[R(t, T)] = 0$ which must be the case if futures prices follow a martingale.

Variance of return may be expressed as:

$$\begin{aligned}\sigma^2(R) &= E[R(t, T) - E(R(t, T))]^2 \\ &= E[\alpha^{T-1}u_{t+1}]^2 \\ &= \alpha^{2T-2}\sigma^2(u)\end{aligned} \quad (4)$$

Thus variance is a function of T, the contract term to maturity. Since α was assumed to be less than one, variance will vary inversely with T.[3]

The martingale property, coupled with the assumption that spot prices are generated by a mean-reverting process, ensures that longer-term assets will exhibit less variance than shorter-term assets. Intuitively, Samuelson's law of increasing volatility may be explained as follows: the assumption that futures prices follow a martingale means that the futures price is the expected spot price, and the assumption of a mean-reverting spot process implies, in turn, that the longer the life of the asset,

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[2] Using the postulative autoregressive scheme $X(T) = \alpha X(T - 1) + u$ of Equation 2, $E[X(t + T)]$ may be represented as:

$$\begin{aligned}E_t[\alpha X(t + T - 1) + u_{t+T}] &= E_t[\alpha^T X(t) + \alpha^{T-1}u_{t+1} + \ldots + u_{t+T}] \\ &= \alpha^T X(t) \text{ since } E_t(u_{t+1}) = E_t(u_{t+2}) = E_t(u_{t+T}) = 0\end{aligned}$$

and $X(t)$, the value of the current spot price, is already known. By the same reasoning, it can be shown that:

$$\begin{aligned}E_{t+1}[X(t + T)] &= \alpha^{T-1}X(t - 1) \\ &= \alpha^{T-1}(\alpha X(t) + u_{t+1}) = \alpha^T X(t) + \alpha^{T-1}u_{t+1}.\end{aligned}$$

Therefore,

$$\begin{aligned}R(t, T) &= E_{t+1}[X(t + T)] - E_t[X(t + T)] = \alpha^T X(t) + \alpha^{T-1}u_{t+1} - \alpha^T X(t) \\ &= \alpha^{T-1}u_{t+1}\end{aligned}$$

and

$$E[R(t, T)] = 0.$$

[3] If spot prices follow a second order autoregressive process $E(R) = 0$ and $\sigma^2(R) = f(T)$ as before, however, the expression for the futures return involves a second-order difference equation in spot prices. That is,

$$R = - u(t)\,(\lambda_1^{T-1} - \lambda_2^{T-1}/\lambda_1 - \lambda_2)$$

with

$$\sigma^2(R) = (\lambda_1^{2T-2} + \lambda_2^{2T-2} - 2\lambda_1^{T-1}\lambda_2^{T-1})\,[\sigma^2(u)/(\lambda_1 - \lambda_2)^2]$$

where λ_1 and λ_2 are the roots of a second order polynomial. Thus, the properties of futures return volatility will depend on the numerical values of the parameters of the second-order process.

the greater the extent at which spot price (hence futures price) fluctuations will be offsetting.[4]

Samuelson's explanation of the increasing volatility of a maturing futures contract is crucially dependent on the mean-reverting properties of Equation 2.[5] This can be shown by examining how spot prices follow a non-mean reverting process such as random walk. The generating process for a random walk is:

$$X_{t+1} = X_t + \{u_t\}$$

and the expression for return has the simple form:

$$R(t, T) = u_{t+1}$$

with

$$E[R(t, T)] = 0 \text{ and } \sigma^2(R) = \sigma^2(u).$$

Expected return is zero, but in this case variance of return is constant, independent of contract maturity, i.e., the variability effect disappears.[6]

SECTION 2: SOME EVIDENCE ON THE RELATION BETWEEN CONTRACT MATURITY AND RETURN VARIABILITY

Daily price quotations from the June and December live-beef futures contract for the period 1965 through June, 1972, have been used to test the hypothesis that there is a systematic relation between return variability and contract maturity.[7] The sample period includes 7½ sets of observations for each contract. In most cases, contracts are outstanding 10 or 11 months before maturity, although there are some cases where price quotations are available as long as 15 months before maturity. Such observa-

[4] Samuelson's explanation of the variability phenomenon is in no way dependent on whether futures prices exhibit normal backwardation or not. Samuelson, probably for expository reasons, assumed that futures prices follow a pure martingale. In a later section of the paper, however, he shows how the analysis can be extended to encompass a martingale with drift — a case he explicitly identifies with Keynesian normal backwardation.

[5] The assumption of a stationary disturbance term also plays a crucial role in this analysis. If the disturbance term were non-stationary, no a priori pattern in return variance could be rejected. In all examples, stationarity of the disturbance terms will be assumed.

[6] By the same reasoning, the same results would emerge if the first differences of spot prices followed a first-order-moving-average process. And in general, return volatility would be unrelated to contract maturity if one were to assume that any number of more complicated higher-order-moving-average processes were generating the spot-price series.

[7] Trading in the live-beef futures was instituted on November 30, 1964, by the Chicago Mercantile Exchange. In addition to December and June contracts, there exist contracts which mature in April, August, October, and February. The correlation between returns on the June and December contracts is high but not perfect —.76 for a sample size of 1,432. Hence, in the statistical tests to follow, we shall report all results by contract and not aggregate the returns.

tions had to be deleted from the sample, however, since trading volume in the maturity range 12 to 15 months is typically low and the reported prices are, in many instances, only nominal quotations.

All statistical tests are presented in terms of the first difference of the daily price expressed in natural logarithms. The first difference of the daily log price is the rate-of-return continuously compounded for holding the futures contract over the day, and for small price changes. The daily log price approximates the daily percentage price change.[8]

As a measure of return variability, the .28 to .72 interfractile range has been computed from daily return series for contract maturities ranging from 11 months to the expiration month of the contract. (For a description of the sampling properties of this statistic, see Fama and Roll, 1971.) An interfractile range, rather than the variance or standard deviation, was used as the primary measure of return variability since futures returns appear to conform to a member of the non-Gaussian family of distributions better than to the Normal distribution.[9] Under these conditions the sample variance is known to be an inefficient measure of variability (Fama and Roll, 1971).

Estimates of the sample interfractile range are reported in Table 1 (along with the sample variance which is included for the sake of completeness). Since the interfractile range is a measure that corresponds to the standard deviation for the Normal distribution, the interfractile range has been transformed to the equivalent of the variance.[10] From here on, the interfractile range will refer to this transformed value.

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[8] We have checked the first part of the Samuelson hypothesis that futures returns follow a martingale. Sample correlation coefficients, defined as $\rho_T = \text{cov}(R_t, R_{t-T})/\sigma(R_t) \cdot \sigma(R_{t-T})$, have been computed for lags of 1 to 10 days. Evidence of serial correlation in the return series would cast doubt on the validity of the martingale assumption. There is virtually no serial dependence in the return series for either the June or December live-beef contract. Out of 20 correlation coefficients, all but four are within two standard errors of zero. The largest value of ρ_T is .10 (first order December) which "explains" only 1 percent of the return variability.

From these results, we may infer that the behavior of returns by maturity, obtained by reclassifying the original return series with respect to number of months to contract maturity, is also consistent with the martingale hypothesis.

[9] Normal probability plots for each of the 12 maturities for the June and December contracts confirmed that the majority of the sample distribution departs from normality. If returns were distributed normally, values of the observation plotted against their fractile value would lie along a straight line having slope $1/S$ and intercept $\bar{x}/S$ where S is the sample standard deviation and $\bar{x}$ is the sample mean. In only 7 of the 24 plots was there little or no evidence of curvature away from the line (7,8 month June and 10, 6, 2, 1 and maturity month December live beef).

[10] For stable distributions, the second moment is defined as $\delta = S/\sqrt{\alpha}$ where α is the characteristic exponent which determines the shape of the distribution and S can be estimated by the interfractile range. Thus, to convert the interfractile range to the equivalent of the variance, S must be raised to the alpha power.

Figures in Table 1 suggest an inverse relationship between contract maturity and return volatility. For both June and December contracts, volatility appears lower in the early months (11 to 8 months for the June contract and 11 to 7 months for the December contract) than later ones and increases sharply in the maturity month.[11]

The correlation coefficient between the interfractile range and length of contract maturity is .74 for the June contract and .59 for the December contract.[12] If the true value ρ were zero, the figures .74 and .59 would represent normal deviates of 2.87 and 2.02. The probability of observing a sample deviate of 2.87 or 2.02 when the true value is zero is only .20 and 2.17 percent.[13]

[11] In the case of live-beef futures, the increase in the interfractile range during the contract maturity month cannot be attributed to suspension of trading limits on daily price movements. For this particular commodity the limits, which are $1 above or below the previous day's closing price, remain in effect until the expiration date of the contract.

[12] Using the variance, rather than the interfractile range, as a measure of volatility ρ drops to .56 and .44, which is understandable in terms of the higher sampling variability of the variance, as opposed to the interfractile range, when returns are distributed stable non-Gaussian.

[13] A second measure of association, which does not necessitate specifying the functional form of the relation between contract maturity and variability, is Kendall's tau statistic. For a description of the statistic and its sampling properties, see Kendall (1962). If there is no relationship between the number of months to con-

TABLE 1

VARIABILITY MEASURES, JUNE AND DECEMBER LIVE-BEEF FUTURES[a]

Month to Maturity	June N	June Interfractile Range	June Variance	December N	December Interfractile Range	December Variance
11	74	.000584	.000148	138	.000483	.000154
10	121	.000596	.000228	127	.001018	.000134
9	125	.000427	.000086	167	.000569	.000179
8	146	.000462	.000104	157	.000558	.000127
7	133	.000739	.000115	160	.000484	.000147
6	161	.001008	.000262	164	.001107	.000230
5	158	.000816	.000219	139	.000753	.000176
4	145	.000954	.000191	147	.000839	.000250
3	167	.001314	.000304	138	.000674	.000111
2	157	.000854	.000214	146	.000827	.000132
1	160	.000815	.000403	133	.000964	.000144
MAT	106	.001149	.000271	93	.001836	.000261

[a] These variability measures, although computed from a daily price series, have been transformed to a weekly equivalent. The reason for doing this will be apparent (see *Section 3: Process Generating Spot Prices*).

Thus, we cannot reject the hypothesis: return variability for live-beef futures is inversely related to contract maturity.[14]

SECTION 3: PROCESS GENERATING SPOT PRICES

If Samuelson's explanation for the existence of a volatility effect is correct, results of the previous section suggest that spot-cattle prices are generated by an autoregressive process. However, finding an appropriate set of cattle prices with which to estimate the process is not an easy task. Although the U.S. Department of Agriculture publishes large quantities of price statistics, most of the reported series are in the form of temporally averaged prices (usually monthly or weekly). Since use of average prices can "introduce correlations not present in the original series" (Working, 1960) such prices cannot be used in situations where the size of the correlation coefficients is used to establish the nature of the generating process.[15,16]

Having rejected the use of temporally averaged prices, an appropriate measurement interval must be chosen. Since the sample of futures returns is based on daily prices, a series of daily spot-cattle prices is used to estimate the generating process. Unfortunately, the properties of daily spot-price changes seem to vary over the week. Using the bottom of the daily price range for Choice slaughter steers, 1,100-1,300 pounds sold at the

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tract closeout and the size of the interfractile range, the value of tau is zero. The values of this statistic are .55 for the June contract and .42 for the December contract which correspond to normal deviates of 2.40 and 1.85. The probability of observing a sample deviate of 2.40 or 1.85 when the true value is zero, is only .8 percent and 3 percent. The value of Kendall's tau statistic for the June and December live-beef contracts, using the sample variance instead of the interfractile range as a measure of return variability, is .48 and .12. The corresponding probabilities of observing such values when the true value of τ is zero is 1.7 percent and 32 percent.

[14] In a study of the relationship between contract maturity and price volatility for wheat futures traded on the Chicago Board of Trade, Segall (1956) concluded that his empirical evidence suggested "only the absence of an easily stated relationship between maturity and price volatility . . ." (p. 206).

From one set of test results, Segall concluded that "maturity is related to price volatility" and that some support was afforded to the position that longer maturities fluctuate less than shorter maturities. On the other hand, the size of mean and median price ranges for contracts having 1 to 8 months to maturity exhibited no regular pattern.

[15] Working (1960) has shown that the use of average prices introduces spurious first-order serial correlation into the series. For instance, according to Working's formula for the first-order correlation coefficient, $(m^2 - 1)/2(2m^2 - 1)$ where m is the number of terms in the averaging interval, if daily prices follow a random walk, the first-order serial correlation coefficient using a monthly average of the daily prices will be .25.

[16] The fact that temporally averaged prices can introduce spurious first-order serial correlation has not deterred researchers from using such series. See for instance, the recent study of spot-cattle prices by Carvalho (1972).

Union Stockyards in Chicago from January, 1964, through July 31, 1971, the mean daily price change, its standard error, and the frequency distribution of price changes for each trading day of the week have been computed.[17] (See Table 2.)

The sample frequency distributions in Table 2 show that Tuesday and Thursday price quotations are nominal ones. From Monday to Tuesday, 83 percent of the price changes are zero; the corresponding figure for Wednesday to Thursday is 98 percent. By contrast, distributions for Tuesday-to-Wednesday, Thursday-to-Friday, and Friday-to-Monday price changes are roughly similar and take on a much higher proportion of non-zero values (65, 64, and 62 percent respectively) than do Monday-to-Tuesday, and Wednesday-to-Thursday distributions.

Table 2 suggests there are at most three effective trading days in the week: Monday, Wednesday, and Friday.[18] Thus, a weekly time series would be a natural choice to use for estimating the process generating spot-cattle prices. Instead, the Monday price series is used here since the largest volume of cattle arrive at the yards for sale on that day.[19]

The proposition that under certain conditions return variability will be systematically related to contract maturity was demonstrated for the case of an autoregressive model that was additive in the error term. A multiplicative form of the model has been chosen to estimate the return generating process model since there is reason to believe that the size of the error term is proportional to the current price level. The relevant generating process is assumed to be:

$$p_t = p_{t-1}\exp(\alpha + \tilde{u}_t) \qquad (5)$$

or taking logarithms

$$\ln p_t = \alpha \ln p_{t-1} + \tilde{u}_t \ln p_{t-1} \qquad (5')$$

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[17] Ideally, one would want to use the closing market price for spot cattle, but since the U.S. Department of Agriculture does not collect open, high, low, or closing livestock market prices, the decision was made to use the bottom of the daily price range. The terminal date of the sample corresponds to the closing of the Union Stockyards. The weight category 1,100-1,300 pounds corresponds most closely to the delivery specifications of the live-beef futures contract. (Data were made available by John McKenna, U.S. Department of Agriculture, Chicago.)

[18] A spot check of daily volume figures for the number of cattle arriving for sale at the Union Stockyards in Chicago for the years 1964, 1966, 1969, and 1970 substantiates the contention that only Monday, Wednesday, and Friday (at most) are effective trading days. Representative volume figures over the week are as follows: Monday, 11,000 head; Tuesday, 2,000; Wednesday, 9,000; Thursday, 500; and Friday, 5,000. In 1964, as many as 18,657 head of cattle arrived at the Union Stockyards on a Monday. By 1970, volume of cattle arriving at the yards had declined dramatically, e.g., Monday volume averaged in the neighborhood of 8,500 head but the Monday-Wednesday-Friday pattern was still pronounced. (Figures supplied by John McKenna, U.S. Department of Agriculture, Chicago.)

[19] As noted, the results reported in the text are based on the Monday price series. All empirical tests, however, have been replicated using the Wednesday and Friday price-change series. In no case were the results substantively different from those reported in the text.

TABLE 2
FREQUENCY DISTRIBUTIONS OF DAILY PRICE CHANGES BY DAY OF THE WEEK

Daily Price Change	Monday-Tuesday	Tuesday-Wednesday	Wednesday-Thursday	Thursday-Friday	Friday-Monday
$-1.25				1	
−1.00	1	3		4	1
− .75		6		4	4
− .50	5	29	1	24	25
− .25	25	90	4	75	85
0	311	138	376	135	142
+ .25	29	85		81	81
.50	4	31	1	44	28
.75		7		6	5
1.00	1	2		5	
1.25					1
N =	376	391	382	379	372
Mean Price Change	$.0013	$−.0013	$−.0026	$.0336	$.0040
Standard Error	(.0074)	(.0158)	(.0023)	(.0173)	(.0008)

where p_t and p_{t-1} are the Monday prices of spot cattle one week apart and u_t is a random error term. A random-walk process would imply that $\alpha = 1$, or alternatively that the first differences of the log cattle prices are serially uncorrelated.

Using a sample of 395 Monday spot-cattle prices, a first-order autoregressive process was estimated.

$$\ln P_t = \underset{(.012)}{.019} + \underset{(.008)}{.987} \ln p_{t-1} \qquad R^2 = .97 \tag{6}$$[20]

Since the point estimate of the regression coefficient is close to, but not actually 1, (the sampling interval of two standard errors wide around it extends from .971 to 1.003) the results are somewhat ambiguous to interpret. In a situation such as this, though, description of the process generating spot-cattle prices depends, in part, on what is being investigated. For instance, if the proposition under discussion is the profitability of trading rules, the conclusion is that for all practical purposes spot-cattle returns behaved as if they followed a random walk. The slight degree of dependence in the return series could not be profitably exploited once transaction costs were taken into account. On the other hand, the case may be that a value of $\hat{\alpha} = .987$ is sufficiently different

[20] A second-order price was also estimated but with no material improvement in fit, i.e., the R^2 increased from .9709 to .9714.

from 1 to account for the pattern in the size of the variability measures for the live-beef futures returns. (See Table 1.)

Using the formula $\sigma^2(R) = \alpha^{2(T-1)}\sigma^2(\tilde{u})$, with $\alpha = .987$ and $\sigma^2(\tilde{u})$ being the interfractile range for the spot-return series, predicted values of $\sigma^2(R)$ (actually the interfractile range) have been computed for $(T - 1) = 11$ months through $(T - 1) = 0$ months and the results have been plotted in Figures 1 and 2, along with the actual interfractile ranges and the regression trend line through them. The correlation between the predicted and actual volatility measures for June live beef is .74; for the December contract it is .60.[21]

Figures 1 and 2 show that although the predicted interfractile range increases as the maturity date of the contract approaches, the initial predicted value at $(T - 1) = 11$ months is too high, and its rate of increase

[21] Assuming that the relationship between futures and spot variability is logarithmic does not materially change the results. The correlation coefficient for the June contract increases from .74 to .76 and for the December contract increases from .60 to .61. Predicted variability measures based on spot variance have also been computed. The correlation coefficients between predicted and actual variance for the June and December contracts are .48 and .19; in logarithmic form they are .45 and .17.

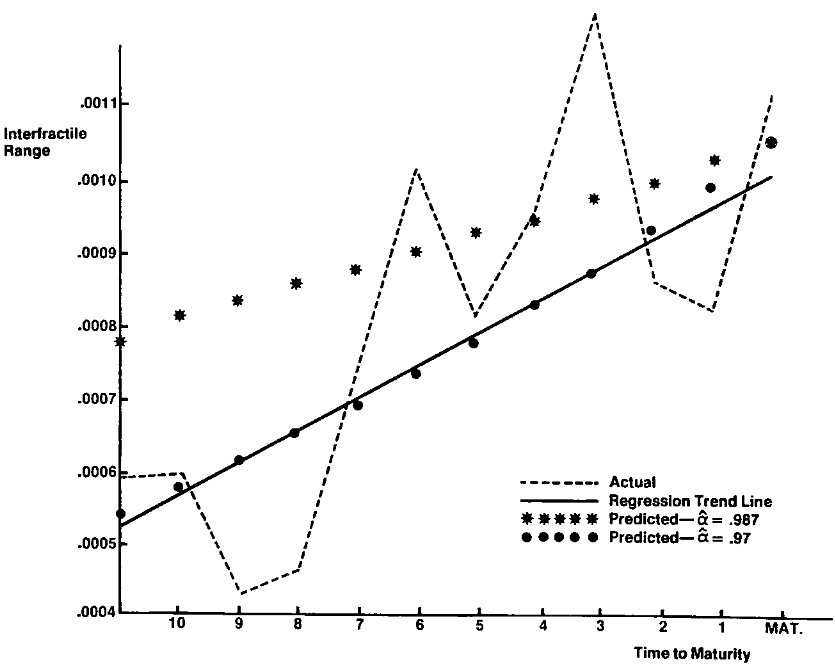

FIGURE 1. JUNE VARIABILITY MEASURES

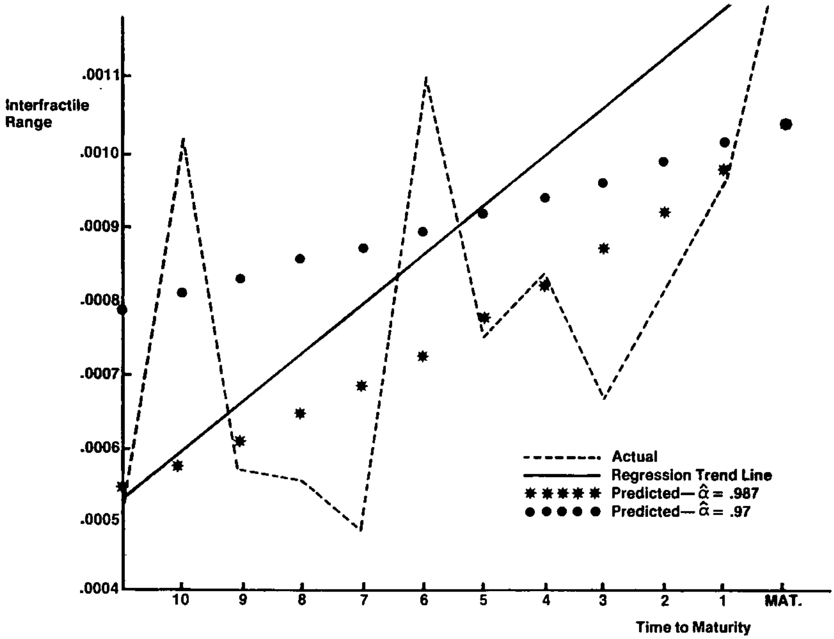

FIGURE 2. DECEMBER VARIABILITY MEASURES

as contract duration decreases is too gradual compared to the actual values of the interfractile ranges.

If alpha were somewhat smaller, the more distant scale factors would be lower, and the ascent to the value of the interfractile range at maturity (i.e., the actual value of the interfractile range for the spot-return series) would be steeper. Consider, for example, the pattern of the predicted interfractile ranges if $\hat{\alpha} = .97$ rather than .987. (The value .97 was chosen since it is the lower endpoint of the interval two standard errors wide around the point estimate of $\hat{\alpha}$). For $\hat{\alpha} = .97$ the predicted values of the interfractile range closely follow the trend line of the actual interfractile ranges. For the June live-beef contract, 9 out of the 12 predicted values of the interfractile range lie almost exactly on the trend line. Correspondence between the predicted and actual variability measures is not as close for the December contract, primarily because the value of the interfractile range at maturity is more than twice the size of the next largest interfractile range. Were this last value to be somewhat smaller, the upward trend in the size of the December variability factors would be less pronounced and would follow more closely the plot of the predicted variability measures for $\hat{\alpha} = .97$.

This last example was chosen to demonstrate that at least one value of alpha exists for which the correspondence between the actual and predicted variability measures would be very close. However, given a sample value of $\hat{\alpha} = .987$ and a standard error of .008, the probability that the true value of alpha could be as low or lower than .971 is only .0166.

Insofar as returns on the live-beef futures are concerned, this evidence on the relation between return volatility and contract maturity should be interpreted rather cautiously. There does appear to be a systematic variability effect present in the structure of futures returns; whether this effect is attributable to the process generating spot prices is open to question. There is certainly a rough correspondence between the predicted and the actual variability measures based on a value of $\alpha = .987$. The fit between predicted and actual interfractile ranges is even closer when $\alpha = .97$, but as we have seen, such a value would probably be rejected as the true value of alpha.

Thus, although return variability on the live-beef futures contract is related to contract duration, the explanation for the phenomenon is probably due only in part to the process generating the spot-cattle price series. Whether these results are characteristic of all commodities, or only live beef, can be answered only by examining more commodities.

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Application and Analysis of Pork-Belly Commodity Spreads

Richard L. Meyer

The objective of this paper is to construct and empirically test mechanical trading rules which can reduce the investor's risk in commodity futures contracts. Frozen pork bellies are the commodities used for empirical testing because price data are readily available, pork-belly contracts are popular with investors in the commodity markets, and pork-belly prices are subject to reasonably wide fluctuations (which may scare the more risk-averse investor).

Three sets of mechanical trading rules are derived and tested; all utilize commodity spreads. The normal commodity spread involves the short sale of a distant futures contract and the purchase of a nearby futures contract when the premium of far over near is judged too great. Such judgments will be based on the ratio of the premium to transactions and carrying charges described in the following section. Strategy 1 calls for spreading all combinations of contracts when the price premium is judged too large. Strategy 2 is the same as Strategy 1 except that only one spread is permitted per combination of contracts. Strategy 3 is like Strategy 1 except that the maximum holding period is predetermined.

Results of the empirical tests indicate that the spreads created via the strategies used here would have been almost uniformly profitable, although the degree of profitability would have varied widely from one spread to another. Furthermore, although losses did occur in individual spreads, most applications of the three strategies showed positive returns outnumbering negative returns by at least 60 percent to 40 percent. In many cases, no negative returns were realized and when negative returns did occur, they were always less than the predetermined permissible maximum.

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CONCEPT OF COMMODITY SPREADS

The theory of spreading commodities is similar to the theory of arbitrage in the securities market.

For instance, in the stock markets, A.T.&T. sells on the Midwest Stock Exchange and the New York Stock Exchange. The price difference between the two markets seldom exceeds the transaction costs involved in the purchase and sale of the security. If the price spread does exceed this amount, the alert investor will simultaneously purchase A.T.&T. on the exchange where it is cheapest and sell short a comparable number of shares on the other. On receiving the shares he has purchased, he can cover his short sale and pocket the profit, thus successfully engaging in a risk-free arbitrage operation.

Prices of commodity futures contracts are bound by a similar constraint. For example, in the pork-belly market, a March contract cannot exceed the price of a February contract by more than trading commissions and one month's carrying charges. If such an imbalance were to exist, investors could buy a February contract and simultaneously sell a March contract.

In February an investor could take delivery of the bellies, store them for a month, and then deliver them in March to cover his sale. His profit would be the difference between the sale price of the March contract and the sum of carrying costs, transaction costs, and the purchase price of the February contract. Again, a risk-free arbitrage operation would be accomplished and because investors will fully exploit all such risk-free opportunities, the maximum price differential of March bellies over February, or August over May, is a known quantity.

Note that no such constraint prohibits the March contract from selling substantially above the May contract, or the March contract above July, and in fact, such a phenomenon is not unusual. On November 30, 1971, July, 1972 contracts were selling at about 33 cents per pound while the August contract for the same year traded at slightly less than 32 cents per pound. Reverse arbitrage is impossible simply because one cannot use the proceeds from an August delivery to meet the obligations of a contract which must be satisfied in July.

While reverse arbitrage is an impossibility, some commodity investors do engage in reverse spreads — shorting a near contract and purchasing the distant contract on the theory that the premium of the near over the far has become too large. Such a transaction cannot, however, be considered risk-free. If the investor's assumption is based on a faulty analysis of market conditions, he may find that the premium of the near over the distant contract increases. Reverse spread cannot be used to precisely determine the maximum loss which may occur, and will not be considered further in this paper.

When considering the ordinary commodity spread, few cases will arise where the price of the distant contract exceeds that of the near contract by more than transaction and carrying costs, precisely because such a situation gives investors the opportunity to achieve risk-free returns and their actions in the marketplace will rapidly eliminate the large price difference. On the other hand, new contracts often sell for more than distant contracts by less than the full amount of the transaction and carrying costs. In these cases, the investor may spread two contracts and know at the outset the maximum loss, which he may be forced to endure, or he may choose to engage in only those spreads where the possible loss cannot exceed some predetermined maximum amount.

For example, assume that a February pork-belly contract is currently trading at 32 cents per pound, that the March contract is 32.50 cents, and that transaction and storage costs are 0.80 cent per pound. If an investor were to buy one February contract and simultaneously sell one March contract his maximum loss would not exceed 0.30 cent per pound or $108 total (0.30 cent per pound times the standard 36,000-pound contract). Regardless of what happens to prices of these contracts, the spread between them will not exceed 0.80 cent and, because it is already 0.50 cent, the maximum loss is thus set at 0.30 cent per pound.

If the maximum loss is predetermined, what profit potential may exist in such an investment strategy? Again referring to the example above: the February contract may rise while the March contract remains constant, or rises by a smaller amount; the March contract may fall while the February contract remains constant or falls by a smaller amount; or, the February contract may increase while the March contract falls. Suppose that February advances 36 cents per pound and March to 36.15 cents. The investor will have gained 4 cents on the long side and lost 3.65 cents on the short side for a gross gain of 0.35 cent per pound, or $126 on a 36,000-pound contract. After subtracting commissions of $45 his net gain is $81. In other words, there are a variety of ways in which prices may change so that the investor realizes positive returns. (See Table 1).

MECHANICAL TRADING STRATEGIES UTILIZING PORK-BELLY SPREADS

Having explored the use of a commodity spread to predetermine maximum losses and still offer the potential for positive returns, we may now develop a set of investment techniques and empirically test their viability using historical pork-belly prices.

These theories make no assumptions about the "correctness" of the level of pork-belly prices at the time when the spread is established, nor do they make any assumptions about the direction in which these prices may

TABLE 1
FIVE HYPOTHETICAL SCENARIOS IN WHICH SPREADS MAY BECOME PROFITABLE

December: Establish Spread	Trades	Price in Cents per Pound
	Buy: 1 February	32.00
	Sell: 1 March	32.50
January: Remove Spread		
1) February rises, March remains constant	Sell: 1 February	33.60
	Buy: 1 March	32.50
	Gross profit:	1.60
2) February rises, March rises by less	Sell: 1 February	33.60
	Buy: 1 March	33.00
	Gross profit:	1.10
3) February remains constant, March falls	Sell: 1 February	32.00
	Buy: 1 March	31.90
	Gross profit:	0.60
4) February falls, March falls by more	Sell: 1 February	31.95
	Buy: 1 March	31.00
	Gross profit:	1.45
5) February rises, March falls	Sell: 1 February	32.40
	Buy: 1 March	32.10
	Gross profit:	0.80

move while the spread remains intact. The trading rules established below are purely mechanical and assume that a spread will be established whenever the appropriate predetermined conditions are met. The idea for developing such a set of mechanical rules grew from the belief that many investors are afraid to invest in commodities futures contracts because returns from these markets are perceived to be too volatile. While this volatility may be tempered by posting more than the required initial margin, many investors find this unpalatable because their ability to diversify is quickly inhibited. If an investor were to post a 50 percent margin on a 36,000 pound contract of pork bellies prices at 30 cents per pound, his initial investment would be $5,400. Few investors can make enough investments of that size to attain satisfactory diversification. Thus, the commodity spread is the one technique that may enable the investor to engage in less volatile commodity transactions without requiring large amounts of capital. As previously explained, once the spread has been established the investor knows for certain the maximum possible loss regardless of what happens to the price of the commodity during the period that the spread is maintained.

The procedure in this study then is to hypothetically establish a spread whenever a particular loss-minimizing trading rule is met, compute the holding period of the spread, and its net profitability. The spread is established by purchasing the nearby contract and simultaneously selling a more distant contract at the closing price in any week that the proper trading rule is met. The spread is assumed to be lifted by simultaneously selling the near contract and buying the more distant contract at the closing prices on Friday of the last week in the month just prior to the expiration month of the near contract. While the investor would not have to repurchase the distant contract at that time, if only half the spread were closed out, he would be exposing himself to precisely those risks that we are trying to eliminate. Investors can only predetermine their maximum possible loss as long as they maintain both sides of the spread.

For example, assume today is the first Friday in October and the price of March pork bellies exceeds the price of February pork bellies by enough to justify establishing a spread. The February contract is purchased at 32 cents per pound and the March contract is sold at 32.50 cents. Then on the last Friday in January (the month just prior to the expiration month of the near contract) the investor lifts the spread by selling February at 34 cents and purchasing March at 34.05 cents.

The holding period of the investment is measured in weeks and extends from the end of the first week in October to the end of the last week in January, a holding period of 16 weeks in this case. The gross return is computed by measuring the gain or loss on the long contract, the gain or loss on the short contract, netting the two, and multiplying by 30,000 (36,000 for 1971 contracts). The net profit is computed by subtracting commissions. From the above example, two cents were made on the long side and 1.55 cents lost on the short side for a combined return of 0.45 cent. On a 30,000-pound contract, this amounts to a gross return of $135. After subtracting the commission of $45, the net return is $90.

Now we must look at the variety of rules which were used to determine the appropriate time for establishing the spread. The previous section pointed out that an investor would not expect to find a distant contract trading at a premium over a near contract by more than carrying and transaction costs, but that it was not uncommon to observe the distant over the near by some portion of those costs. The first step, then, is the development of a model which approximates the total of these costs. Included here are storage, interest, insurance, and transaction costs.

From figures supplied by the Chicago Mercantile Exchange, the fixed portions of the costs were determined to be 0.20 cent for 1965 and earlier, 0.21 cent from 1966 through 1969, and 0.24 cent beginning in 1970. These change because commissions were raised from $34, to $36, to $45, respectively. Insurance and storage costs are approximately 0.28 cent times the number of months between the two contracts, (t). Interest charges are approximated by multiplying the current price of the near contract by 10 percent, dividing by 12 months and multiplying by t. The appropriate equation for spreads undertaken during 1967 may be expressed as:

$$\text{Total Cost} = .0021 + .0028t + [(\text{Price/lb.})(.10t)]/12 \qquad (1)$$

Strategy 1

The first set of trading rules requires that a spread be established whenever a distant contract sells over a near contract by more than some amount (alpha) where alpha is a percentage of the total cost. The data have been tested against alpha levels ranging from 10 percent of total costs to 90 percent of total costs in increments of 10 percent. Suppose an investor is looking at closing prices in the third week of November and sees that the standard five pork-belly contracts are being traded (February, March, May, July, and August) and that alpha has been set at 40 percent of total costs. Alpha is computed for all possible combinations of contract spreads (February-March, . . . , February-July, February-August, March-May, . . . , March-August, etc.). The actual price premiums are compared for each combination and if the price premium exceeds alpha the spread is established and the holding period and gross and net returns are computed. Advancing to the fourth week in November, an investor repeats the above process and continues until all weeky data have been investigated. The alpha level is then changed to 50 percent of total costs and the entire computation process is repeated on all weekly data. This continues until all data have been investigated at an alpha level equal to 90 percent of total costs.

Note that this first set of mechanical trading rules may find an investor holding multiple positions in the same spread. Returning to the above example, he may find that a February-March spread is in order during the third week in November and that this spread also meets requirements in the fourth week. This first set of rules assumes that the investor would then hold two February-March spreads and perhaps a good many more if this combination continued to meet the requirements in later weeks.

As will be shown in the next section, such a situation arose frequently and investors would often have been put in a position where a high proportion of the spreads which were established would have been over the same two futures months.

Strategy 2

The second trading technique seeks to eliminate the above problem by prohibiting more than one spread position in any given combination of contracts. In the above example, if a February-March spread were initially established in the third week of November, even though that same combination may again qualify in the fourth week, it is not permitted. Other than this exception, the second trading strategy follows exactly the same process outlined for the first.

Strategy 3

Another potential problem arises in both the first and second applications of mechanical trading rules in that the holding periods vary substantially. Some are as short as one week while others may extend to 39 weeks. Since some investors may not want to consider commodity investments whose holding period exceeds a certain number of weeks, a third set of trading rules was established. In Strategy 3 all combinations of contracts, which meet the requirements as laid out in Strategy 1 above and whose holding periods do not exceed some predetermined number of weeks, are included as spreads. Note that multiple spreads in the same combination of contracts are again possible under Strategy 3. The holding period restrictions range from 2 weeks or less, to 40 weeks or less with 2-week increments.

THE DATA

Data for this paper were gathered from the commodities section of the *Wall Street Journal.* Weekly observations were taken from each Monday's *Journal* so that figures used represent the last trades which took place on Friday of the previous week. Data cover the period from March, 1964, when pork-belly trading was first reported in the *Journal* through August of 1971.

When no data were published referring to the Friday closing prices or when no Monday *Wall Street Journal* was published, the Monday closing prices were used or the next closest set of closing prices if Monday prices were not available. These occurrences were relatively unusual. For the most part, readings were taken at seven-day intervals so that deviations from this pattern should not create any serious biases.

Data include the trading date on which observations were taken, such as the third week in March, 1964, or the first week in February, 1969. Then, the expiration date of each futures contract, which was currently being traded, and its closing price were recorded. For instance, data available at the end of the second week of September, 1970, shows all five futures months of 1971 were then being traded (February, March, May, July, and August).

Recording the closing prices presents somewhat of a problem because sales may have been occurring in a range of prices at the close. In approximately three-fourths of the observations, more than one price was reported at the close. In such cases, the closing price was assumed to be the average of the high and low prices of this range. While no trades may have actually occurred at the computed average price, its use should not seriously affect the average returns shown in this study for three reasons: 1) in about 25 percent of the cases, only a single closing price was reported; 2) the range of prices reported at the close was often five-hundredths of a cent or less, and in the majority of cases was a tenth of a cent or less, so that any bias which occurs is reasonably small; 3) even if a significant bias existed, the effect should average out if a large number of observations exist (there are approximately 1,700 observations of futures prices in this paper).

Use of average data may, however, exert a downward bias on the standard deviation of returns and while the average return would not be biased, real trades in the spreads studied here may have resulted in a wider range of gains and losses. This also means that the number of spreads showing negative returns may be downward biased. Although losses could have been more frequent and larger than these results indicate, they would still not exceed the investor's predetermined maximum.

During some years, sporadic trading was reported in futures months other than the five standard contracts listed above. These price observations were omitted from this study.

ANALYSIS OF RESULTS

In analyzing the data, a rather extraordinary fact emerges. All variations of Strategies 1 and 2 yield profits and from the 180 variations of Strategy 3 tested here, on the average, all but seven showed positive returns. Furthermore, for almost all variations of each of the three strategies, gains outnumbered losses and no negative returns occurred when an alpha level of 60 percent or greater was used.

Strategy 1 requires that a spread be established whenever a distant contract month is priced over a near contract by at least a certain percent of the carrying and transaction costs (the alpha level). If an investor had followed this trading rule using a 10-percent alpha level, he would have received an average return of $48.39 over an average investment period of 16.48 weeks. (See Table 3.) Between March, 1964 and August, 1971, he would have invested in 748 spreads with 327 giving negative results. On the average, the investor would have made almost 100 such investments per year. However, the average number of investments per year may be somewhat misleading. Table 2 shows the number of investments the investor would have made in each year at two alternate alpha levels.[1]

At the 10-percent alpha level, few investments would have been made, in years like 1966 and 1969, while an abundance of opportunities existed in 1964 and 1970 (no data were recorded before March, 1964). Returns shown in Table 3 must be interpreted carefully. While the average gain for a 10-percent alpha level was $48.39 and gains outnumbered losses 421-327, in some years, the strategy did not show a profit. For instance, in 1966, 36 of the 57 spreads showed negative returns and in 1969, 28 of the 38 spreads were negative.

On the other hand, had an investor applied Strategy 1 on an alpha level of 60 percent or higher, he would have shown a profit on virtually every transaction. However, at this level a total of only 90 combinations would have been spread or an average of 12 per year. Again, the average figure is misleading. (See Table 2.)

[1] Yearly breakdowns are reported for each alpha level in the Appendix.

TABLE 2
NUMBER OF INVESTMENTS PER YEAR USING TWO ALPHA LEVELS (STRATEGY 1)

10-Percent Alpha Level	
Year	Number of Investments
1964	128
1965	95
1966	57
1967	85
1968	104
1969	38
1970	181
1971	60

60-Percent Alpha Level	
Year	Number of Investments
1964	2
1965	3
1966	3
1967	1
1968	2
1969	4
1970	66
1971	9

TABLE 3
STRATEGY 1: SPREAD ALL COMBINATIONS OF CONTRACTS WHEN PREMIUM EXCEEDS PRESCRIBED ALPHA LEVEL

Alpha (Percentage)	Average Return (Dollars)	Standard Deviation of Return	Average Investment Period (Weeks)	Standard Deviation of Investment Period	Number of Contracts	Number of Negative Contracts
.10	48.39	246.30	16.48	10.16	748	327
.20	53.99	189.99	16.10	10.16	578	230
.30	59.90	129.80	16.29	9.91	430	150
.40	79.28	105.85	16.40	9.24	311	76
.50	118.30	99.08	16.84	8.73	180	15
.60	159.02	98.40	14.94	8.10	90	0
.70	180.50	83.86	11.69	6.40	42	0
.80	243.56	69.21	8.38	3.50	8	0
.90	229.80	59.75	7.60	3.78	5	0

In examining Table 3 certain general statements can be made. Had a group of investors followed Strategy 1, those applying higher alpha requirements would have received higher average returns with each increment in alpha except in going from the 80-percent level to the 90-percent level. While the average return increased as alpha rose, the standard deviation decreased with each increment. Since this is a measure of the variation about the mean, a conclusion can be made that the dispersion of returns decreased with each increase in alpha.

Table 3 also shows that the number of acceptable contract combinations declined rapidly as the alpha requirement was increased. Of course, this conclusion would be anticipated because any combination of contracts meeting a 60-percent alpha level would also meet the 10-percent level, but not vice versa. For all alpha levels of 50 percent or lower, the average investment period was between 16 and 17 weeks.

At levels of 70 percent and above, the holding period rapidly declined because a large proportion of the combinations meeting these high alpha requirements are found within 20 weeks of the expiration date of the near contract. The standard deviations of the holding periods are generally about 50 to 60 percent as large as their mean figures.

Profitability is the most difficult problem. If results shown in Table 3 are to be used to determine future investment policy, which variation of Strategy 1 would be deemed optimal? There may be no single correct answer. If total profits earned are to be the measure of optimality, a 10-percent alpha level would be chosen because historically that level produced total gains of $36,195 (748 contracts times the average return of

$48.39). Each succeeding higher alpha level is inferior to the previous one. However, this is probably not the best measure for two reasons: 1) the number of spreads would be prohibitively large for most investors; and 2) any investor with enough funds to use an alpha level of 10 percent could have used these same funds to purchase four spreads of each combination of acceptable contracts at the 50-percent level. This approach would then have yielded $85,200 total profits (180 contracts times $118.30 average returns times 4) which is clearly superior to those achieved at the 10-percent level. If average returns per spread (or nonannualized rates of return) are perceived as the best measure of profitability, the optimal alpha level would be 80 percent where the average historical gain was $243.56. However, investors would probably not select this strategy because it yields a total of only 8 separate investments in 7½ years (2 in 1966, 4 in 1970, and 2 in 1971). While investors could have taken a large number of positions in each of the 8 combinations to produce greater total returns, many investors would no doubt prefer to invest their funds in a wider range of spreads.

This variation of Strategy 1 may predict a less than acceptable level of diversification. Assuming margin deposits of $1,000 per spread, the alpha level yielding the highest annualized rate of return occurs when alpha equals 90 percent (312 percent return). Selection of this alpha level suffers from the same problems described immediately above for the 80-percent level. Annualizing the rates of return is also misleading in this case. Purporting that an investor who follows Strategy 1 at an alpha level of 90 percent would have earned a 312-percent compound rate of return on his investment from 1964 to 1971 is simply not accurate. The investor would have made no investments until 1966, and then he would have had to make two spreads over roughly the same period. The same thing occurred in 1971, and the investor would have invested in one spread in 1970. An investor who had been prepared to begin investing in 1964, and had a minimum of $2,000 available (enough to margin two spreads simultaneously), would have earned a compound rate of return considerably smaller than 312 percent (the approximate internal rate of return would have been 8 percent).

An investor who uses the results in Table 3 to formulate his future investment strategy may find alpha levels of 40 to 60 percent to be the most attractive requirements because observed returns were reasonably large, negative returns were small in proportion to total spreads, and the total number of spreads meeting the investment criteria was reasonably large.

We can now turn to an evaluation of Strategy 2, which would have investors spread all combinations of contracts in which the premium of the distant contract month over the near month exceeds some predetermined alpha level, but would not permit more than one spread per combination of contracts. The results of applying this strategy at each alpha level are shown in Table 4. Again, the most important point to note is that every alpha level tested with this strategy showed positive results. However, the magnitude of returns does not now appear to be a function of the alpha level. The average returns would have been $175.60 at the 10-percent level, would have fallen to a low of $109.07 at alpha equals 40 percent, and then would have risen to $256.26 and $230.60 at respective alphas of 80 percent and 90 percent. The standard deviations of returns are inversely related to the magnitude of the alpha requirement.

The average investment period is considerably longer, at most alpha levels, for Strategy 2 than it was under Strategy 1 because under Strategy 2 each average holding period is approximately 10 weeks longer for the first six alpha tests than under Strategy 1. This was to be expected. Under Strategy 2, if a February-March spread is established 33 weeks before it must be closed out, no other February-March spread may be established for that particular year. With Strategy 1, the investor may have established that same spread at 33 weeks, 20 weeks, 10, and perhaps even 1 week, and would thus have had a shorter average holding period. The standard deviation for each holding period is less than one-half of the mean for most alpha levels under Strategy 2. Thus, the coefficient of variation of returns is lower for Strategy 2 than for Strategy 1.

The maximum number of contracts which would have been held over the 7½ year period for which data are available was 71 (10 combinations

TABLE 4
STRATEGY 2: SPREAD ALL COMBINATIONS MEETING ALPHA REQUIREMENTS BUT NOT PERMITTING MORE THAN ONE SPREAD PER COMBINATION

Alpha (Percentage)	Average Return (Dollars)	Standard Deviation of Return	Average Investment Period (Weeks)	Standard Deviation of Investment Period	Number of Contracts	Number of Negative Contracts
.10	175.60	491.20	28.43	8.34	49	17
.20	141.23	282.96	27.50	9.37	42	16
.30	131.57	264.36	26.46	10.31	37	13
.40	109.07	157.52	24.45	9.90	29	9
.50	135.33	158.62	23.17	12.16	23	3
.60	170.80	161.39	23.40	11.66	15	0
.70	182.71	91.74	15.45	9.27	11	0
.80	256.26	86.68	9.20	3.56	5	0
.90	230.60	81.18	9.33	4.04	3	0

of each of the 5 standard contracts in 1965-1971 and 1 combination in 1964). In fact, the largest number of contracts which would have qualified was 49 at the 10-percent alpha level and this number declined until only 3 contracts were included over this time span when alpha was set at 90 percent. The last column in Table 4 shows the number of spreads producing negative returns at each test level. The negative returns declined rapidly until none existed at the 60-percent level and above. Negative contracts as a percentage of total contracts reached a maximum of 38 percent when alpha was 20 percent.

An interesting variation of Strategy 2, as opposed to Strategy 1, is that investment opportunities are more evenly spread from one year to the next. For example, the 10-percent requirement shows that the 49 total contracts purchased were fairly evenly distributed from 1964 through 1971. (See Table 5.)

Again, average figures may be somewhat misleading. The investors' yearly average returns at the 10-percent alpha level can also be seen in Table 5. While the average return per contract over the entire period would have been $175.60, Table 5 shows that the average returns were "reasonable" in only three of the seven years, and that losses were realized in one. These numbers seem to indicate that although profits were attainable, on the average, investors would have had to be patient to achieve them.

In conducting this same analysis, when alpha was set at 40 percent the yearly results that would have been obtained are seen in Table 6. The yearly results are still fairly well dispersed with an average loss occurring again in 1968, and an average return of $265.50 in 1966. These results

TABLE 5
NUMBER OF INVESTMENTS AND YEARLY AVERAGE RETURNS USING A 10-PERCENT ALPHA LEVEL (STRATEGY 2)

Year	Number of Investments	Number of Investments with Negative Returns	Returns
1964	7	3	$ 40.78
1965	6	0	1,030.75
1966	9	5	24.44
1967	7	1	133.07
1968	8	4	−35.24
1969	3	0	417.50
1970	9	4	1.33
1971	0	0	0.00

also confirm the fact that the investor would have needed patience to achieve the average results for the whole period as shown in Table 4.

Finally, some interpretation is needed as to the real rate of return an investor may have been able to realize. A conservative approach assumes the investor had, at the beginning of 1964, enough funds available to margin 10 spreads simultaneously and that he received no interest on idle funds. Furthermore, assume each spread is margined at $1,000. Using yearly data for alpha equals 10 percent, the internal rate of return is slightly less than 3 percent and about 1 percent at the 20-percent alpha level. This probably cannot be interpreted as the investor's perceived return because he surely would not have permitted his unused cash to remain idle. On the other hand, if the returns per investment are annualized for the 10-percent alpha level, again assuming $1,000 margin, the rate of return is about 34 percent. This approach has certain deficiencies which were discussed above. Realistically, the investor seldom would have had the opportunity to invest in more than one spread per $1,000 investment per year even though the average holding period was roughly half a year at the 10-percent alpha level. If he could have earned $20 from savings for half a year (approximately 4 percent interest per $1,000) and $175.60 on his spread positions, his rate of return would have been between 19 and 20 percent, on funds actually invested. The main point is that, under Strategy 2, reasonably large positive returns have been earned on the average spread by the patient investor.

The final set of trading rules would have investors spread all combinations of contracts that meet the predetermined alpha requirements and would tie up their funds for fewer than a predetermined number of weeks. Strategy 3 was tested for 20 holding periods ranging from maximum

TABLE 6
NUMBER OF INVESTMENTS AND YEARLY AVERAGE RETURNS USING A 40-PERCENT ALPHA LEVEL (STRATEGY 2)

Year	Number of Investments	Number of Investments with Negative Returns	Returns
1964	7	3	$ 45.28
1965	0	0	0.00
1966	4	1	256.50
1967	4	1	185.62
1968	4	3	−9.00
1969	1	0	135.00
1970	8	2	77.06
1971	1	0	228.59

holding periods of 2 to 40 weeks. Results of applying Strategy 3 are shown in Table 7.

Table 7 shows that extremely short holding periods (2 and 4 weeks) resulted in negative or small returns for all those alpha levels that generated a substantial number of spreads. However, when the holding period tested was 6 weeks or more, the average returns were always positive (although admittedly small in some instances).

As a general rule, returns increased as alpha increased, but there is an inverse relationship between the standard deviations of returns and alpha. These trends in results strongly resemble the trends observed with Strategy 1. The holding periods tend to be relatively stable from one alpha level to another except when the holding periods are at a high end of the range. The average holding periods decline at very high alpha levels. The size of the average holding period is usually only about one-half as large as the maximum permissible holding period because Strategy 3 has two requirements. Strategy 3 permits spreading when: 1) a particular alpha is met, and 2) the holding period is equal to or less than the designated maximum. As a rule, the standard deviations of the holding periods are 40 to 60 percent as large as the average holding periods. Again, the number of combinations qualifying for spreads is inversely related to the alpha level. However, the interpretation of the results of Strategy 3 is mainly to be found by intercomparisons of Table 7.

At an alpha level of 10 percent, the average returns increased to a high of $46.47 as the permitted holding period was lengthened to 20 weeks; then, as the holding period was lengthened still further, the average returns dropped back to $39.48 at 40 weeks. A similar pattern is repeated for the 20-percent alpha level. The 30-percent alpha requirement shows that the greatest average returns would have been generated when the holding period was 22 weeks or less. For alpha levels of 40 to 70 percent, the greatest average returns occur when the holding period is restricted to about one-quarter of a year. At alpha levels of 80 to 90 percent, little trend in returns can be observed because so few contracts are involved.

A disproportionately large number of negative combinations are found in the short holding periods. For instance, at the 10-percent alpha level in the six-week holding period, 158 combinations would have been spread and 100 of these would have produced negative returns. At the 10-percent alpha level in the 40-week holding period, 748 would have been selected with 327 giving negative returns. Thus in the 6-week holding period, losses occurred in 63 percent of the spreads, while in the 40-week holding period losses occurred in only 44 percent of the spreads. At an alpha of 40 percent in the 10-week period, losses occurred in 32 percent of the

TABLE 7
STRATEGY 3 RESULTS

Buy All Contracts When Investment Will Not Exceed:	Alpha (Percentage)	Average Return (Dollars)	Standard Deviation of Return	Average Investment Period (Weeks)	Standard Deviation of Investment Period	Number of Contracts	Number of Negative Contracts
2 weeks	.10	−28.29	77.65	1.51	0.51	47	40
	.20	−33.94	77.00	1.52	0.51	40	35
	.30	−24.74	78.55	1.45	0.51	31	27
	.40	−21.53	88.68	1.53	0.51	17	16
	.50	56.05	175.14	1.75	0.50	4	3
	.60	318.60	0.00	2.00	0.00	1	0
	.70	318.60	0.00	2.00	0.00	1	0
4 weeks	.10	−11.09	77.65	2.62	1.12	105	73
	.20	−11.80	101.87	2.59	1.12	86	61
	.30	− 2.05	93.02	2.47	1.17	60	41
	.40	15.31	96.78	2.53	1.13	34	22
	.50	71.33	117.44	3.14	1.03	14	5
	.60	131.49	107.63	3.57	0.79	7	0
	.70	177.90	127.55	3.25	0.96	4	0
	.80	252.00	0.00	4.00	0.00	1	0
	.90	252.00	0.00	4.00	0.00	1	0
6 weeks	.10	2.51	119.66	3.58	1.66	158	99
	.20	13.53	118.77	3.55	1.68	128	77
	.30	38.75	115.37	3.47	1.74	90	51
	.40	55.08	116.27	3.74	1.72	58	28
	.50	128.43	118.57	4.29	1.41	28	5
	.60	178.02	107.36	4.63	1.15	16	0
	.70	218.93	107.32	4.60	1.35	10	0
	.80	288.30	74.17	5.25	0.96	4	0
	.90	260.40	59.84	5.00	1.00	3	0

8 weeks	.10	12.79	144.35	4.50	2.22	207	120
	.20	26.81	144.55	4.53	2.26	170	92
	.30	42.64	117.49	4.41	2.32	117	57
	.40	67.53	114.19	4.60	2.21	75	30
	.50	135.03	110.64	5.21	1.92	39	5
	.60	181.51	98.19	5.41	1.65	22	0
	.70	223.24	92.27	5.43	1.79	14	0
	.80	288.30	74.17	5.25	0.96	4	0
	.90	260.40	59.84	5.00	1.00	3	0
10 weeks	.10	16.09	145.47	5.44	2.81	255	140
	.20	32.11	144.40	5.45	2.81	209	106
	.30	53.07	121.65	5.33	2.87	143	64
	.40	87.04	115.38	5.59	2.80	94	30
	.50	146.07	105.00	6.18	2.45	51	5
	.60	184.15	93.27	6.50	2.33	30	0
	.70	219.47	82.77	6.81	2.48	21	0
	.80	266.04	81.26	6.20	2.28	5	0
	.90	239.55	64.24	6.25	2.63	4	0
12 weeks	.10	18.79	144.79	6.27	3.32	296	155
	.20	36.42	142.69	6.20	3.29	239	115
	.30	56.17	122.72	6.14	3.39	165	70
	.40	94.26	112.56	6.52	3.34	112	30
	.50	150.35	102.97	6.90	2.93	59	5
	.60	181.67	89.53	7.31	2.81	36	0
	.70	208.71	83.50	7.56	2.87	25	0
	.80	251.10	71.12	7.71	3.20	7	0
	.90	239.55	64.24	6.25	2.63	4	0

TABLE 7, STRATEGY 3 (cont.)

Buy All Contracts When Investment Will Not Exceed:	Alpha (Percentage)	Average Return (Dollars)	Standard Deviation of Return	Average Investment Period (Weeks)	Standard Deviation of Investment Period	Number of Contracts	Number of Negative Contracts
14 weeks	.10	22.35	146.45	7.36	4.02	349	176
	.20	41.04	140.37	7.15	2.94	275	125
	.30	60.61	122.18	7.36	4.14	198	78
	.40	99.68	110.57	7.78	4.05	137	32
	.50	150.75	99.13	8.23	3.73	74	5
	.60	177.02	85.75	8.65	3.59	46	0
	.70	194.33	84.31	8.71	3.51	31	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
16 weeks	.10	34.41	210.81	8.37	4.63	398	191
	.20	42.17	136.95	8.16	4.59	313	136
	.30	62.55	118.91	8.37	4.72	226	84
	.40	97.69	107.20	8.89	4.63	160	36
	.50	140.87	101.07	9.39	4.35	88	9
	.60	171.84	84.19	9.78	4.17	55	0
	.70	187.19	86.49	9.12	3.78	33	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
18 weeks	.10	44.19	249.63	9.27	5.17	442	205
	.20	42.06	133.48	9.20	5.23	352	148
	.30	62.14	116.09	9.47	5.33	257	91
	.40	94.65	104.63	10.01	5.20	184	40
	.50	133.36	101.19	10.50	4.92	102	12
	.60	167.69	84.08	10.78	4.70	63	0
	.70	180.38	86.69	9.81	4.29	36	0
	.80	243.50	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0

20 weeks	.10	46.47	242.26	10.07	5.67	479	216
	.20	46.06	131.77	10.03	5.75	383	155
	.30	65.66	115.61	10.39	5.85	283	96
	.40	93.67	103.27	10.99	5.71	205	44
	.50	133.05	98.03	11.53	5.46	115	12
	.60	164.02	83.54	11.76	5.23	71	0
	.70	182.66	85.54	10.54	4.85	39	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
22 weeks	.10	46.22	234.36	10.98	6.26	521	230
	.20	46.75	129.99	10.86	6.29	413	163
	.30	64.87	113.49	11.26	6.36	207	102
	.40	90.91	101.91	11.96	6.25	226	49
	.50	127.68	95.63	12.82	6.11	132	13
	.60	159.29	83.96	12.53	5.69	77	0
	.70	182.66	85.54	10.54	4.85	39	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
24 weeks	.10	44.86	227.60	11.96	6.89	565	245
	.20	46.36	127.37	11.75	6.88	444	173
	.30	64.19	112.52	12.18	6.93	332	109
	.40	88.56	102.43	12.90	6.77	246	54
	.50	124.55	93.93	13.63	6.51	143	13
	.60	157.91	82.82	12.95	5.97	80	0
	.70	179.71	84.74	11.17	5.51	41	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0

TABLE 7, STRATEGY 3 (cont.)

Buy All Contracts When Investment Will Not Exceed:	Alpha (Percentage)	Average Return (Dollars)	Standard Deviation of Return	Average Investment Period (Weeks)	Standard Deviation of Investment Period	Number of Contracts	Number of Negative Contracts
26 weeks	.10	42.23	221.79	12.94	7.50	609	261
	.20	44.37	125.87	12.59	7.43	473	183
	.30	61.27	111.60	13.05	7.46	355	117
	.40	86.42	101.11	13.62	7.20	261	57
	.50	121.96	92.26	14.41	6.96	153	13
	.60	155.45	83.28	13.26	6.21	82	0
	.70	179.71	84.74	11.17	5.51	41	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
28 weeks	.10	41.08	218.44	13.43	7.90	635	268
	.20	43.71	124.80	13.22	7.87	494	188
	.30	59.51	110.79	13.67	7.86	371	121
	.40	84.80	99.93	14.23	7.59	273	58
	.50	119.13	91.14	15.06	7.36	161	13
	.60	154.56	83.17	13.43	6.38	83	0
	.70	179.71	84.74	11.17	5.51	41	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
30 weeks	.10	39.48	215.22	14.18	8.35	662	282
	.20	41.97	123.43	13.91	8.37	516	199
	.30	56.86	110.09	14.44	8.39	390	131
	.40	81.16	99.85	15.02	8.13	288	65
	.50	116.90	90.21	15.65	7.75	168	13
	.60	153.15	83.17	13.81	6.76	85	0
	.70	179.71	84.74	11.71	5.51	41	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0

32 weeks	.10	43.70	230.81	14.82	8.82	687	294
	.20	48.21	159.13	14.54	8.84	535	207
	.30	60.38	127.99	15.07	8.84	405	137
	.40	79.50	99.73	15.57	8.52	298	69
	.50	115.57	90.01	16.20	8.14	174	14
	.60	152.90	82.71	14.01	6.97	86	0
	.70	179.71	84.74	11.17	5.51	41	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
34 weeks	.10	49.15	247.13	15.50	9.34	713	307
	.20	53.52	186.63	15.12	9.30	552	215
	.30	60.01	127.56	15.33	9.05	411	140
	.40	79.98	99.98	15.81	8.70	302	71
	.50	115.80	89.90	16.39	8.28	176	14
	.60	152.51	82.63	14.44	7.46	88	0
	.70	180.50	83.86	11.69	6.40	42	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
36 weeks	.10	48.81	247.47	15.99	9.74	731	317
	.20	54.36	190.01	15.49	9.61	562	221
	.30	59.04	127.35	15.67	9.33	418	145
	.40	78.04	100.44	16.13	8.98	307	74
	.50	116.08	89.85	16.60	8.48	178	14
	.60	153.29	82.49	14.69	7.76	89	0
	.70	180.50	83.86	11.69	6.40	42	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0

TABLE 7, STRATEGY 3 (cont.)

Buy All Contracts When Investment Will Not Exceed:	Alpha (Percentage)	Average Return (Dollars)	Standard Deviation of Return	Average Investment Period (Weeks)	Standard Deviation of Investment Period	Number of Contracts	Number of Negative Contracts
38 weeks	.10	48.37	246.73	16.39	10.07	745	326
	.20	54.00	190.39	15.98	10.05	575	229
	.30	59.96	130.06	16.13	9.76	427	149
	.40	79.28	105.85	16.40	9.24	311	76
	.50	118.30	99.08	16.84	8.73	180	15
	.60	159.02	98.40	14.94	8.10	90	0
	.70	180.50	83.86	11.69	6.40	42	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0
40 weeks	.10	48.39	246.30	16.48	10.16	748	327
	.20	53.99	189.99	16.10	10.16	578	230
	.30	59.90	129.80	16.29	9.91	430	150
	.40	79.28	105.85	16.40	9.24	311	76
	.50	118.30	99.08	16.84	8.73	180	15
	.60	159.02	98.40	14.94	8.10	90	0
	.70	180.50	83.86	11.69	6.40	42	0
	.80	243.56	69.21	8.38	3.50	8	0
	.90	229.80	59.75	7.60	3.78	5	0

TABLE 8
NUMBER OF INVESTMENTS AND AVERAGE RETURNS BY YEAR, 14-WEEK HOLDING PERIOD, 50-PERCENT ALPHA LEVEL (STRATEGY 3)

Year	Number of Investments	Returns
1964	10	$ 59.60
1965	7	144.43
1966	2	288.00
1967	0	0.00
1968	0	0.00
1969	3	65.00
1970	37	186.97
1971	15	99.24

spreads while at the 40-percent alpha level in the 40-week holding period losses were in only 24 percent of total spreads.

Again, these averages may be misleading. For example, in Table 7 we see that with a maximum holding period of 14 weeks, at alpha equal 50 percent, average returns would have been $150.75 and a total of 74 spreads undertaken (an average of almost 10 per year). The actual distribution of returns and spreads is seen in Table 8.

Although the investor would have earned positive returns in each year when spreads were possible, average returns were higher than $150.75 only in 1966 and 1970. Also, the spreads are not evenly distributed over the years as none were possible in 1967 and 1968, while half of the total would have been undertaken in 1970.

Strategy Selection

Investors differ as to risk aversion and acceptable investment horizons. Thus, selecting which variation of the final set of trading rules is the optimal guide for investors is impossible. As risk aversion increases, investors opt for higher and higher levels of alpha until finally at alpha equal 1.0, an investor would be operating in a risk-free environment. Also, his perceived investment horizon would affect the maximum number of weeks over which an investment could be held.

Some general comments can be made as to which variation would be most appealing to the "average" investor of modest means whose potential investment horizon reaches to at least 40 weeks. The 2- and 4-week holding periods should probably have been ignored because returns were negative in most cases and where positive, few investment opportunities existed. For holding periods ranging from 6 to 40 weeks, alpha levels of 10 or 20 percent should have been avoided because when the number of opportunities was of the size an investor could manage, returns (though positive) were low. Then when the average returns were relatively large, the number of investment opportunities became so large as to be beyond the grasp of all but the wealthy investor. At alpha levels of 70 percent and above, returns were large but investment opportunities over the 7½-year period would have been strictly limited. This leaves us with the spectrum of alpha from 40 through 60 percent and holding periods of 6 to 40 weeks. Many investors may also consider the 40-percent variation inferior to the remaining two. For instance, at 40 percent the greatest average returns, $99.68, occurred when the holding period was restricted to 14 weeks or less. These criteria have selected 137 spreads. However, when an alpha of 50 percent and 22-week maximum is selected, average returns reach $127.68 over 132 spreads. For this latter strategy, the number of opportunities would have been nearly the same as in the former while substantially higher returns would have been realized. Alpha levels of 50 to 60 percent and maximum holding periods of 16 to 40 weeks would seem to be most acceptable for the average investor.

The beauty of Strategy 3 may lie not in selecting the optimal strategy for the average investor but rather in showing that positive returns could have been earned by investors with widely differing investment criteria. The three strategies show that investors could have specified a variety of investment constraints over a relatively long period of time and earned positive returns, on the average, that would have been risk-free. While these spreads would not have been risk-free, the investor could have predetermined his maximum loss at some satisfactory level and prevented the chance of a catastrophic loss. The individual investor must decide whether the rate earned in excess of the risk-free rate would have been enough to compensate for the level of risk accepted.

Results of Selective-Spread Combinations

Results of an investigation of the popularity and profitability of the individual combinations of contracts are shown in Tables 9 and 10 for Strategies 1 and 2 at the 10- and 50-percent alpha levels.

In all except the 50-percent alpha level of Strategy 2, the combinations selected most often were May-July and March-May. For Strategy 1, at the 10-percent alpha level these two spreads account for 39 percent of the total spreads. For Strategy 2 at the 10-percent and 50-percent alpha levels, these two spreads account respectively for 30 percent and 43 percent of the total. Strategy 1 at the 50-percent level has the March-May and March-July spreads making up 47 percent of all contracts spread.

Combinations with the highest percent of returns above $100 for Strategy 1 at an alpha of 10 percent were February-May, February-August, and March-August. Fifty percent (77/154) of these spreads

TABLE 9
STRATEGY 1: PROFITABILITY OF PARTICULAR SPREADS AT VARIOUS ALPHA LEVELS

Alpha Level	Spread	Loss of $50 or More	Loss of 0–$49.99	Gain of $.01–$100	Gain of $100.01–$200	Gain of $200.01–$300	Gain of $301.01 or More	Totals
10-percent	February–March	0	1	31	2	1	6	41
	February–May	23	6	8	9	18	10	74
	February–July	11	9	13	16	6	0	55
	February–August	2	5	6	10	3	0	26
	March–May	48	15	69	9	4	0	145
	March–July	41	3	26	31	9	2	112
	March–August	2	4	21	11	13	3	54
	May–July	79	27	32	1	2	6	147
	May–August	27	8	6	5	1	0	47
	July–August	10	6	18	11	0	2	47
	Totals	243	84	230	105	57	29	748
50-percent	February–March	0	0	1	2	1	1	5
	February–May	0	0	0	2	16	4	22
	February–July	0	1	6	13	1	0	21
	February–August	0	0	0	1	3	0	4
	March–May	0	0	41	1	3	0	45
	March–July	0	0	13	23	4	0	40
	March–August	0	0	0	8	0	2	10
	May–July	0	5	16	1	1	0	23
	May–August	0	5	0	0	0	0	5
	July–August	0	4	0	0	0	1	5
	Totals	0	15	77	51	29	8	180

TABLE 10

STRATEGY 2: PROFITABILITY OF PARTICULAR SPREADS AT VARIOUS ALPHA LEVELS

Alpha Level	Spread	Loss of $50 or More	Loss of 0–$49.99	Gain of $.01–$100	Gain of $100.01–$200	Gain of $200.01–$300	Gain of $301.01 or More	Totals
10–percent	February–March	0	0	3	0	0	1	4
	February–May	2	0	1	0	1	2	6
	February–July	2	0	1	1	0	1	5
	February–August	1	0	1	1	0	0	3
	March–May	3	0	1	2	1	0	7
	March–July	2	0	1	2	1	0	6
	March–August	0	0	3	1	0	1	5
	May–July	2	2	1	0	1	1	7
	May–August	0	2	1	0	0	0	3
	July–August	1	0	0	1	0	1	3
	Totals	13	4	13	8	4	7	49
50–percent	February–March	0	0	1	1	0	1	3
	February–May	0	0	0	1	0	0	1
	February–July	0	0	1	0	0	0	1
	February–August	0	0	0	0	1	0	1
	March–May	0	0	4	0	2	0	6
	March–July	0	0	1	1	0	0	2
	March–August	0	0	0	1	0	1	2
	May–July	0	1	2	0	1	0	4
	May–August	0	1	0	0	0	0	1
	July–August	0	1	0	0	0	1	2
	Totals	0	3	9	4	4	3	23

showed returns exceeding $100. At the 50-percent level for Strategy 1, the most profitable spreads were again the three listed above. All such spreads undertaken at this alpha level showed returns above $100. For Strategy 2, at the 10-percent level, the most favorable combinations of spreads were February-May, March-May, and March-July. Fifty percent of the February-May and March-July spreads and 43 percent of the March-May spreads showed returns exceeding $100. Strategy 2, at the 50-percent level, showed the same contract months found under Strategy 1 to be most profitable. In this case, 100 percent of the returns were greater than $100 (although a total of only four spreads were taken in these combinations).

The worst combinations for spreads under Strategy 1, at the 10-percent alpha level, were May-August where 57 percent of the contracts had losses of more than $50; May-July with 57 percent having losses greater than $50; and March-May and March-July each showing one-third of the contracts losing $50 or more. At the 50-percent level under Strategy 1, no contracts showed losses greater than $50 but 100 percent of the May-August spreads and 80 percent of the July-August spreads were losses. Twenty-two percent of the May-July investments showed negative returns. Under Strategy 2, at the 10-percent level, March-May contracts suffered losses 43 percent of the time while May-July and May-August incurred losses 57 percent and 67 percent of the time respectively. At the 50-percent level, Strategy 2 incurred its worst losses in the May-August and July-August spreads.

For the best spreads, the average number of months between the long and short contracts was 5 while the number of months between the long and short contracts for the worst spreads was 1.8. An overall appraisal of the empirical data seems to indicate that those spreads with the greatest time span showed higher profits. Also, the higher returns were often earned when the long portion of the spread was a February contract.

SUMMARY

Structure of the Study

The purpose of this study was to examine investment strategies in commodity futures contracts that reduce the risk to which the investor exposes himself and still afford him the opportunity to earn "reasonable" profits. There are essentially two ways of accomplishing this goal:

1. Have the investor purchase futures contracts on higher margin immediately reducing both the rates of returns and the variation of these rates of returns (risk). This approach was dismissed because of the large

dollar investment required and the belief that few investors have the means to diversify with this strategy.

2. Utilize the commodity spread. Spreading essentially involves purchase of a near-term contract and the simultaneous sale of a more distant contract. This is typically undertaken when the distant is priced over the near by some amount that approaches the transaction and storage costs which must be covered to run a risk-free arbitrage operation. This was the approach examined in this paper.

The commodity-spread approach has two features which allow for a satisfactory method of reducing risk:

1. Investors can predetermine their maximum loss or, conversely, have the ability to prevent catastrophic loss. A distant contract will rarely sell over a near contract by more than the total of transaction and storage costs, so the investor knows the maximum premium that may exist.

2. Spreads can be undertaken on reasonably small margins providing most investors with the ability to diversify with more than one spread at any point in time (or at least the ability to have a small percentage of their funds invested in any one commodity spread at any point in time).

Three strategies involving spreads were tested here:

Strategy 1 involved investing in every combination of spreads in which the distant contract sold at some percent, alpha, or more, of transaction and carrying charges. This strategy permits taking multiple spreads in the same combination of contracts.

Strategy 2 utilized the same rules as Strategy 1 but did not permit more than one spread in the same combination of contracts. Once a particular combination of contract months had been spread, no other similar investments were permitted.

Strategy 3 involved retesting Strategy 1 subject to maximum holding periods. In other words, all combinations of contracts were spread, as long as the price premium exceeded the alpha requirement, and as long as the investment would not be held for more than some predetermined number of weeks. Multiple holdings of the same spread were again permitted under Strategy 3.

All three strategies are purely mechanical in nature. No assumption is made about the "fairness" of current price levels of the commodity contracts nor about the direction of prices in the future.

Results and Biases of the Study

The results indicate that spreading in frozen pork bellies would have resulted in positive returns under almost every variation of all three strategies. A total of 198 different variations were tested and negative results occurred in only seven cases. Under Strategy 1, returns varied from $48.39 at the 10-percent alpha level where 748 spreads were undertaken to a high of $243.56 at the 80-percent alpha level where 8 combinations were spread. Under Strategy 2, the lowest average return was $109.07, at an alpha of 40 percent where 29 spreads occurred. The highest was $256.26 at the 80-percent alpha level for 5 spreads. The worst results occurred under Strategy 3 on an alpha of 20 percent when the investment period could not exceed 2 weeks. The result was a negative $33.94 over 40 spreads. The best results under Strategy 3 occurred at an alpha level of 80 percent when the holding periods were restricted to 6 weeks and less, or 8 weeks and less. The average return for these variations was $288.30 for 4 spreads.

Obviously, spreads in frozen pork bellies would have, on the average, been profitable investments while, at the same time, the investor had personally regulated the maximum size of his potential loss. No doubt investors could have earned rates of return between 15 percent and 20 percent for many of the strategies if they had margined their spreads at $1,000 each and had invested idle funds at a rate of 4 percent (maximum amount payable on savings deposits during most of the period studied). Results of testing back data are *not* necessarily indicative of returns which may be earned in the future. Some changes may have occurred in the structure of market prices and price trends that preclude positive returns via such strategies.

While the average results were almost unanimously positive, some problems may still exist in using spreads as a regular investment medium. For instance, there is a problem in data bias. Averages were taken in computing closing prices so the range of returns would probably have been wider than we have seen here. There would have been more spreads with higher returns and more losses (but none in excess of the predetermined maximum). Thus, results dealing with the number of losses and the standard deviation of returns may be biased downward. However, there is no reason to believe that any bias exists in the average figures. Another problem is that for Strategies 1 and 3, the number of spreads undertaken in any given year varied dramatically and returns varied widely from one year to the next. The investor who insisted on a regular stream of investment opportunities would have been better off under Strategy 2. The variance in yearly returns may simply indicate that investors must be willing to have the patience for a long-run investment strategy.

Implications for Future Research

The two most important areas for future research would seem to be: investigations that attempt to explain the wide variation of investment opportunities over the 7½ year period and those that can explain the variance in profitability from one year to the next. Also, it would be interesting to see if general results found here for frozen pork bellies are indicative of opportunities for profitable investment in spreads in other commodities or across other commodities such as spreads between frozen pork bellies and contracts in hogs. Finally, a study of the historical returns on reverse spreads could prove interesting.

APPENDIX 1

Strategy 1: Number of Investments by Year and Alpha Level

	Alpha (Percentage)								
Year	.10	.20	.30	.40	.50	.60	.70	.80	.90
1964	128 (53)[a]	126 (53)	119 (52)	94 (34)	40 (9)	2 (0)	—	—	—
1965	95 (45)	73 (42)	45 (28)	25 (13)	12 (5)	3 (0)	2 (0)	—	—
1966	57 (36)	33 (18)	12 (4)	9 (1)	5 (0)	3 (0)	2 (0)	2 (0)	2 (0)
1967	85 (35)	48 (22)	23 (11)	13 (9)	2 (0)	1 (0)	1 (0)	—	—
1968	104 (77)	49 (32)	21 (16)	7 (5)	2 (0)	2 (0)	1 (0)	—	—
1969	38 (28)	29 (20)	16 (10)	8 (3)	4 (0)	4 (0)	2 (0)	—	—
1970	181 (24)	169 (20)	150 (11)	131 (5)	98 (0)	66 (0)	31 (0)	4 (0)	1 (0)
1971	60 (29)	51 (23)	44 (18)	24 (6)	17 (1)	9 (0)	3 (0)	2 (0)	2 (0)
Totals	748 (327)	578 (230)	430 (150)	311 (76)	180 (15)	90 (0)	42 (0)	8 (0)	5 (0)

[a] Numbers in parentheses indicate number of spreads having negative returns.

APPENDIX 2

Strategy 2: Number of Investments by Year and Alpha Level

Year	Alpha (Percentage) .10	.20	.30	.40	.50	.60	.70	.80	.90
1964	7 (3)[a]	7 (3)	7 (3)	7 (3)	6 (3)	2 (0)	—	—	—
1965	6 (0)	3 (0)	2 (0)	0 (0)	0 (0)	1 (0)	2 (0)	—	—
1966	9 (5)	9 (5)	5 (2)	4 (1)	3 (0)	2 (0)	1 (0)	1 (0)	1 (0)
1967	7 (1)	6 (1)	6 (1)	4 (1)	2 (0)	1 (0)	1 (0)	—	—
1968	8 (4)	6 (3)	6 (4)	4 (3)	1 (0)	1 (0)	1 (0)	—	—
1969	3 (0)	2 (0)	2 (0)	1 (0)	3 (0)	3 (0)	1 (0)	—	—
1970	9 (4)	9 (4)	8 (3)	8 (2)	8 (0)	5 (0)	4 (0)	3 (0)	1 (0)
1971	—	—	1 (0)	1 (0)	—	0 (0)	1 (0)	1 (0)	1 (0)
Totals	49 (17)	42 (16)	37 (13)	29 (10)	23 (3)	15 (0)	11 (0)	5 (0)	3 (0)

[a] Numbers in parentheses indicate number of spreads having negative returns.

Section 2: Forward-Pricing Efficiency

Forward pricing has always been an important economic role of the commodity futures market, but featuring it in published research has occurred mainly since the introduction and trading success of nonstorable commodities. For storable commodities, an analysis of forward pricing is generally tied to the inventory allocation process, and forward prices and the current cash price are viewed as being within a constellation. The set of current and forward prices is linked by storage costs, and their level is interpreted as that price which will allocate the inventory throughout the crop year.

For nonstorable commodities the allocation process is less direct, so the forward-pricing role is the research focal point. The set of current and forward prices is not viewed as within a single constellation, but in many cases the prices are considered independent of each other. Hence, there is a rapidly growing body of literature concerned with the forward-pricing ability of futures markets. Such research comes under the titles of market efficiency, market performance, and forward-pricing accuracy; much of it is reviewed by Leuthold and Hartmann (1979).

Parallel to this commodity futures-market literature, another body of literature has been developed by financial analysts and macroeconomists investigating the efficiency of forward-exchange and interest-rate markets. Although the jargon varies between the two sets of literature, the basic hypotheses and methodological approaches are often identical. Surely, in a few short years these efforts will be more closely linked, and hopefully, this anthology will contribute to that process.

Many of the commodities possessing characteristics that attract tests of forward-pricing efficiency are traded on the Chicago Mercantile Exchange. So, an emphasis on this subject among this set of fellowship papers is not surprising. In this section, papers by Panton and Joy, and Levich test the efficiency of the international-currency futures market, while Marquardt compares the forward-pricing ability of agricultural futures markets with public "outlook" advice. Folks and Stansell are concerned indirectly with futures markets, attempting to ascertain if pending exchange-rate changes can be detected in advance.

In the finance literature, concern with the efficiency of forward-exchange markets dates back to the early 1800s, as documented by Levich. The one article that most carefully distinguishes among different approaches to studying market efficiency, and is a focal point for recent empirical work, is by Fama (1970). He classified empirical tests into "weak form," "semi-strong form," and "strong form," terms now widely used by foreign-currency and financial-instrument analysts. Although applicable, these terms have not received much attention by agricultural economists.

In the agricultural literature, Working (1949) first wrote about economic expectations and futures markets. He coined the phrases "necessary inaccuracy" and "objectionable inaccuracy." Necessary inaccuracy refers to that forward-pricing error due to the lack of information, which comes randomly, making this error unpredictable. Objectionable inaccuracy is the remaining portion of the total error, and might result from poor quality speculation, inability to assess or react to information, a market imbalance, or possibly even manipulation. It may be possible to predict this error.

These phrases have not received much attention, despite the possibility of distinguishing empirically between the two inaccuracies. Many studies in the finance literature of the efficient-market hypothesis essentially test for the existence of objectionable inaccuracy. Most of the tests of market efficiency on agricultural commodities have been of the "weak form" type. (See references in Section 1, Price Behavior.) These studies usually investigate whether a historical price series is random or not. Leuthold and Hartmann (1979) provide an initial attempt to combine terminology and hypotheses from financial and agricultural economics literature, and perform a "semi-strong form" test of the live-hog futures market. More "semi-strong form" tests are needed to ascertain if markets utilize all of the available information and only necessary inaccuracy exists.

Also in this section, Panton and Joy may be one of the first to investigate the performance of international-currency futures contracts such as those traded on the International Monetary Market of the Chicago Mercantile Exchange. Specifically, they examine: 1) whether currency-futures prices are consonant with the interest rate parity theorem; 2) whether currency-futures prices are biased; and 3) what has been the holding-period return of currency futures. In examining futures contracts for eight currencies, they find mixed results concerning whether currency-futures prices are at a level that would be predicted from the interest rate parity theorem. Only the Mexican peso exhibits a significant bias in its futures price, while with the use of a simple model, the returns to speculators from the long side were not, in most cases, significantly different from zero over the data tested.

Levich tests the efficiency, or performance, of international-money markets. The prices in these markets contain information for forecasting future spot-exchange rates. The efficient-market hypothesis states that market prices reflect all available information. Using data from nine countries and the United States, Levich tests the accuracy of exchange-rate forecasts implied by the market prices and finds that the markets efficiently reflect available information concerning future exchange rates. However, a composite forecasting model can reduce forecast errors. Since the markets are efficient, forecasts based on publicly available information do not lead to unusual profits in forward speculation.

Marquardt, also concerned with information, tests whether the futures market forward prices more accurately than "outlook letters" disseminating from commercial advisory services, government, and land-grant college sources. The gathering of this information is costly to the individual. In general, Marquardt found futures markets give more accurate information both in terms of average deviation errors and in direction of change. Most importantly, futures markets provide more frequent and timely information about future conditions than do alternative information sources. These tests are made with the wheat, corn, soybeans, cattle, and hog futures contracts.

Folks and Stansell, while being concerned with exchange-risk management by U.S. corporations with overseas investments, attempt to ascertain if the statistical technique, multiple discriminant analysis, is of any value in providing an early warning of impending exchange-rate changes. Using readily available macroeconomic data for 38 countries, they find the technique useful in discriminating between potentially devaluing and nondevaluing countries. Apparently, the data contain substantial information warning of future exchange-rate changes. This information can be valuable to corporate exchange-risk managers attempting to minimize risk exposure when assets are held in several currencies.

Missing from this set of papers is any reference to the tie between market efficiency and rational expectations, a relationship that has important theoretical and empirical bearing on research. Articles by Hamburger and Platt (1975), and Cargill (1975) will introduce the reader to that literature and locate citations to important works.

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Empirical Evidence on International Monetary Market Currency Futures

Don B. Panton and O. Maurice Joy

INTRODUCTION

This paper empirically investigates three questions concerning currency futures traded on the International Monetary Market (IMM) of the Chicago Mercantile Exchange: 1) Are currency futures prices consonant with the interest rate parity theorem? 2) Does a characteristic bias exist in the currency futures prices? 3) What has been the holding period return experience of currency futures since their inception on the IMM?

One of the uncertainties in international business is that which is associated with the future currency exchange rate between the domestic currency and the currency of the foreign country. When an agreement calls for a future cash flow in a foreign currency, economic agents may ultimately face an exchange rate quite different from the one in effect at the time the agreement was signed. One method of hedging against this uncertainty is through the use of currency futures contracts that are traded on the International Monetary Market of the Chicago Mercantile Exchange.

Another alternative open to the hedger is to enter into a "forward" contract with the foreign-exchange department of a bank. In theory, there is little difference between a forward contract and a futures contract. As a practical matter, however, there are some considerable differences. For example:

1. Regulation — The forward market is self-regulating; the futures market is regulated by the Commodity Futures Trading Commission.
2. Price fluctuations — The forward market has no daily limit on price fluctuations; the futures market has a daily limit imposed by the exchange.

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3. Frequency of delivery — More than 90 percent of forward contracts are settled by actual delivery; less than 1 percent of the IMM futures contracts are settled by delivery.
4. Accessibility; Size of contract — Individually tailored contracts in the forward market tend to be much larger than the standardized contract on the futures market.

Each market offers some advantages not available in the other. Since the forward market has enjoyed recent examination,[1] we direct our study to the relatively neglected IMM futures market.

A currency futures contract is an agreement to buy and receive or to sell and deliver a quantity of a specified currency at a future date. The exchange rate that will be in effect at that future date, for the purposes of the futures contract, is determined at the time of contract acceptance. This "contract price" or futures price is binding on both parties to the agreement. Since the currency futures contract represents an example of a zero-sum game (at least in terms of monetary reward), except for transaction costs, any gains reaped by one of the two parties to the transaction are the losses of the other party.

As indicated, we are concerned with three empirical questions in this paper. The first is a test of the interest rate parity theorem, which maintains that, in the absence of transaction costs and exchange accessibility restrictions,[2] the following relation[3] must hold:

$$F_i = S_i(1 + r_d)/(1 + r_i) \tag{1}$$

where F_i = futures price of one unit of foreign currency i, quoted in units of the domestic currency

S_i = spot price of one unit of foreign currency i, quoted in units of the domestic currency

r_d = present domestic interest rate on risk-free instruments with maturity equal to that of the relevant futures contract, and

r_i = present interest rate in foreign country i on risk-free instruments with maturity equal to that of the relevant futures contract.

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[1] See, for example: Kohlhagen (1975), Giddy and Dufey (1975), Kaserman (1973), and Brown (1971).

[2] Exchange accessibility restrictions include all capital movement prohibitions contemporaneous with the initial contracting and the risk of the imposition of any such restrictions during the remaining life of the contract.

[3] See, for example, the discussions in Sharpe (1978), and Rodriguez and Carter (1976). Some may object to the causal relationship implied by Equation 1. We recognize that the equilibrating process permits simultaneous adjustment of all four variables. However, interest rates are not particularly sensitive to foreign arbitrage operations; rather, they are predominantly determined by domestic transactions and monetary policies. Similarly, spot rates are most influenced by trade demands and government influences.

In our study, the domestic country is the United States. Proponents of this theory argue that if interest rate parity did not hold, riskless arbitrage transactions would be possible. The theory yields a succinct linking of the futures price with three explanatory variables; no variables other than the spot price and two interest rates are recognized as having any direct effect whatsoever.[4]

The second question addressed in this study is directed at the relation between the magnitudes of: 1) contract prices for currency futures prior to maturity, and 2) contract prices for the same obligations on the last day of trading for that specific contract. If the futures price on a currency contract is determined to be systematically greater or less than the contract price which occurs on the last day of trading, we shall conclude that a bias exists. Thus, our definition of bias is a tendency of the currency contract price observed prior to the last day of trading to deviate systematically in one direction from the contract price on the last day of trading. In an economic environment where international cash flows are increasingly prominent, knowledge of a contract price bias in currency futures is important to several groups. Financial officers of corporations that have a policy of avoiding exchange-rate risk may wish to re-examine that policy if the costs of hedging in currency futures outweigh the benefits. Speculators who require an expected return as payment for absorbing variance are interested in determining the magnitude of any possible return bias and whether that bias exists on the long or short side of the futures transaction.

Then, we summarize the rate of return evidence on IMM futures contracts that has accumulated since origination of this market. That section of the paper is purely descriptive of investor experience over the study period.

The next section of the paper discusses the data employed. The following section is devoted to methodology and presentation of results, and the last section summarizes the paper.

DATA

The primary data used in this study consist of three sets of observations covering the period June 18, 1972 to December 15, 1976. These data — futures prices, spot prices, and open-market interest rates — are described in detail below:

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[4] Frenkel and Levich (1975) concluded that, during the period 1962-1967, empirical data were consistent with the interest rate parity theorem and that covered interest arbitrage did not permit profit opportunities.

A. Futures prices. The eight foreign currencies represented in the study were:

1. British pound (BP)
2. Canadian dollar (CD)
3. German mark (GM)
4. Dutch guilder (DG)
5. French franc (FF)
6. Japanese yen (JY))
7. Mexican peso (MP)
8. Swiss franc (SF)

The futures quotes were settlement prices at five points in the lives of the futures contracts: contract maturity; and twelve months, nine months, six months, and three months prior to contract maturity. All such dated settlement prices were supplied by the Chicago Mercantile Exchange.

B. Spot prices. These exchange prices were noon selling rates in New York for cable transfers, collected from issues of the *Wall Street Journal.* The dates of the spot-exchange prices correspond to those of the forward prices in (A).

C. Interest rates. These are open-market rates on low-risk debt instruments in the U.S. and in six foreign countries. In the cases of Canada, the United Kingdom, and the Netherlands, these yields were based upon average returns on three-month treasury bills. The figures for West Germany were based upon average returns on 60- to 90-day treasury bills; yields for France and Japan were average money market rates for securities maturing in less than one year. Interest rate data on the U.S., Canada, the United Kingdom, West Germany, and the Netherlands were collected from monthly issues of the *Federal Revenue Bulletin;* interest rate data on France and Japan were collected from monthly issues of *International Financial Statistics.*

This particular portion of our primary data — that is, interest rates in the foreign countries — is, admittedly, somewhat lacking in precision. First, the foreign rates are monthly averages, not daily quotes. We would have preferred to have had the rates which were available on the corresponding days of the futures quotes in (A). Second, for the most part, interest rate yields in the foreign countries were for instruments having one specified maturity — usually three months. Optimally, a test of the interest rate parity theorem calls for yields on risk-free securities having maturities corresponding perfectly with those of the futures contracts in (A).

EMPIRICAL EVIDENCE

The Interest Rate Parity Theorem

The interest rate parity theorem maintains that, in equilibrium, the forward-exchange price for currency i, the spot price for currency i, the domestic interest rate, and the foreign interest rate are related according to Equation 1 in the previous section. When Equation 1 is satisfied, there exist no profit opportunities from covered interest arbitrage. Strictly speaking, however, the theory requires that there be zero transaction costs and no access restrictions to exchange-rate markets either now (at initial contract time) or in the future (during contract life). Observed, significant deviations from the interest rate parity theorem would indicate that there are substantial transaction costs, governmental controls[5] to market access, a time differential between observing a profit opportunity and executing the arbitrage activity, differential tax treatments,[6] or inexact interest rate and spot-exchange-rate data.

If the interest rate parity theorem holds, we would expect to see close congruence between actual (observed) futures prices traded on the IMM and predicted futures prices, where the prediction is via the interest rate parity theorem.

Let $AF_{i,k}$ = actual IMM futures price of currency i contract with k months remaining until contract maturity

$PF_{i,k}$ = predicted IMM futures price of currency i contract with k months remaining until contract maturity.[7]

then the interest rate parity theorem says:

$$u_{i,k} = 0$$

where $u_{i,k} = AF_{i,k} - PF_{i,k}$.

If $u_{i,k}$ is significantly different from zero, then there must be either substantial transaction costs associated with exchange or debt markets or there must be important accessibility blockages or risk of future blockage.

Table 1 presents evidence regarding the magnitude of these differences. Data are presented for only six of the eight foreign countries. Mexico and Switzerland were excluded because we were unable to find a series of weekly quotations for interest rates meeting the following two conditions: 1) the series covered the entire period of the study, and 2) the yields

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[5] Exchange restrictions in effect during the period 1972-1976 are detailed in the *Twenty-Third* through the *Twenty-Sixth Annual Report on Exchange Restrictions*, published by the International Monetary Fund.

[6] See, for example, Aliber (1973), and Frenkel (1973).

[7] PF is determined by Equation 1. That is,

$$PF_{i,k} = S_i\left(1 + \frac{r_{d,k}}{12}\right) \Big/ \left(1 + \frac{r_{i,k}}{12}\right).$$

TABLE 1

DEVIATIONS OF OBSERVED FUTURES EXCHANGE RATES [$AF_{i,k}$] FROM PREDICTED FUTURES EXCHANGE RATES [$PF_{i,k}$], BASED ON THE INTEREST RATE PARITY THEOREM

$$u_{i,k} = AF_{i,k} - PF_{i,k}$$

Currency		Number of Observations	Mean Difference ($)	Standard Deviation of Mean Difference ($)	t
British pound	12 month	12	−.0407	.0077	
	9 month	13	−.0302	.0070	
	6 month	15	−.0237	.0054	
	3 month	14	−.0186	.0042	−4.43
Canadian dollar	12 month	10	−.0066	.0033	
	9 month	13	−.0020	.0026	
	6 month	13	−.0007	.0012	
	3 month	14	.0003	.0006	.50
German mark	12 month	11	−.0009	.0016	
	9 month	16	.0014	.0013	
	6 month	15	.0014	.0012	
	3 month	14	.0007	.0009	.78
French franc	12 month	5	.0013	.0025	
	9 month	6	.0026	.0021	
	6 month	6	.0018	.0018	
	3 month	6	−.0031	.0022	−1.41
Japanese yen	12 month	7	.0001	.00007	
	9 month	8	.0001	.00004	
	6 month	10	.0001	.00006	
	3 month	12	.0000	.00003	.00
Dutch guilder	12 month	7	−.0043	.0022	
	9 month	10	−.0030	.0017	
	6 month	9	−.0023	.0015	
	3 month	10	−.0003	.0010	−.30

were on short-term, government-backed securities. As illustrated by the *t* values[8] in Table 1, the mean deviation is significantly different from zero (at the 5-percent α-level) only in the case of the three-month[9] futures contract on the British pound. This evidence implies that, in the

[8] Mean difference $= \mu_u = \sum_n u_{i,k}/n$, where n is sample size.

Standard deviation of mean difference $= \sigma_\mu = \sigma_u/n^{1/2} = \left[\sum_n (u_{i,k} - \mu_u)^2/(n-1)\right]^{1/2}/n^{1/2}$.

$t = \mu_u/\sigma_\mu$.

[9] No statistical tests are offered for the 6-, 9-, and 12-month futures since these observations cover overlapping time periods and are thus not independent.

case of the pound, futures prices derived through use of the interest parity theorem were systematically greater than observed futures prices.

Thus far we have only tested one implication of the interest rate parity theorem, namely, that the mean difference between actual and predicted futures prices is zero. Strictly speaking, that is not a sufficient test of the interest rate parity theorem. A test of mean difference is not sufficient because the actual arbitrage mechanism works with respect to individual contracts. Thus, there may be no statistical difference across all contracts, but there may be profitable arbitrage opportunities in one or more individual contracts. A more exhaustive test of the interest rate parity theorem would entail an analysis of each pair of actual and predicted prices.

Whereas even one instance of a discrepancy between actual and predicted futures prices would, in theory, refute the validity of the interest rate parity theorem, in actuality, the magnitude of any observed deviations must be compared with realistic transaction costs that are necessarily incurred in covered-interest arbitrage operations. That is, the existence of transaction costs implies that deviations of acual futures prices from predicted prices may be unimportant, if such deviations are circumscribed within the dimensions of the transactions "band" about the interest rate parity theorem predictions.

It is difficult to be precise with regard to the magnitude of total transaction costs in currency futures trading. However, commission costs (approximately $45 for a round trip) plus foregone interest on security deposit funds may justify a transaction costs band of approximately 85 percent of the spot value of currency represented in the futures contract.[10]

As shown in Table 2, we observed several points which lay outside this band. In fact, a few contract prices deviated from the interest rate parity line by nearly 5 percent of the monetary value of the contract unit. Clearly, these deviations are not consistent with the pure interest rate parity theorem, modified only by the introduction of transaction costs. We are not certain of the exact cause of observed points outside the transaction costs band. Extreme deviations from the interest rate parity line could result from many factors: differential tax treatment, governmental controls, time differential between observing a profit opportunity

[10] This calculation assumes an interest rate of 8 percent per year, a security deposit of 10 percent of the spot value of the contract unit, and a dollar value of approximately $80,000 for the contract unit. At best, the transaction costs estimates are extremely crude, not only because of the explicit assumptions about interest rate levels and dollar value of the contract, but also because the spot prices used are only "asked" prices, and because we implicitly presume that transactions can be achieved at the stated spot price, which is a 3:00 P.M. Eastern time zone price.

TABLE 2

FREQUENCY DISTRIBUTION FOR ABSOLUTE VALUES OF DEVIATIONS OF OBSERVED FUTURES EXCHANGE RATES $[AF_{i,k}]$ FROM PREDICTED FUTURES EXCHANGE RATES $[PF_{i,k}]$, EXPRESSED AS PERCENTAGES OF CURRENCY SPOT PRICES $[SP_i]$

$$\gamma_{i,k} = |[AF_{i,k} - PF_{i,k}]/SP_i|$$

Currency		Number of Observations	Percentages γ <1	1-3	>3
British pound	12 month	12	4	6	2
	9 month	13	6	7	
	6 month	15	6	9	
	3 month	14	10	4	
Canadian dollar	12 month	10	7	3	
	9 month	13	10	3	
	6 month	13	13		
	3 month	14	14		
German mark	12 month	11	7	4	
	9 month	16	10	4	2
	6 month	15	10	4	1
	3 month	14	10	4	
French franc	12 month	5	2	3	
	9 month	6	1	4	1
	6 month	6	1	4	1
	3 month	6	2	3	1
Japanese yen	12 month	7		1	6
	9 month	8		3	5
	6 month	10	1	4	5
	3 month	12	5	5	2
Dutch guilder	12 month	7	2	4	1
	9 month	10	4	5	1
	6 month	9	6	3	
	3 month	10	8	2	

and executing the appropriate arbitrage activity, and inexact interest rate and spot-exchange rate data. Of course, the deviations may also be a product of measurement errors associated with our data, as discussed earlier.

Our conclusions for this portion of the study are mixed. In most cases, the means of deviations from the interest rate parity line are not significantly different from zero; however, some individual futures prices deviate from the interest rate parity line by more than can be explained with the presence of crudely estimated transaction costs.

Characteristic Biases

A characteristic bias is said to exist if futures prices are systematically higher or lower than the prices of the contract immediately before expiration.

In the case of seasonal products, several researchers[11] have concluded that a bias exists in favor of the long side of futures contracts. This bias is sometimes "explained" as necessary inducement to speculators who are relieving hedgers of burdensome risk. However, in the case of currency futures, the assumption that relates the dichotomous classifications (hedger-speculator and long side-short side) is less easily justified. American importers of Swiss watches need hedge protection; so do Swiss importers of American machine tools.

If international trade were not in perfect balance, some countries could have net demands for speculators' services. Any effects upon futures prices (via a discount or premium), however, would necessarily be limited to the extent permitted by deviations from the assumptions of the interest rate parity theorem.

Although we would like to address the question, "Are futures prices systematically less than or greater than expected future spot prices?", our data do not permit us to do so. The expectations theory deals with ex ante future spot prices, whereas our empirical test has been applied to ex post data. Anticipated and realized future spot prices will not necessarily be equal except in a world of perfect certainty. Since we do not possess expectational data, our examination must be confined to addressing the question, "During the period covered have futures prices been systematically less than or greater than realized spot prices at contract maturity?"[12] Thus, we do not directly examine the expectations hypothesis.

Let $AF_{i,0}$ = settlement price for currency i contract on the day the contract expires. If there is no characteristic bias, then

$$E[\delta_{i,k}] = 0$$

where $\delta_{i,k} = AF_{i,k} - AF_{i,0}$.

Evidence related to the characteristic bias issue is presented in Table 3. Mean differences and standard deviations of mean differences are shown for three-month futures in all eight currencies.[13] As before, the t

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[11] See Gray (1960, 1961) and Houthakker (1957), and Cootner (1960) for examples of discussions regarding bias in grain futures.

[12] Kohlhagen (1975), and Giddy and Dufey (1975) addressed this question using bank forward data. Kohlhagen's data represented the period 1973-1974; Giddy and Dufey's data covered two periods: 1919-1925 and 1971-1974. Neither study found the forward rate to be a biased predictor of the future spot rate.

[13] See Footnotes 8 and 9.

statistic provides an indication of any departure from zero characteristic bias. In only one instance — the Mexican peso — is the mean difference significantly different from zero at the 5-percent level of significance. The peso result is inconsistent with the view that there were no important characteristic biases in the eight exchange rates during the period studied. It appears that the traders in peso futures may have expected a devaluation against the dollar during the period covered by our data. The devaluation, however, did not come until September, 1976.

Rates of Return on Futures

The last issue we address concerns the realized rates of return that investors would have experienced from "buying" futures contracts in currency i with k months remaining life and then "selling" the contract on maturity. In Equation 2, we define this observed annualized return as $RR_{i,k}$. The required security deposit was assumed to be 10 percent of the monetary value of the contract trading unit, based upon the current futures price:

Let[14,15,16] $$RR_{i,k} = \frac{AF_{i,0} - AF_{i\,k}}{.10\,AF_{i,k}}\left(\frac{12}{k}\right)\left(100\right) \qquad (2)$$

Results from Equation 2 are shown in Table 4.

We shall not attempt to explain or ex post rationalize the return distribution statistics given in Table 4; rather, we will attempt only to identify a few salient factors. In the cases of the French franc, the Japanese yen, the Canadian dollar, and the Dutch guilder, the signs of mean returns are mixed; none of these mean returns was significantly different from zero. Returns to the holders of long sides in futures contracts on Mexican pesos, German marks, and Swiss francs were positive; however, only the mean return on three-month peso contracts was significantly different from zero. Returns to the holders of long sides in British pounds were negative, but not significantly different from zero.

Whether the distributions of returns in futures contracts are temporarily stable is not known. The summary statistics in Table 4 are, for the most part, offered only as an early look at historical returns to market participants, and as a basis for comparisons with future investigations of ex post returns.

[14] In July, 1976, the initial security deposit varied from $1,500 for the Canadian dollar (approximately 1.5 percent of the value of the contract unit) to $8,000 for the Mexican peso (approximately 10 percent of the value of the contract unit).

[15] Grubel (1965) also assumed a 10-percent margin.

[16] Multiplying by (12/k) approximately annualizes the rate of return, and multiplying by 100 puts the result in percent units.

TABLE 3
DEVIATIONS OF OBSERVED FUTURES EXCHANGE RATES $[AF_{i,k}]$ FROM REALIZED SPOT RATES AT MATURITY $[AF_{i,0}]$

$$\delta_{i,k} = AF_{i,k} - AF_{i,0}$$

Currency		Number of Observations	Mean Difference ($)	Standard Deviation of Mean Difference ($)	t
British pound	12 month	12	.0471	.0528	
	9 month	13	.0486	.0482	
	6 month	15	.0207	.0422	
	3 month	14	.0082	.0296	.28
Canadian dollar	12 month	10	.0168	.0086	
	9 month	13	.0128	.0055	
	6 month	13	.0029	.0083	
	3 month	14	−.0008	.0053	−.15
German mark	12 month	11	−.0001	.0144	
	9 month	16	−.0096	.0112	
	6 month	15	−.0062	.0100	
	3 month	14	−.0029	.0070	−.41
French franc	12 month	5	.0080	.0119	
	9 month	6	.0083	.0086	
	6 month	6	.0026	.0105	
	3 month	6	−.0027	.0071	−.38
Japanese yen	12 month	7	.0001	.00011	
	9 month	8	.0001	.00011	
	6 month	10	.0000	.00006	
	3 month	12	−.0000	.00006	−.00
Mexican peso	12 month	12	−.0024	.0006	
	9 month	12	−.0023	.0006	
	6 month	13	−.0018	.0005	
	3 month	13	−.0011	.0003	−3.67
Swiss franc	12 month	13	−.0274	.0103	
	9 month	14	−.0215	.0100	
	6 month	14	−.0144	.0086	
	3 month	14	−.0073	.0060	−1.22
Dutch guilder	12 month	7	−.0037	.0137	
	9 month	10	.0043	.0103	
	6 month	9	.0037	.0117	
	3 month	10	.0028	.0062	.45

TABLE 4

RETURNS TO LONG SIDES OF CURRENCY FUTURES CONTRACTS, COVERING THE PERIOD JUNE 18, 1972 TO MARCH 16, 1976

$$RR_{i,k} = \left[\frac{AF_{i,0} - AF_{i,k}}{(.1)\, AF_{i,k}}\right]\left(\frac{12}{k}\right)(100)$$

Currency		Number of Observations	Mean Percent	Standard Deviation Percent	t
British pound	12 month	12	−21.22	24.05	
	9 month	13	−28.73	28.48	
	6 month	15	−19.91	38.40	
	3 month	14	−17.91	51.85	.35
Canadian dollar	12 month	10	−16.39	8.43	
	9 month	13	−16.36	10.51	
	6 month	13	−4.80	16.67	
	3 month	14	3.71	21.15	.18
German mark	12 month	11	10.38	40.07	
	9 month	16	48.18	44.93	
	6 month	15	47.89	55.87	
	3 month	14	44.73	73.04	.61
French franc	12 month	5	−28.34	68.36	
	9 month	6	−42.56	62.12	
	6 month	6	−12.88	106.04	
	3 month	6	57.78	125.54	.46
Japanese yen	12 month	7	−35.38	33.00	
	9 month	8	−24.51	32.46	
	6 month	10	−0.50	41.89	
	3 month	12	19.48	59.22	.33
Mexican peso	12 month	12	31.69	8.44	
	9 month	12	39.58	10.54	
	6 month	13	47.92	13.50	
	3 month	13	57.29	17.08	3.35
Swiss franc	12 month	13	94.29	32.97	
	9 month	14	100.87	42.16	
	6 month	14	100.53	53.87	
	3 month	14	100.89	73.24	1.37
Dutch guilder	12 month	7	13.35	35.90	
	9 month	10	−10.82	34.52	
	6 month	9	−12.15	59.59	
	3 month	10	−24.22	62.34	.39

SUMMARY

We have addressed three separate issues in this paper. First, we compared observed IMM futures prices with prices predicted by the interest rate parity theorem. In the case of the British pound, we found a systematic tendency for observed futures prices to be less than futures prices predicted via the interest rate parity theorem. Also, some individual contract prices for the German mark, the French franc, and the Japanese yen deviated from the interest rate parity line by much more than could be explained by the presence of transaction costs alone. Second, we investigated the question of any characteristic bias in futures prices. Three-month contracts on the Mexican peso exhibited a significant difference between futures price and spot price at contract maturity. We attribute this peso bias to expectations of a devaluation, which, in fact, occurred soon after the time period represented in our data base. Last, we presented some preliminary rate of return data on IMM futures contracts.

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An Assessment of Forecasting Accuracy and Market Efficiency in the International Money Market: 1967-1975

Richard M. Levich

For 20 years, a substantial research effort has been directed toward developing and testing the efficient market hypothesis. Stated simply, an efficient market is one "in which prices always 'fully reflect' available information" (Fama, 1970). Investors collect and process information in order to assess the value of an asset. Trading occurs so that market prices continuously reflect the information set; as a consequence, unusual profit opportunities are quickly eliminated.

The main laboratory for testing the efficient market hypothesis has been the market for financial claims (primarily equities) in the United States.[1] The motivation for research presented in this paper is to test the efficient market hypothesis on a uniform set of data from the international money market. Stated in this manner, the hypothesis is too general for empirical testing. Therefore, two more specific hypotheses are formulated:[2] 1) prices of particular financial claims imply accurate and consis-

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[1] For a survey of the efficient markets literature see Fama (1970, 1976). Surveys with special reference to international financial markets are in Kohlhagen (1978), and Levich (1978).

[2] A more fundamental hypothesis is that unusual profit opportunities in covered-interest arbitrage are quickly eliminated. This hypothesis is more fundamental in the sense that efficiency here rests on the relatively simple process of policing a boundary condition; all inputs for this single period model are known with certainty. Earlier research reported by Frenkel and Levich (1975, 1977) indicates that when transaction costs are included and the financial assets are comparable in terms of risk, unusual arbitrage profits are quickly eliminated. It is therefore appropriate to test hypotheses which consider uncertainty.

tent forecasts of future spot-exchange rates; and 2) unusual speculative profits should not be earned by investors who use exchange-rate forecasts based on publicly available information.

The first hypothesis assumes that prices reflect information. Since investors' expectations of the future spot-exchange rate are part of the information set, observed prices of spot rates, forward rates, and interest rates, for example, should reflect the market's consensus estimate of the future spot rate. A test of this hypothesis can be based on the statistical properties of exchange-rate forecasts implied by market prices. Under the null hypothesis that the international money market is efficient, these statistical properties should agree with our theoretical expectations.

The second hypothesis considers the usefulness of exchange-rate forecasts based on publicly available information. One risky investment opportunity is speculation in forward contracts. Market efficiency suggests that publicly available forecasts of the future spot rate should not lead to unusual profits in forward speculation.

These ideas are definitely not new. Statements describing the speed of foreign exchange traders and the efficiency of foreign exchange markets can be found in Ricardo (1811), Goschen (1862), and Walras (1874). This paper applies a thorough statistical analysis on a large, uniform data base covering nine major industrial countries in the sample period 1967-75.

Overall, this research suggests we cannot reject either hypothesis. First, although exchange-rate forecasts based on market prices are not perfect, they do display many statistical properties consistent with efficient use of available information. Second, publicly available forecasts do not lead to unusual profits in forward speculation. This research, therefore, cannot reject the hypothesis that the international money market is efficient.

STATISTICAL METHODS AND EXCHANGE-RATE FORECASTING

One approach to the exchange-rate forecasting problem is to specify a structural model of the economy.[3] If the spot rate can be expressed as a function of lagged endogenous and exogenous variables, and if forecasts of the future values of the exogenous variables are available, then a conditional forecast of the future spot rate can be generated.

Alternatively, forecasting can rely on principles associated with spot and forward currency speculation. An early statement that the interest rate differential between assets denominated in two currencies should

[3] Alternative models of exchange-rate determination are described in Bilson (1978), Dornbusch (1976), Frenkel (1976), and Hodrick (1978).

reflect anticipated exchange-rate changes is associated with Irving Fisher (1896).[4] The basic thrust of Fisher's analysis is that in order for the asset market to clear, investors demand a higher nominal return on assets denominated in a (relatively) depreciating unit of account; investors accept a lower nominal return on assets denominated in a (relatively) appreciating unit of account. In a world of certainty, the market's implied one-period ahead forecast of the spot rate is given by:

$$\hat{S}_{t+1} = S_t(1 + r_d)/(1 + r_f) \qquad (1)$$

where S_t = spot-exchange rate (in domestic currency per unit foreign currency) at time t,
r_d = one-period interest rate on domestic currency asset,
r_f = one-period interest rate on foreign currency asset.

Equation 1 represents a great simplification; to forecast the future spot rate we need only two inputs — the two interest rates. The cost is that we no longer see how underlying economic variables affect the exchange rate. Implicitly, we are acting as though Equation 1 is the reduced form equation for the spot rate in a correctly specified structural model; thus, markets are assumed to be efficient processors of information on exchange-rate expectations.[5]

In the case where interest rate parity holds, spot speculation and forward speculation are equivalent investments.[6] Equation 1 can then be rewritten as:

$$\hat{S}_{t+1} = F_t \qquad (2)$$

where F = one-period forward rate at time t. The formulation assumes

[4] Fisher presents data for the period 1865-1895 on Indian debt, partly denominated in silver, and partly denominated in gold. Interest on the silver bonds is paid by draft on India (in rupees) and interest on the gold bonds is paid in gold. Both securities are traded in London. Fisher also presents a matching time series on rupee exchange rates. He concludes:

> From 1884 exchange fell much more rapidly than before, and the difference in the two rates of interest rose accordingly, amounting in one year to 1.1 percent. Since the two bonds were issued by the same government, possess the same degree of security, are quoted side by side in the same market, and are in fact similar in all important respects *except in the standard in which they are expressed,* the results afford substantial proof that the fall of exchange (after it began) was discounted in advance. Of course, investors did not form perfectly definite estimates of the future fall, but the fear of a fall predominated in varying degrees over the hope of a rise (p. 390 emphasis added).

[5] For a further elaboration of the role of expectations, see Bilson (1978), Mussa (1976), and Stockman (1978).

[6] A proof of the statement assuming uncertainty is in Tsiang (1959), p. 86-92.

that the forward market efficiently reflects information on exchange-rate expectations.[7]

Equations 1 and 2 assume a world of certainty and no transaction costs. When transaction costs exist, the forecast-point estimate becomes a neutral band with upper bound (U) and lower bound (L) given by:

$$U = \hat{S}_{t+1}/\Omega$$
$$L = \Omega\hat{S}_{t+1}$$

where $\Omega = \prod_{i=1}^{n} (1 - t_i)$

t_i = cost of transaction i

and n is the number of transactions required to take the speculative position. Therefore the presence of transaction costs may lead to forecast errors even under perfect foresight and rational behavior.

If market forces are efficient in assessing information about the future spot-exchange rate, then a large fraction of sample observations should be bounded by the neutral band. In this case, we will not reject hypothesis one. However, if the fraction of observations bounded is low, there are two alternative conclusions. First, it may be that market participants are inefficient in processing exchange-rate expectations. Second, it may be that Equations 1 and 2 are not the correct reduced-form models of exchange rates which market participants use to set prices. This conundrum is common to any data which reject market efficiency and empirically, there is no technique for distinguishing the correct conclusion.

When uncertainty exists, forecast errors may arise because unanticipated events occur after the forecast is formulated. In this case, Equations 1 and 2 should be modified to include an error term, u_{t+1}. If the mean of the error term is zero, the forecast is unbiased. Furthermore, if the market is efficient, the error terms will be serially uncorrelated.

However, forecasts can be biased with a non-zero mean error term[8] — the existence of bias does not necessarily imply market inefficiency. Equilibrium expected returns could be set so that the compensation for bearing exchange risk is non-zero.

Another explanation for bias is currency preference (Aliber, 1973). The currency preference argument is that there may be a convenience or other non-pecuniary yield associated with a currency. For example, a London importer (who is risk averse) may hold dollar balances to lessen exposure

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[7] There is substantial literature to support this assumption. For example, Working (1961) argues that "Futures prices tend to be highly reliable estimates of what should be expected on the basis of contemporarily available information . . ."

[8] For a theoretical description of the sources of bias, see Stockman (1978). An alternative explanation based on international portfolio theory is in Solnik (1973).

to exchange risk and to reduce transaction costs from trading in and out of sterling. A U.S. investor may hold Swiss franc assets to benefit from anonymity in the Swiss banking system. In both examples, the nominal interest rate does not adequately measure the desirability of these assets for investors.

The empirical evidence on forecasting bias in Equations 1 and 2 is mixed.[9] The issue will be examined again in this paper.

Another approach to forecasting which uses market data is based on time-series analysis.[10] In an efficient market, the price of spot exchange itself will reflect the information set. If the underlying factors determining exchange rates are generated by a stationary process, the time-series description of the spot rate may be useful for forecasting. One possible description of the spot series is a random walk model with zero drift which leads to the forecast:

$$\hat{S}_{t+1} = S_t \tag{3}$$

Note that the random walk description of the exchange rate is not the only model consistent with market efficiency. Equation 3 was selected because it is a naive model that may have been postulated by market participants during this period.[11]

The Data Base

The data for this paper are taken exclusively from the Harris Trust and Savings Bank of Chicago's *Weekly Review*. Data for nine countries (Canada, United Kingdom, Belgium, France, Germany, Italy, the Netherlands, Switzerland, and Japan) and the United States are reported. End-of-week bid quotations from the interbank market are reported for the spot rate, the forward premium, the domestic treasury bill rate and the external or Euro-currency deposit rate. All quotations reported as a percent per annum are converted to their per period equivalents.[12]

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[9] Fisher (1896) observed that a 0.2 to 0.3 percent interest rate differential between gold and silver assets existed, even when the exchange rate was unchanged. A re-examination of these data (Levich, 1977) indicates that, under the 25 year sample period, the null hypothesis that the error terms have mean zero and are serially uncorrelated cannot be rejected. For evidence on other periods see Kohlhagen (1975), Bilson (1976), and Frenkel (1977).

[10] For an explanation of time-series estimation methods, see Box and Jenkins (1970), and Nelson (1973). For a comprehensive analysis of the determination of exchange rates implementing a time-series analysis approach, see Hodrick (1978).

[11] A time-series analysis of weekly spot-exchange rates over the period 1973-1975 indicates that the strict random walk model is valid only for the Italian lira and the Swiss franc. However, the precise time-series specification could only be learned using in-sample observations. See Levich (1977).

[12] For a discussion of the problems introduced by using annualized data in models of a shorter horizon, see Frenkel and Levich (1975, 1977).

Forecasts of the future spot-exchange rate, $\hat{S}(i, j, k, l)$, in U.S. dollars per foreign unit are generated for: $i = 1, \ldots 9$ countries; $j = 1, \ldots 4$ forecasting models; $k = 1, \ldots 3$ forecasting horizons; and $l = 1, \ldots$ 430 weekly observations. The four forecasting models are: Model 1a using treasury bill rates (Fisher domestic); Model 1b using Euro-currency deposit rates (Fisher external); and Models 2 and 3.

The 430 weeks cover the period January 3, 1967 to May 9, 1975. Forecasting horizons analyzed are one, three, and six months. These horizons are consistent with the maturity of interest rates and forward contracts in the data base. However, since the *Weekly Review* is published weekly, forecasting horizons must be translated to 4, 13, and 26 weeks. For example, today's one-month forward rate is compared to the spot rate 4 weeks from today. The three- and six-month forward rates are compared to spot rates 13 and 26 weeks in the future. This compromise may increase the magnitude of forecast errors at the one-month horizon. For the three- and six-month horizon, the effect should be small.

Percentage forecast errors, e_t, are calculated using:

$$e_t = (S_{t+n} - \hat{S}_{t+n})/S_{t+n}.$$

Therefore, positive (negative) forecast errors indicate underestimation (overestimation). Note also that the forecast errors are subscripted for time t — the time when the forecast was made. Therefore, when forecasts are aggregated over some time period, say 1974, the summary statistics describe errors of forecasts which were formulated in 1974.

In the case of missing observations, the forecast is omitted. Data points are not interpolated or estimated using other sources. Missing observations sometimes occurred because an exchange "crisis" forced official markets to close. At other times, the Harris Trust and Savings Bank of Chicago observed that no single number could adequately represent the hectic trading observed during the day.[13] Omitting observations of this type does not bias the results in any apparent way.

For all countries, methods and horizons for which data are available, a

[13] For example, in the week ending November 21, 1967 a number of forward quotations were omitted. The *Weekly Review* commented, "The foreign exchange markets this week were steadier and more real than they have been since the devaluation of the Pound Sterling on November 18. The forwards, however, were still quoted rather than traded." On March 1, 1968 most forward quotations were omitted with the warning "the Forward Market was too erratic for a meaningful quotation." A number of quotations were omitted for the week of March 18, 1968 when the two-tier gold system was introduced. Finally, during the week ending November 22, 1968, the *Weekly Review* reported that most forward prices were "by negotiation." They commented: "The markets were nervous as the week opened and became chaotic by Tuesday . . . by Wednesday the major European foreign exchange markets were closed and remained closed for the week."

forecast and percentage forecast error is calculated. If all the data for all 430 weeks were available, we could construct 426 four-week-ahead forecasts, 417 13-week-ahead forecasts, and 404 26-week-ahead forecasts for each of the nine countries and four forecasting methods, for a total of 44,892 forecasts. Because of missing observations (mainly one- and six-month domestic interest rates), the number of forecasts actually constructed is 37,393.

STATISTICAL PROPERTIES OF FORECAST ERRORS

Forecasting Performance and Forecasting Model

The forecasts that were generated can be analyzed across the four alternative models. Table 1 displays the mean squared error (MSE) statistic for each model. Table 1 indicates that, given the currency, time period, and horizon, the MSE is similar across models. Considering the entire sample period, Table 1 also shows that there is little difference among the models. For all 27 country-horizon episodes, the average ratio of the highest MSE to the lowest MSE is 1.05. Therefore, in their overall performance, the models are very similar.

Nevertheless, for most countries, the model that produces the lowest MSE at one horizon also produces the lowest MSE at other horizons. For example, the Fisher external model leads to the lowest MSE forecast for Germany, the Netherlands, and Switzerland. For Belgium, France, and Italy, the lagged-spot forecast leads to the lowest MSE at all horizons. One interpretation of this result is that markets are integrated across maturities. For example, investors in external security markets collect information about exchange-rate changes. They set prices so that the term structure of relative interest rates reflects their term structure of exchange-rate expectations. If their expectations about one horizon are correct, internal consistency of prices suggests they may be correct about other horizons. In this sense, many models may be "horizon blind" — they work well regardless of forecast horizon.

This does not necessarily mean that a model is "time blind." The model that produces the lowest MSE in the overall sample does not necessarily produce the lowest MSE in every subperiod. For example, in forecasting the German mark, the Fisher external forecast (1b) produces the lowest MSE in the overall 1967-75 sample period. However, in several yearly subperiods, Table 2 indicates that there is often a model with a lower MSE.

Data in Table 1 can be collapsed further. The lowest MSE model in each of the 27 country-horizon episodes is marked with the letter "a." Totals indicate that on 13 episodes, the Fisher external model has the

TABLE 1
MEAN SQUARED ERROR ACROSS FORECASTING HORIZONS: 1967-75

Country	Horizon (Month)	Fisher Domestic	Fisher External	Forward	Lag Spot
Canada	1	0.374	0.380	0.385	0.365[a]
	3	1.491	1.486	1.517	1.463[a]
	6	3.501	3.179[a]	3.291	3.243
United Kingdom	1	3.968[a]	4.144	4.052	3.982
	3	15.520	15.924	15.983	15.065[a]
	6	33.180	29.779[a]	33.783	32.039
Belgium	1		4.406	4.434	4.110[a]
	3	17.247	18.064	17.935	16.714[a]
	6		36.087	38.525	34.093[a]
France	1		6.277	5.881	5.460[a]
	3	32.053	22.803	22.280	21.493[a]
	6		53.252	54.189	50.555[a]
Germany	1		5.590[a]	5.636	5.687
	3	24.112	23.550[a]	23.737	24.501
	6		45.158[a]	45.415	49.972
Italy	1		2.094	2.241	2.067[a]
	3	13.421	8.557	8.395	7.408[a]
	6		12.909	13.907	12.110[a]
The Netherlands	1		4.481[a]	4.554	4.545
	3	16.681	15.282[a]	15.385	16.135
	6		28.728[a]	32.717	31.768
Switzerland	1		5.448[a]	5.469	5.458
	3	1.255[b]	20.864[a]	21.057	20.952
	6		45.881[a]	46.347	47.819
Japan	1		5.623[a]	5.671	5.704
	3	24.248	23.605[a]	23.788	24.500
	6		46.687	45.892[a]	49.947
Column Total of [a]		1	13	1	12

[a] Lowest MSE given country and horizon.
[b] Based on only 34 observations.
Mean squared error is in units of percent squared.

TABLE 2
MEAN SQUARED ERROR BY YEAR AND HORIZON, GERMANY

Period	Model	One Month	Horizon Three Month	Six Month
1967	1a		0.455	
	1b	0.096	0.291	0.451
	2	0.089	0.297	0.431
	3	0.076[a]	0.181[a]	0.198[a]
1968	1a		1.222	
	1b	0.300	1.250	2.506
	2	0.265	1.161	2.457
	3	0.192[a]	0.526[a]	0.282[a]
1969	1a		10.842	
	1b	2.695[a]	9.641[a]	14.662
	2	2.798	9.799	14.364[a]
	3	3.057	13.224	29.667
1970	1a		0.228[a]	
	1b	0.098[a]	0.447	2.170[a]
	2	0.105	0.470	2.258
	3	0.098	0.462	2.380
1971	1a		12.066	
	1b	1.614[a]	10.363[a]	33.110[a]
	2	1.637	10.605	33.680
	3	1.860	11.710	37.144
1972	1a		17.360[a]	
	1b	0.424	17.724	70.886
	2	0.430	17.512	69.823[a]
	3	0.312[a]	17.900	78.154
1973	1a		100.050[a]	
	1b	30.121	100.691	186.070
	2	30.059[a]	100.691	185.989[a]
	3	31.255	105.544	193.670
1974	1a		46.822[a]	
	1b	9.272	48.219	47.366[a]
	2	9.447	48.552	47.424
	3	8.844[a]	47.448	55.220
1975	1a		3.070[a]	
	1b	3.842	3.188	
	2	3.837	3.148	
	3	3.702[a]	3.488	

[a] Lowest MSE given year and horizon.

lowest MSE, 12 for the lagged-spot model and one each for the remaining two models.

This is a surprising result given the empirical evidence on interest parity. If interest parity holds exactly, then the Fisher external- and forward-rate forecasts are identical. Therefore, these two models were anticipated to be very similar. While the Fisher external regularly outperforms the forward rate, the difference is generally small enough to be explained by transaction costs or sampling errors. Still, data suggest that if forecasting must rely on a single model, then either the Fisher-external or lagged-spot model should be selected. Across all countries, horizons, and time periods, these two models tend to produce the lowest MSE forecast.

Some further information on the distribution of forecast errors is given in Table 3. Note that the skewness statistic is small (near zero) indicating a symmetric distribution of forecast errors. The kurtosis statistic is large, indicating a peaked distribution with fat tails. A Kalmogorov-Smirnov test confirms that for most countries the distribution is non-normal.[14] The economic significance of this result is that exchange-risk management models that rely on a normal distribution of speculative returns or forecast errors are not appropriate. The data were not examined further to see if other two-parameter distributions adequately describe the data.

Forecasting Performance and Currency

In this section, forecast errors are analyzed in the currency dimension. This classification raises the intuitive question: Which currency is "easiest" to forecast? A more careful analysis suggests that an unambiguous stan-

[14] The distribution of exchange-rate changes is discussed in Westerfield (1975).

TABLE 3
SUMMARY STATISTICS FOR FORECAST ERRORS

Statistic	Horizon One Month	Three Month	Six Month
Mean	0.292	1.060	2.156
Standard deviation	2.359	4.761	6.393
T(Mean)	2.539	4.518	6.738
Skewness	0.985	0.170	0.306
Kurtosis	9.968	6.136	7.196
Minimum	−9.974	−17.808	−25.008
Maximum	12.754	18.316	27.980
N	421.	412.	399.

NOTE: Forward rate Model 2, 1967-75 for Germany only.

dard for comparison is lacking, and therefore the question cannot be answered.

In part, forecast errors are a function of transaction costs and the risk premium. If these factors differ across currencies, then the conclusion that a currency is difficult to forecast is not necessarily justified. Investors may have formed accurate expectations; but they have decided that action on these expectations is not profitable. Therefore, prices remain unchanged and (apparent) forecast errors result.

To argue the same point in another way, observers have noted that some exchange-rate series are (statistically) more volatile than others. This is due, in part to changes in exchange rates which reflect underlying variables including changes in monetary policy. Monetary policies differ widely across countries and over time. As a purely theoretical matter, the increased variability in underlying (monetary) factors will not (necessarily) lead to a decrease in forecasting precision because some of this variability will be anticipated and therefore reflected by forecasters. Thus, a series can become more volatile (statistically) and yet the forecast errors for that series may decline. For these reasons, intercountry comparisons must be viewed with caution.

Table 4 presents data on the lowest MSE forecast for each country and horizon. Canada has the lowest MSE of all countries at each horizon. The MSE for the one-month horizon is 0.365 percent which implies an average forecast error (or root mean squared error) of 0.6 percent. At the six-month horizon the MSE increases to 3.179 percent, and the average error increases to 1.78 percent. Four countries (France, Germany, Switzerland, and Japan) have MSEs greater than 5.0 percent at the one-month

TABLE 4
LOWEST MEAN SQUARED ERROR AND RANKING FOR COUNTRY AND HORIZON

Country	Horizon One Month	 Three Month	 Six Month
Canada	0.365 (1)	1.463 (1)	3.179 (1)
United Kingdom	3.968 (3)	15.065 (3)	29.779 (4)
Belgium	4.110 (4)	16.714 (5)	34.093 (5)
France	5.460 (7)	21.493 (7)	50.555 (9)
Germany	5.590 (8)	23.550 (8)	45.158 (6)
Italy	2.067 (2)	7.408 (2)	12.110 (2)
The Netherlands	4.481 (5)	15.282 (4)	28.728 (3)
Switzerland	5.448 (6)	20.864 (6)	45.889 (7)
Japan	5.623 (9)	23.605 (9)	45.892 (8)

NOTE: Rank in parentheses.

horizon and 45.0 percent at the six-month horizon, or approximately 15 times as great as for Canada. Therefore, the average forecast error is three to four times greater for these countries than Canada.

An alternative measure of forecasting performance is to record the percentage of forecast errors bounded within a neutral band.[15] This technique is especially appropriate for Models 1 and 2 where forecast errors are directly associated with transaction costs so that:

$$L \leq \hat{S}_{t+n} \leq U. \tag{4}$$

To illustrate that the mean forecast error may give misleading results, assume that transaction costs are 1.0 percent. Then, persistent 0.5 forecast errors would not be disturbing in the sense that they represent a market inefficiency. Knowledge of these serially correlated, non-zero errors cannot lead to a profit opportunity through spot or forward speculation.[16] Alternatively, forecast errors may be +2.0 percent and −2.0 percent in equal proportion. The market appears inefficient since Equation 4 never holds; still, the mean forecast error is zero. Similarly, the MSE may appear greater than what is necessary for profitable speculation. This overall result could be caused by the domination of a few large outliers in the sample. This might be the case since exchange-rate changes and forecast errors are non-normal. For these reasons we consider a neutral band analysis. A summary of forecast errors bounded by neutral bands of width 0.5 percent, 1.0 percent and 2.0 percent is presented in Table 5.

In Table 5, the data for the 1967-75 period indicate that the forecast errors for Canada and Italy fall within narrower bounds than for the United Kingdom, France, Germany, or Japan. The methods, therefore, differ in their rankings of Switzerland and the United Kingdom. Table 5 indicates that nearly twice as many forecasts fall within the 1 or 2 percent bounds for Canada as for Japan. This is an alternative measure of the relative difficulty in forecasting currencies.

Forecasts and Currency Preference

The previous section demonstrated that if investors prefer to hold assets denominated in a particular currency, then exchange-rate forecasts based on interest rates may result in forecast errors that are systematically positive or negative. In this section, the mean forecast errors are analyzed. When the mean error is significantly different from zero, forecast bias

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[15] This technique was used to analyze deviations from interest parity in Frenkel and Levich (1975).

[16] This knowledge may be important when a point estimate of the expected future spot rate is used as an input for a balance-of-payments model or corporate cash management model.

TABLE 5

PERCENTAGE OF THREE-MONTH FORWARD RATE FORECASTS WITHIN 0.5 PERCENT, 1.0 PERCENT, AND 2.0 PERCENT OF FUTURE SPOT RATE

	1967			1971			1972			1973			1974			1975			1967–75		
Country	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0
Canada	57	83	100	45	61	100	31	43	92	33	60	87	16	36	92	0	17	83	44	66	90
United Kingdom	66	68	70	4	37	50	12	24	34	2	6	14	6	14	38	17	34	67	25	44	61
Belgium	91	100	100	34	38	42	47	68	86	6	14	20	4	8	16	17	34	83	48	60	69
France	57	100	100	53	61	71	22	47	75	4	10	16	2	4	26	0	0	0	28	48	63
Germany	54	98	100	8	12	24	29	56	72	6	8	12	4	10	16	17	50	67	28	45	60
Italy	98	100	100	36	42	74	59	69	85	10	20	34	8	18	40	0	0	0	48	62	75
The Netherlands	94	100	100	14	28	42	22	42	77	6	10	20	6	10	20	17	34	100	36	56	70
Switzerland	64	94	100	25	29	56	12	30	72	4	8	16	4	8	14	17	50	67	38	58	70
Japan				47	57	57	15	28	43	10	14	31	10	18	30	17	17	34	29	36	46
Average	73	93	96	30	41	57	28	45	71	9	17	28	7	14	32	11	26	56	36	53	67

exists. According to the Fisherian theory, if the forecast exchange-rate change is greater than the actual exchange-rate change, then the foreign currency is preferred. If the forecast exchange-rate change is less than the actual exchange-rate change, then the domestic currency (U.S. dollar) is preferred. In this study, *negative* forecast errors correspond to a preference for the *foreign* currency; significant positive forecast errors correspond to a preference for the *domestic* currency.

Information on the t-statistic of the mean forecast error is summarized in Table 6.[17] Entries marked with an "a" are not significantly different from zero at the 5-percent level. Therefore, it appears that in most cases, the forecasts display a positive bias, indicating that the U.S. dollar was the preferred currency during this period.[18] The most prominent clustering of unbiased forecasts are in the United Kingdom. Both Fisher forecasts and the forward rates, appear to be unbiased forecasters in the United Kingdom. The lagged-spot forecast also appears to be unbiased in France and Italy.

Estimates of transaction costs in the spot and 90-day foreign exchange market range between approximately 0.05 percent in the 1962-67 period to about 0.5 percent in the 1973-75 period.[19] Transaction costs in Eurocurrency deposits are smaller, between 0.03 percent and 0.1 percent. During the sample period 1967-75, it seems likely that a bias of 0.5 percent or 1.0 percent could be consistent with transaction costs. Most mean forecast errors at the three-month horizon fall within this range. It is therefore possible to conclude that while the bias may be statistically significant, it is not economically significant.

Note also that there is a general tendency for bias to increase, approximately, in proportion to horizon. This agrees with the result in Moses (1969) that currency preferences may be expressed as a constant rate per unit of time.

In Table 6 the country-horizon episodes which did not contain an unbiased forecasting model were considered separately. In this group (of 16) the model with the smallest bias (in absolute value) is marked by the letter "b." In 13 of these 16 cases the Fisher external model produces the

[17] It is important to note that the standard errors were calculated using a dependent sample of, at most, 426 observations for the one-month forecast, 417 observations for the three-month forecast, and 404 observations for the six-month forecast. Using an independent, nonoverlapping sample, the sample sizes, at most, would be 105, 32, and 15, respectively. Consequently, using an independent sample, the sample t-statistics would fall by at least one-half. In this case, bias is significant for only six cases in Table 6.

[18] The one exception is Swiss treasury bills. Holders of these securities yielded about 1 percent less per three-month period than if they had held U.S. treasury bills.

[19] See Frenkel and Levich (1977).

TABLE 6
MEAN FORECASTING ERROR ACROSS FORECASTING HORIZON: 1967-75

Country	Horizon (Month)	Fisher Domestic	Fisher External	Forward	Lag Spot
Canada	1	0.062	0.004[a]	0.043	0.050[a]
	3	0.309	0.107[b]	0.178	0.212
	6	0.640	0.345[b]	0.458	0.487
United Kingdom	1	0.017[a]	0.005[a]	0.054[a]	−0.184
	3	0.073[a]	−0.001[a]	0.078[a]	−0.567
	6	0.088[a]	0.166[a]	−0.021[a]	−1.229
Belgium	1		0.262[b]	0.340	0.309
	3	1.027	0.941[b]	1.040	1.029
	6		1.784[b]	2.145	1.976
France	1		0.194[a]	0.339	0.137[a]
	3	1.027	0.862	0.937	0.402[a]
	6		1.313	1.644	0.568[a]
Germany	1		0.269[a]	0.292	0.453
	3	1.167	1.031[b]	1.060	1.520
	6		2.130[b]	2.156	3.036
Italy	1		0.118	0.238	−0.021[a]
	3	0.070	0.283	0.527	−0.075[a]
	6		0.359	0.802	−0.245[a]
The Netherlands	1		0.212[b]	0.247	0.352
	3	0.695[b]	0.844	0.899	1.195
	6		1.691[b]	2.026	2.314
Switzerland	1		0.263[b]	0.291	0.468
	3	−1.017[b]	1.075	1.096	1.587
	6		2.219[b]	2.251	3.136
Japan	1		0.233[b]	0.254	0.444
	3	1.082	0.984[b]	1.015	1.510
	6		2.317	2.294[b]	3.060
Column total of [a] and [b]		5	19	4	7

[a] *Not* significantly different from zero at 5-percent level.
[b] Model with lowest absolute mean bias.

smallest bias. This result could be expected since the Fisher external models tended to have low MSE and bias is one of the two components in MSE.

The data in Table 6 can be further collapsed by adding the number of entries that are marked "a" or "b" in each column. There are 19 entries marked for the Fisher external model; the next highest is the lag spot model with seven. This result indicates that overall, the Fisher external model leads to a greater number of unbiased or smallest bias forecasts among the models that are tested. In this overall sense, the Fisher external model appears to be best.

From a purely forecasting viewpoint, bias is important as a correction factor for the naive model. For example, a watch which is consistently five minutes fast is a very good forecaster of the correct time. If Fisher external consistently overestimates the future spot rate by 1 percent, it will be a very helpful forecasting model. In both of these examples the important factor is the consistency or stationarity of the forecast errors over time.

This issue is analyzed using two approaches. In the first approach, weekly Fisher external forecasts for the three-month horizon were aggregated by calendar year. Significant positive mean forecast errors are recorded as (+); significant negative mean forecast errors are recorded as (−). When the mean forecast error is not significantly different from zero, a (0) is entered. Table 7 summarizes these results.

Table 7 indicates that the sign of forecast errors changes over time. Significant positive and negative errors exist for each country during some time period. The bias does not appear to follow any clear time pattern. A statistical runs analysis test of the series in Table 7 was not performed, however, since a dependent sample of weekly forecasts was aggregated to calculate yearly bias.

Instead, the second approach calculates the serial correlation of forecast errors in an independent sample. For example, at the one-month hori-

TABLE 7

TIME PATTERN OF FORECASTING BIAS WITH THE FISHER EXTERNAL MODEL, THREE-MONTH HORIZON

Country	1967	1968	1969	1970	1971	1972	1973	1974	1975	1967–75
Canada	0	+	−	+	0	0	0	−	−	0
United Kingdom	−	+	+	+	+	−	0	+	0	0
Belgium	+	−	+	−	+	+	0	+	+	+
France	0	0	−	+	+	+	0	+	+	+
Germany	−	−	+	+	+	0	0	+	0	+
Italy	−	−	−	+	+	+	−	+	+	+
The Netherlands	0	−	−	0	+	0	0	+	+	+
Switzerland	−	−	−	−	+	+	0	+	−	+
Japan	NA	NA	NA	+	+	0	0	−	0	+

NOTE: + = significant (at 5-percent level) positive forecast bias.
− = significant (at 5-percent level) negative forecast bias.
0 = forecast bias not significantly different from 0.
NA = not available.

zon, the sample consists of every fourth forecast error; at the three-month horizon, the sample consists of every 13th forecast error, and so on. Table 8 summarizes these results.

At the three-month and six-month horizons, serial correlation of forecast errors is not significant. At the one-month horizon, serial correlation is significant. However, it seems likely that this correlation is the result of using one-month interest rates to forecast spot-exchange rates four weeks in the future. If forecast errors are serially uncorrelated, as the data suggest, the implication is that bias (i.e., significant forecast errors) cannot be predicted; currency preferences are likely to be random. In this case, the standard approach of correcting the naive forecasting model for bias will not necessarily improve forecasting performance because the bias is not stationary.

Forecasting Performance and Horizon

The relationship between forecasting accuracy and forecast horizon is easily developed using time-series methods. A standard result is that the variance of the forecast error is proportional to the forecast horizon. Thus, the MSE is also proportional to the forecast horizon.

The data in Table 1 are used to test the theoretical relationship between

TABLE 8
Q-STATISTIC TO TEST SERIAL CORRELATION OF FORECAST ERRORS

Country	Horizon One Month	 Three Month	 Six Month
Canada	47.4	17.4	7.5
United Kingdom		20.4	11.5
Belgium		18.1	12.2
France	49.9	11.3	8.6
Germany	47.4	11.3	8.6
Italy		14.8	15.6
The Netherlands	25.5	12.9	9.5
Switzerland	48.1	19.5	9.4
Japan			
	N = 105	N = 32	N = 15

NOTE: Entry in table is

$$Q = N \sum_{i=1}^{k} \hat{r}_i \text{ where } k = 24$$

for one-month and three-month forecast and $k = 12$ for six-month forecast. Entry is for method (2), and forward rate. Results for other methods were very similar.
Sample points from the chi-square distribution are:

	X^2	d.f. 23	10
significance	10 percent	32.0	17.3
level	5 percent	35.2	19.7

MSE and horizon. First, the ratio of three-month MSE to one-month MSE is calculated; the theoretical value of this ratio is 3.0. Second, the ratio is calculated for six-month and three-month forecasts; the theoretical value of this ratio is 2.0. Table 9 summarizes the results.

The three-month to one-month ratio is consistently greater than 3.0. In part, this may be because we are comparing 13-week and 4-week forecasts, and so, the theoretical value of the ratio may be 3.25. However, the sample ratios are even greater than this number.

The results of the six-month and three-month comparison are more consistent with theory. The sample values are generally near two. At these maturities, the data support the hypothesis that MSE rises in proportion to forecast horizon. The economic significance of this result is that the market-based forecasts display a property of a time-series forecast which is a minimum MSE forecast. This is another piece of evidence to support the view that market prices efficiently forecast the future spot rate.

TABLE 9
RATIO OF MEAN SQUARED ERROR FOR PAIRS OF FORECAST HORIZONS

Country	Ratio[a]	Fisher Domestic	Fisher External	Forward	Lag Spot
Canada	3/1	3.99	3.91	3.94	4.01
	6/3	2.35	2.14	2.17	2.22
United Kingdom	3/1	3.91	3.84	3.94	3.78
	6/3	2.14	1.87	2.11	2.13
Belgium	3/1		4.10	4.04	4.07
	6/3		2.00	2.15	2.04
France	3/1		3.63	3.79	3.94
	6/3		2.34	2.43	2.35
Germany	3/1		4.21	4.21	4.31
	6/3		1.92	1.91	2.04
Italy	3/1		4.09	3.75	3.58
	6/3		1.51	1.66	1.63
The Netherlands	3/1		3.41	3.38	3.55
	6/3		1.88	2.13	1.97
Switzerland	3/1		3.83	3.85	3.84
	6/3		2.20	2.20	2.28
Japan	3/1		4.20	4.19	4.30
	6/3		1.98	1.93	2.04

[a] 3/1 = Ratio of three-month to one-month MSE.
6/3 = Ratio of six-month to three-month MSE.

An alternative technique for measuring the horizon effect is illustrated in Table 10, which reports the percentage of forward-rate forecast errors inside a given neutral band. As the forecast horizon lengthens, this percentage decreases. For example, the percentage of forecast errors within a 0.5 percent band drops from 47 percent to 13 percent as the forecast horizon increases from one to six months. For a 2.0 percent band, the decrease is not as sharp — from 80 percent to 47 percent.

Forecasting Performance and Time

In this section, forecast errors are analyzed in the time dimension. Figures 1-9 present a time-series plot of weekly forecast errors using the three-month forward rate for the nine currencies. These figures are representative of the other forecasting models and horizons. The vertical axes are scaled alike so intercountry comparisons are possible.

The figures suggest several qualitative observations. First, for each country large forecast errors are associated with discrete changes in exchange rates or exchange-rate systems (e.g., United Kingdom, 1967; France, 1969; Germany, 1969). Second, forecast errors tend to be smaller during pegged-rate periods — except when there is a discrete change in the rate. In the managed float period, forecast errors have become larger and more volatile. The graphs for Belgium, France, Germany, Italy, and the Netherlands show the large forecast errors associated with the oil crisis of 1973-74. However, both positive and negative errors are observed; the errors tend to fluctuate about some value near zero. The figures for the United Kingdom, Germany, the Netherlands, and Japan seem to indicate that forecast errors have decreased during the managed float period.

A quantitative examination of the time dimension begins with Table 5,

TABLE 10
PERCENTAGE OF FORWARD-RATE FORECAST ERRORS WITHIN NEUTRAL BANDS[a]

Width of Neutral Band	Horizon One Month	Three Month	Six Month
0.5 percent	47	28	13
1.0 percent	68	45	26
2.0 percent	80	60	47
3.0 percent	87	66	55
4.0 percent	92	72	59
5.0 percent	94	77	66

[a] Germany only, 1967-1975.

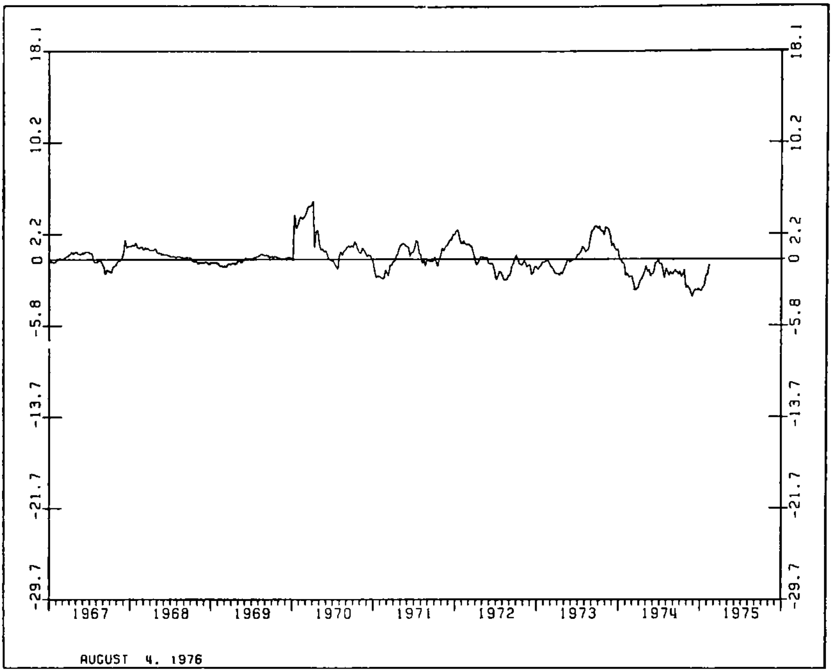

FIGURE 1. FORECAST ERRORS, FORWARD RATE THREE MONTH — CANADA

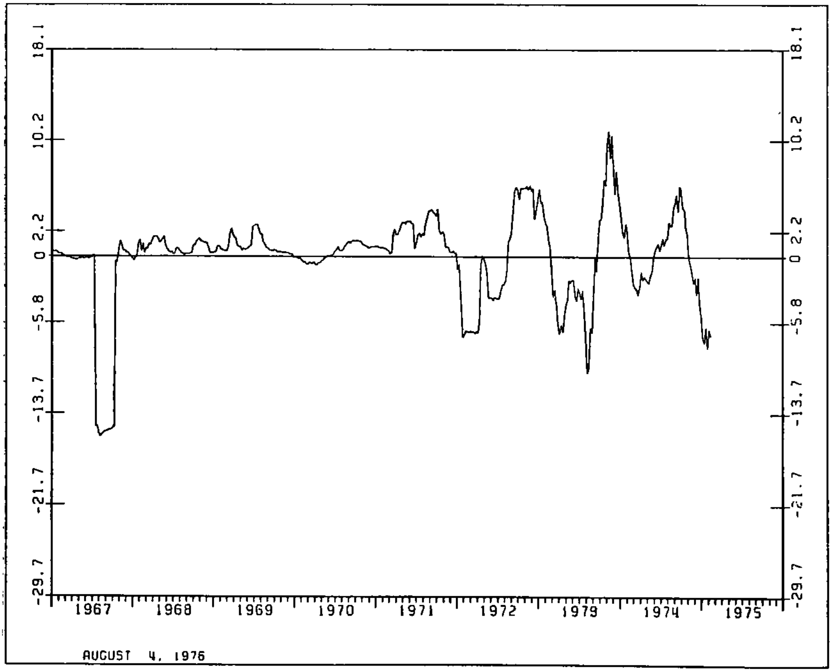

FIGURE 2. FORECAST ERRORS, FORWARD RATE THREE MONTH — ENGLAND

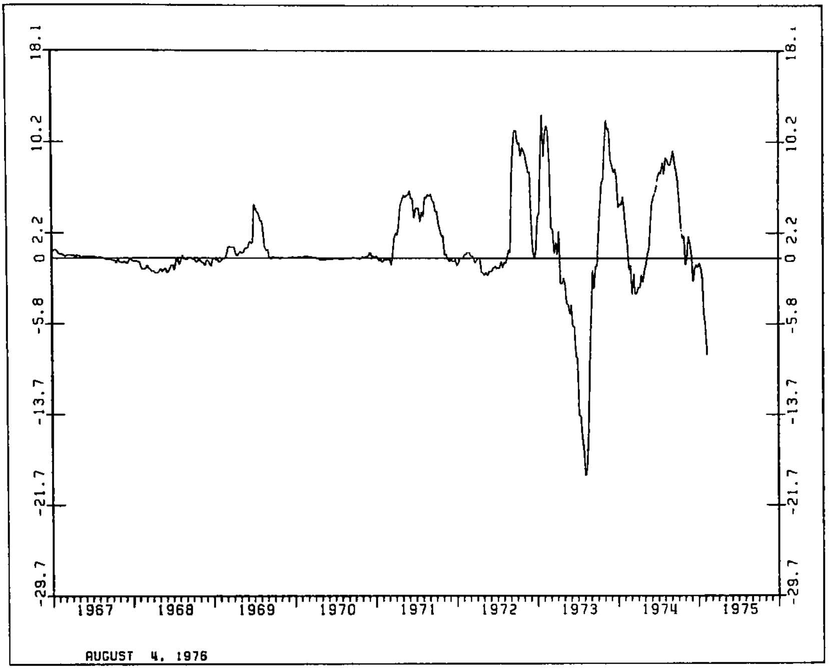

FIGURE 3. FORECAST ERRORS, FORWARD RATE THREE MONTH — BELGIUM

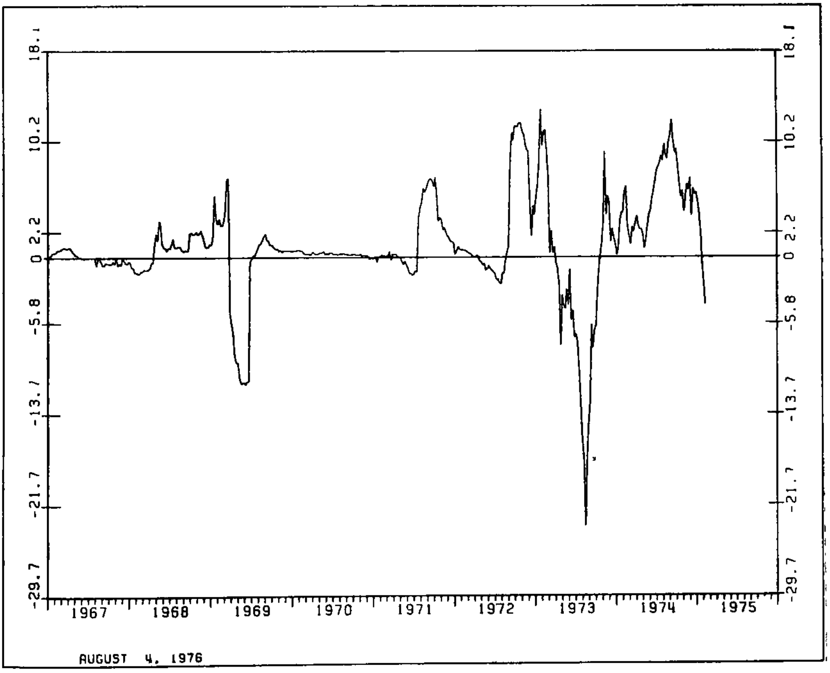

FIGURE 4. FORECAST ERRORS, FORWARD RATE THREE MONTH — FRANCE

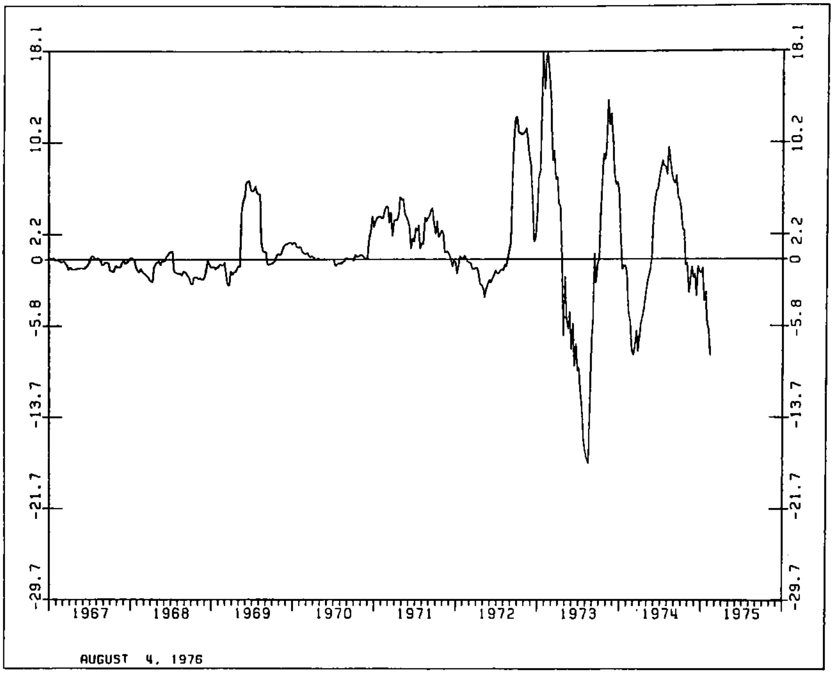

FIGURE 5. FORECAST ERRORS, FORWARD RATE THREE MONTH — GERMANY

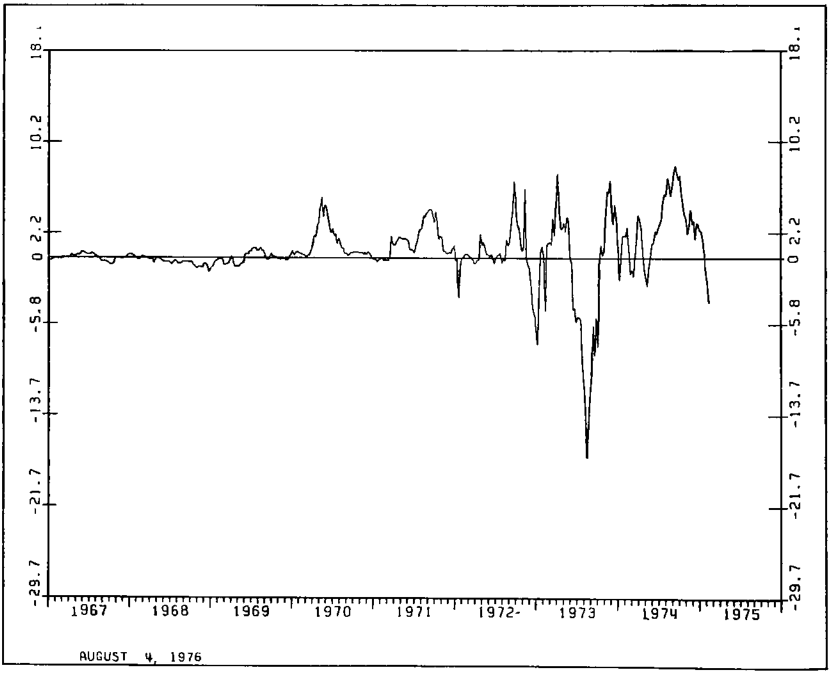

FIGURE 6. FORECAST ERRORS, FORWARD RATE THREE MONTH — ITALY

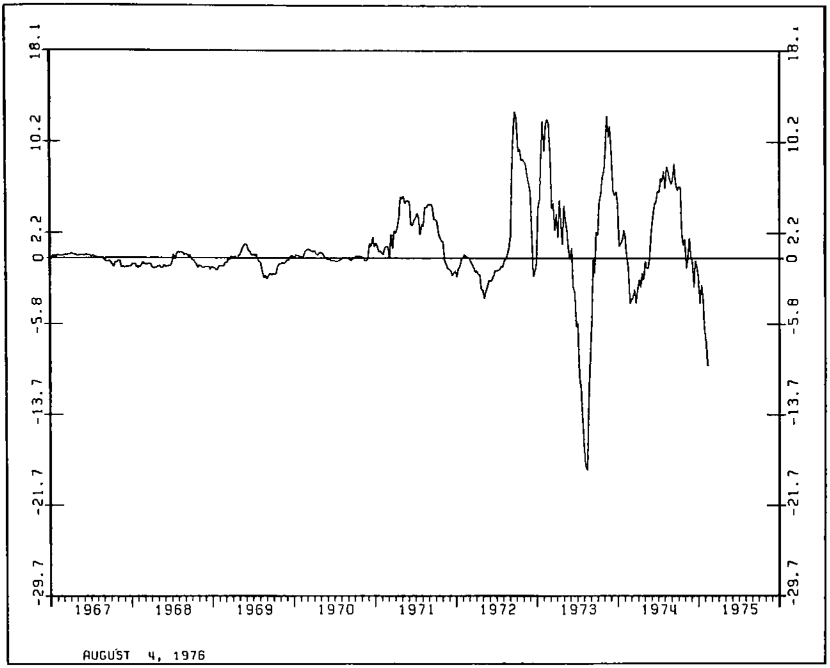

FIGURE 7. FORECAST ERRORS, FORWARD RATE THREE MONTH — THE NETHERLANDS

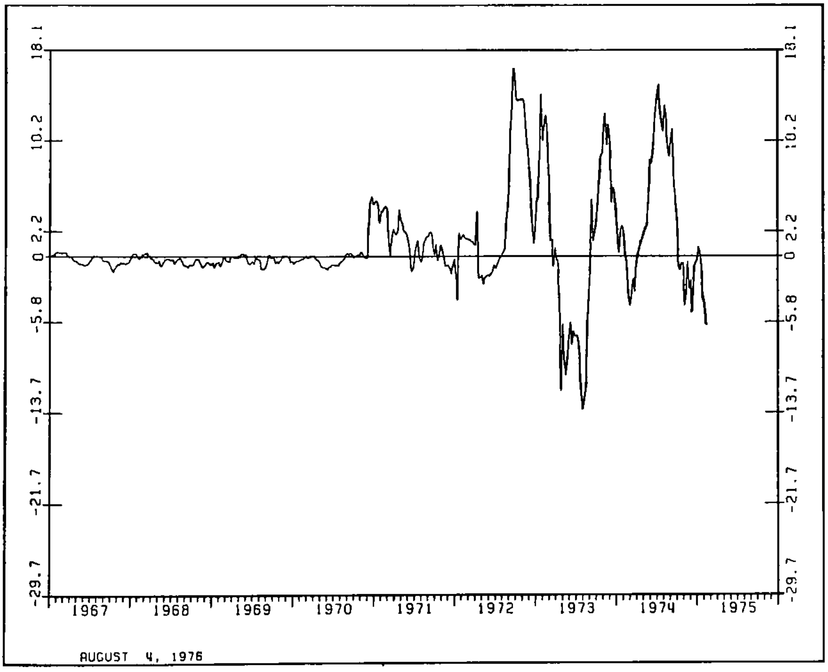

FIGURE 8. FORECAST ERRORS, FORWARD RATE THREE MONTH — SWITZERLAND

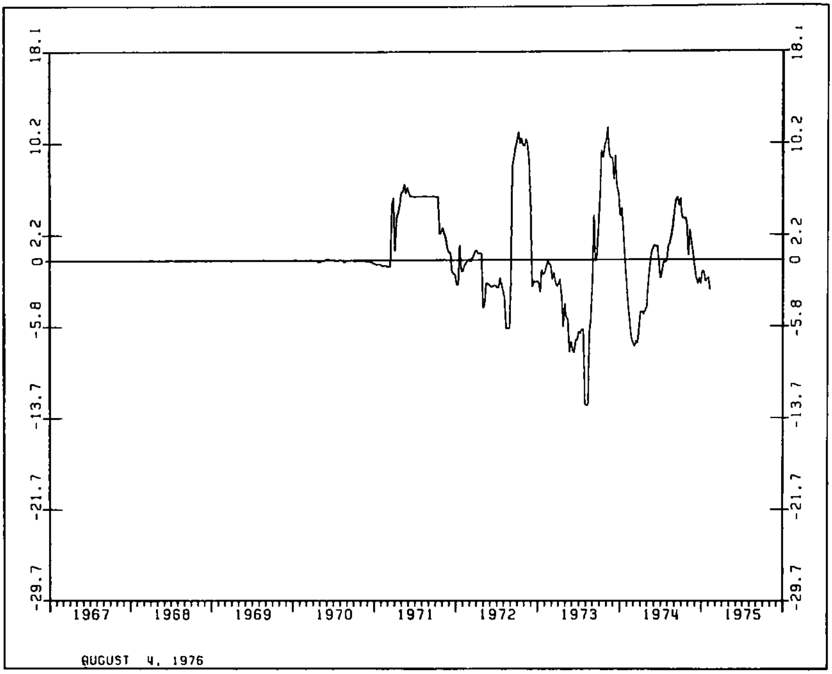

FIGURE 9. FORECAST ERRORS, FORWARD RATE THREE MONTH — JAPAN

which reports the fraction of forecast errors with a neutral band. The estimates of transaction costs in Levich (1977) suggest a neutral band of no more than 0.5 percent during the quiet period. With transaction costs increasing during speculative periods and during the managed float, a 2.0 percent neutral band is a reasonable estimate.

Table 5 indicates that in 1967, the three-month forward rate was within 0.5 percent of the future spot rate on 73 percent of the sample weeks. As the width of the band increases to 1 percent and 2 percent, the number of forecasts meeting this tolerance rises to more than 90 percent.

In later periods, 1971 and 1973, the spot-exchange rate is more volatile. Concurrently, the forward rate becomes a less precise forecast of the future spot rate. In 1973, the first year of managed floating, the number of forecast errors within the 2 percent band is 34 percent compared with 72 percent in the previous year. In 1974, forecasting performance is unchanged and in 1975, accuracy improves so that 50 percent of the weekly forecasts fall within a 2 percent band. Statistically, therefore, there is some evidence that forecast errors are becoming smaller as the managed float continues.

Since the percentage of forecast errors inside a 0.5 percent neutral band has decreased over the sample period, we could conclude that the predictive power of the forward rate has declined. However, transaction costs have increased over the period. The data suggest that transaction costs account for a similar, large percentage of forecast errors in most yearly subperiods. In many cases, therefore, the forward rate will be an accurate forecast of the future spot rate.

Table 2 conveys a similar picture. The MSE statistic is smallest during pegged-rate periods except in years when the exchange rate changes. MSE tends to increase with the introduction of floating rates. However, MSE tends to decline in 1974 and 1975 from the levels reached during 1973.

Figures 1-9 indicate positive serial correlation in the weekly series of three-month (13-week) forecast errors. This is expected since the observations are a dependent series.[20] Therefore, an independent sample of forecast errors was selected to check for serial correlation. The calculation for the Box-Pierce Q-statistic appears in Table 8. At the three-month and six-month horizon, serial correlation appears insignificant. Significant autocorrelation is present in the one-month forecasts. Earlier the suggestion was made that this may be because the forward-rate and interest-rate maturities are one month, while the differencing interval for spot rates is four weeks. It should be reiterated that serial correlation of forecast errors is not a sufficient condition to reject market efficiency. Serial correlation of unprofitable investment opportunities is consistent with market efficiency. Since the mean forecast error at the one-month horizon is very small (see Table 6), this serial correlation may not be economically significant.

Forward Rate Forecasts — An Alternative Test for Bias

In Levich (1977), a theory of the time pattern of forecast errors is developed. The theory predicts that positive forecast errors (underestimates) will be most common when the spot rate is rising and negative forecast errors (overestimates) will be most common when the spot rate is falling.

Figures 10, 11, and 12 plot the spot-exchange and the lagged-forward rate at the one-, three-, and six-month maturities. The data are for Germany and are representative of the experience of other countries. The figures support the theory. Note especially that in the managed float-

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[20] Using time-series methods, the weekly (dependent) series of k-week ahead forecasts can easily be shown to follow a moving average process of order $k - 1$. Using a dependent sample, Bilson and Levich (1977) demonstrate that the forward rate efficiently reflects the time dependence in the spot-exchange rate.

ing period the forward rate is commonly an underestimate (overestimate) of the future spot rate when the spot rate is rising (falling).

One way to test the theory statistically is to classify each time period along two dimensions; 1) the forecast error, positive or negative; and 2) the change in the spot rate, positive or negative. Accordingly, a 2 × 2 contingency table can be constructed for each country horizon episode. A sample table for the German one-month episode appears in Table 11. The null hypothesis is that the sign of the forcast error is independent of the sign of the rate of change in the spot rate. The test statistic:

$$\sum_{I=1} \sum_{J=1}^{2} [A(I, J) - E(I, J) **2]/E(I, J)$$

is approximately chi-square on one degree of freedom. The chi-square value for Table 11 is 67.0, which is highly significant. Table 12 summarizes these chi-square statistics for all nine sample countries. Independent samples were selected for each horizon so the observations are nonoverlapping. At the 5-percent level, all country-horizon episodes are con-

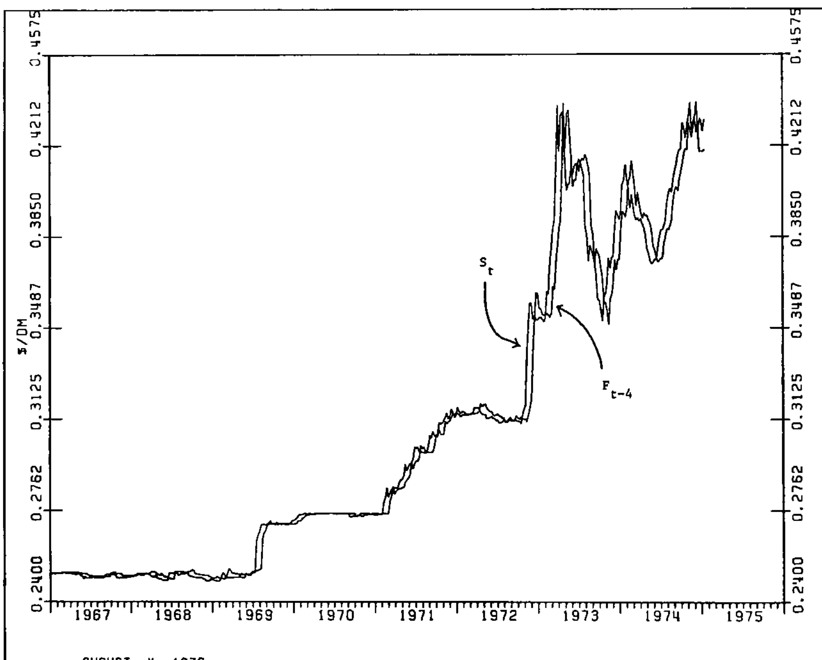

FIGURE 10. GERMANY, SPOT-RATE AND FORWARD-RATE FORECAST — ONE-MONTH HORIZON

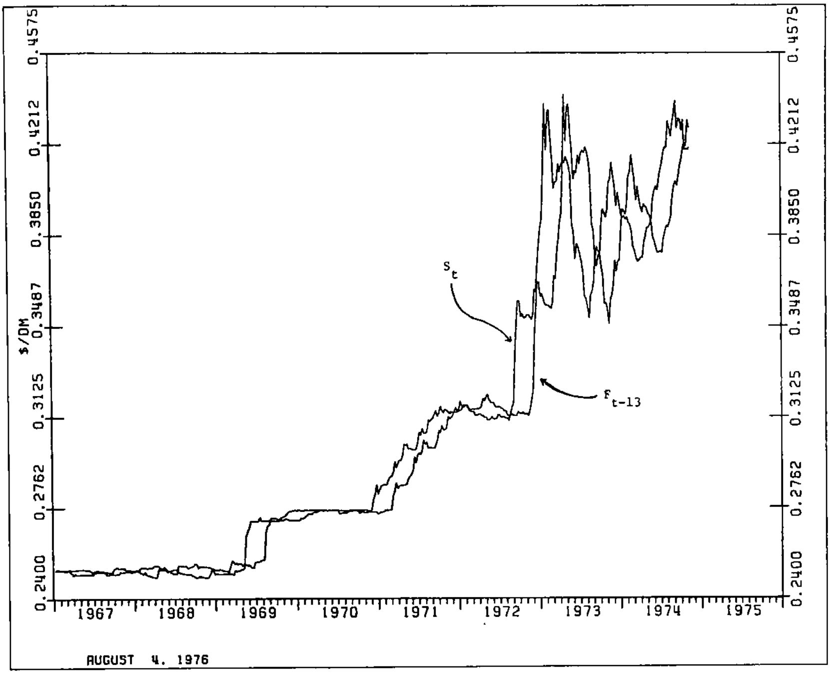

FIGURE 11. GERMANY, SPOT-RATE AND FORWARD-RATE FORECAST — THREE-MONTH HORIZON

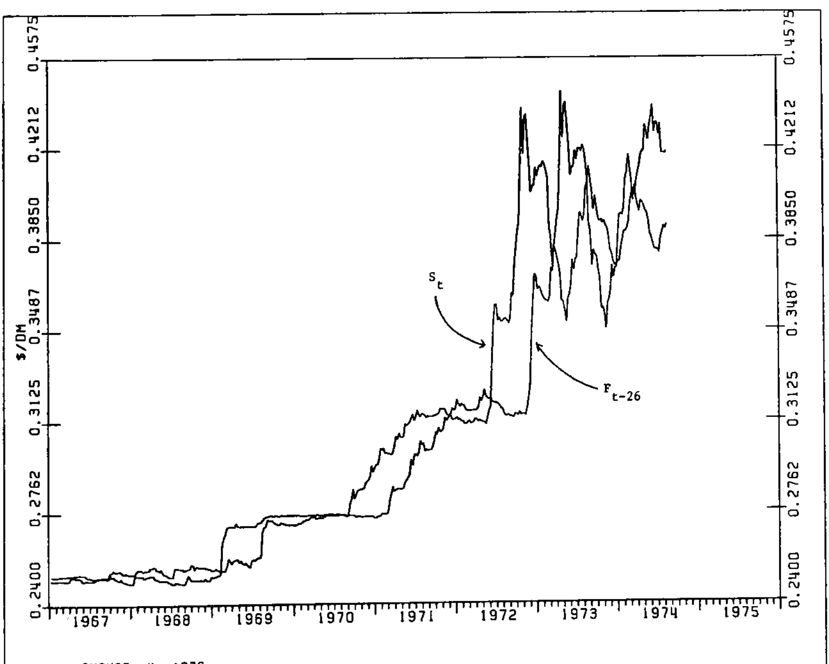

FIGURE 12. GERMANY, SPOT-RATE AND FORWARD-RATE FORECAST — SIX-MONTH HORIZON

TABLE 11
FORWARD-RATE BIAS IN GERMANY: ONE-MONTH HORIZON

	$S_{t+1} > S_t$	$S_{t+1} < S_t$	Row Total
$S_{t+1} > F_t$	$A_{11} = 60$ $E_{11} = 40$	$A_{12} = 6$ $E_{12} = 26$	66
$S_{t+1} < F_t$	$A_{21} = 4$ $E_{21} = 24$	$A_{22} = 35$ $E_{22} = 15$	39
Column total	64	41	105

NOTE: A_{ij} = Actual number of observations in cell (i,j).
E_{ij} = Expected number of observations in cell (i,j).

sistent with the forward-rate bias described by our theory. The results are particularly significant for the one-month maturity.[21]

Although the data support our theory, this pattern does not imply profit opportunities, since the forecast errors are a function of transaction costs. The theory will be useful for currencies following a trend rate of growth. In these cases, the forecast can be improved by adjusting the forward rate for transaction costs.

[21] The blanks in Table 12 indicate that because of missing observations, an independent sample could not be formed. In similar tests using a dependent sample of weekly observations, all X^2 statistics were significant at the 5-percent level.

The use of the word "bias" in this section is not in exact agreement with the usual statistical definition. For example, if the spot rate increases for 10 periods and then decreases for 10 periods, the underestimates in the first 10 periods may cancel the overestimates in the second 10 periods. Overall, the forward rate may appear unbiased while in each subperiod, an apparent bias develops.

TABLE 12
SUMMARY OF X^2 TESTS FOR FORWARD BIAS[a]

Country	One Month	Three Month	Six Month
Canada	71.2	20.7	10.9
United Kingdom		15.2	8.0
Belgium		6.4	11.4
France	37.3	14.8	3.2
Germany	67.0	21.1	11.2
Italy		9.7	6.6
The Netherlands	44.7	12.6	5.6
Switzerland	63.2	14.5	15.0
Japan			
N =	105	32	15

[a] Critical values of $X^2(1) = 3.84$ at 5 percent, and 6.63 at 1-percent level.

Composite Models

The theory of composite forecasting is to combine several alternative forecasts of the future spot rate. Even if the overall results are similar across models, the composite forecast can increase accuracy if the correlation of error terms across models is less than one.[22]

According to one view, when information is costly, prices will never fully reflect information (Grossman and Stiglitz, 1976). In this case, composite forecasting may be helpful since an analysis of more markets may exploit more information. The composite model provides a framework for analyzing a prospective forecasting technique. If the new forecast reflects information that is not reflected in the existing models, the new forecast will lead to a significant reduction in MSE in the composite model.

Alternatively, information may be costless and all markets efficient, and *still* composite forecasting may improve on simple forecasting. The reason is that there may be several sources of uncertainty in the world. In this case, several prices may be required to completely summarize (i.e., provide a sufficient statistic for) the current state of the world, even though each individual price fully reflects available information.[23]

Regression analysis is used to construct the composite forecast ($\hat{S}_t$), using the four forecasting models ($\hat{S}_{i,t}$) analyzed in this study:

$$\hat{S}_t = b_o + b_1\hat{S}_{1,t} + b_2\hat{S}_{2,t} + b_3\hat{S}_{3,t} + b_4\hat{S}_{4,t}.$$

This equation is estimated for every country-horizon episode in the sample. A dependent sample of observations is selected from two subperiods — the 1967-73 prefloating period and the 1973-75 floating period.

To examine the impact of the composite forecast, the ratio of the composite forecast MSE to the MSE from a single forecasting model is calculated. A ratio less than 1.0 implies that MSE has been reduced in the composite model. The results appear in Table 13 and Table 14.

Composite forecasting appears to have a greater impact during the floating period and when the forecasting horizon is longer. For some countries such as Canada and Germany, the improvement is negligible. For others, such as the Netherlands (at the one-month horizon), and France, Switzerland, and Japan (at the six-month horizon), the improvement is large and significant. The largest reduction in MSE is 69 percent for the six-month forecast of the Japanese yen. Most of the reductions are in the 10 to 30 percent range.

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[22] For a discussion of the theory and an application, see Nelson (1972).
[23] I am indebted to Alan Stockman for raising this issue.

TABLE 13
RATIO OF MEAN SQUARED FORECASTING ERROR: COMPOSITE MODEL/FORWARD-RATE MODEL

	Horizon					
	One Month		Three Month		Six Month	
Country	Prefloat	Float	Prefloat	Float	Prefloat	Float
Canada	.93	.92	.81	.93	.75	1.00
United Kingdom	1.00	.78	.95	.71	.89	.77
Belgium	.95	.88	.84	.77	.80	.66
France	.96	.83	.92	.74	.78	.49
Germany	.96	.97	.78	.96	.77	.94
Italy		.88		.88		.77
The Netherlands	.63	.71	.94	.86	.83	.87
Switzerland	.98	.92	.92	.69	.88	.48
Japan		.81		.60		.31
Average	.92	.86	.88	.79	.81	.70

Composite forecasting does not appear to have a smaller impact on those spot series that move randomly over time. For example, although the Swiss franc and Italian lira appear to follow a random walk, a six-month composite forecast reduces the MSE by 52 percent and 24 percent respectively, during the floating period.

Generally, composite forecasting seems to lead to substantial reductions in MSE, especially as the forecast horizon lengthens. One interpretation

TABLE 14
RATIO OF MEAN SQUARED FORECASTING ERROR: COMPOSITE MODEL/LAGGED SPOT MODEL

	Horizon					
	One Month		Three Month		Six Month	
Country	Prefloat	Float	Prefloat	Float	Prefloat	Float
Canada	.96	.98	.83	.96	.80	.95
United Kingdom	.98	.88	.95	.82	.92	.89
Belgium	.95	.93	.79	.83	.74	.76
France	.94	.92	.88	.84	.68	.60
Germany	.90	.97	.67	.94	.66	.90
Italy		.96		.91		.76
The Netherlands	.64	.69	.86	.81	.72	.81
Switzerland	.94	.92	.86	.69	.78	.48
Japan		.97		.89		.57
Average	.90	.91	.83	.85	.76	.75

is that there are several sources of uncertainty in the world. Another interpretation is that exchange-rate expectations are not reflected equally in all market sectors. This may be due to efforts by central banks to restrict price movements or to differential transaction costs or information costs across markets. When the markets are segmented and the forecast horizon is longer, the data indicate that a composite model can significantly reduce forecast errors.

FORECASTS AND RISKY INVESTMENT OPPORTUNITIES

A Methodology for Testing the Profitability of Forecasting Models

In the previous section, the possibility of using data-based models to generate consistent and accurate forecasts of the future spot-exchange rate was investigated. Having shown that there are models which can forecast the future spot rate within an error term that depends on transaction costs and a risk premium, our concern shifts to test hypothesis two: Can these models be used to make an unusual speculative profit?

A general profit opportunity that is available to all investors is forward speculation. By taking an open forward position, investors gain a profit that is proportional to the difference between the future spot rate, S_{t+n}, and today's n-period forward rate, $F_{t,n}$.[24] This section examines whether or not our forecasting models can lead to unusual profit in forward speculation.

A framework for testing for unusual profits in a domestic equity market was developed by Fama, Fisher, Jensen, and Roll (1969). This technique relies on an asset-pricing model to estimate expected returns. Actual returns in excess of expected returns are "unusual." In the foreign exchange literature, no consensus exists on a model relating speculative returns with risk. Furthermore, data limitations preclude a thorough testing of alternative models. Therefore, an alternative methodology is developed.

Assume that the speculator has made a forecast, $\hat{S}_{t+n}$, of the future spot rate. Observing $\hat{S}_{t+n} > F_{t,n}$ is a signal to buy the foreign currency forward while observing $\hat{S}_{t+n} < F_{t,n}$ is a signal to sell the foreign currency. Assume that the speculator buys one unit of currency forward independent of the deviation between his forecast and the forward rate observed in the market. Our investor is therefore risk neutral — he gam-

[24] Testing our forecasts or any other forecasts in this way does not imply that the firm does or should speculate in foreign exchange. The issues of the accuracy of the forecast and the firm's use of the forecast are separable. Assume that the firm uses the forward rate as its estimate of the future spot rate. A new forecast, which is more accurate than the forward rate and therefore leads to speculative foward profits should increase the profits of the firm.

bles a fixed amount after comparing the expected value of his forecast with the forward rate. Assuming a 100 percent margin, the mean profit rate from following this strategy for M periods can be calculated as:

$$\sum_{i=1}^{M} d_i \, (S_{t+n,\,i} - F_{t,\,i})/(M * F_{t,\,i}) \tag{5}$$

$$\text{where } d_i = \begin{cases} +1 \text{ if } \hat{S}_{t+n} > F_{t,\,n} \\ -1 \text{ if } \hat{S}_{t+n} < F_{t,\,n}. \end{cases}$$

If the investor had "perfect information," he could gain a profit in every period with the proper selection of d_i. Profits assuming perfect information are calculated as:

$$\sum_{i=1}^{M} | \, S_{t+n,\,i} - F_{t,\,i} \, | / (M * F_{t,\,i}). \tag{6}$$

In Levich (1976) it is shown that the ratio

$$H = \sum_{i=1}^{M} d_i \, (S_{t+n,\,i} - F_{t,\,i}) \Big/ \sum_{i=1}^{M} | \, S_{t+n,\,i} - F_{t,\,i} \, | \tag{7}$$

has expected value $(2p - 1)$ and variance $4p(1 - p)/m$, where p is the probability of choosing d_i correctly in any period and m is the number of independent sample observations. For example, a rule which is correct half of the time has $p = 0.5$ and $E(H) = 0.0$. "Unusual" profits correspond to the case where H is greater than zero or p is greater than one-half.

In this paper, five rules for selecting the d_i are considered:

1) Select d_i using a forecast based on traditional interest rates.
2) Select d_i using a forecast based on external interest rates.
3) Select d_i using a forecast based on the lagged spot rate.
4) Select $d_i = +1$ for all i.
5) Select $d_i = -1$ for all i.
6) Select d_i assuming perfect information.

Rules 1-5 are compared to Rule 6.

Empirical Results

Table 15 displays the mean percentage profit from three-month forward speculation for alternative rules. Note that the results describe a dependent sample of observations for the entire sample period. In other words, we assume our investor makes a three-month investment decision in every week of our sample period. The reported profits are per three-month period; they have not been annualized.[25]

[25] A similar set of calculations were made for one-month and six-month forward speculation. The results for the three-month horizon appear representative of the

TABLE 15

MEAN PERCENTAGE PROFIT FROM SPECULATION FOLLOWING ALTERNATIVE RULES

	Alternative Rules					
Country	(1)	(2)	(3)	(4)	(5)	(6)
Canada	−.103	.203[a]	.175	.178	−.178	.878
United Kingdom	.676[a]	.327	.044	.078	−.078	2.438
Belgium	.186	.486	.498	1.040[a]	−1.040	2.430
France	−.869	1.126[a]	.679	.937	−.937	2.912
Germany	−.322	.555	−.312	1.060[a]	−1.060	3.042
Italy	.371	.721[a]	.431	.527	−.527	1.669
The Netherlands	−.537	.760	−.531	.899[a]	−.899	2.277
Switzerland	−.327	1.331[a]	.500	1.096	−1.096	2.603
Japan	.382	−.457	.601	1.015[a]	−1.015	3.295

NOTE: The entries are percentage profit per three-month period. The sample period is 1967-75. For an explanation of numbering, see text.
[a] Most profitable rule for this country.

The several rules lead to a substantial difference in mean profit for each currency. For example, there are six currencies where one rule results in negative profits while another rule results in statistically significant positive profits.[26] For the other three currencies, the difference between profits from following the worst rule and the best rule is at least a factor of two.

Of the three forecast based rules (1, 2, and 3), Rule 3 is consistently dominated by Rule 2 or Rule 4 — the "always buy foreign currency" rule. This is true even for countries (e.g., United Kingdom and Italy) whose currency generally declined in value over the sample period. Similarly, Rule 1 generally leads to negative or near zero speculative profits.

Overall, there are four cases where Rule 2 is the most profitable; four cases for Rule 4; and one case for Rule 1. In each of these cases, the mean profit is significantly greater than zero. With the possible exception of Canada, these profits appear to be in excess of transaction

other two periods. Since the data base consists of bid prices for both spot and forward rates, profits from speculative purchases of foreign currency are overestimated while profits from speculative sales of foreign currency are underestimated. Mean speculative profits may be unbiased and variability overstated if long and short foreign currency positions balance out over time. However, if the investor has a consistent long position in one currency, the estimate of mean speculative profits will be biased.

[26] A rule which leads to a negative profit can be adapted to result in a positive profit just by reversing the speculative activity indicated by the rule (i.e., reverse the d_t). In other words, if the forecast indicates that S_{t+n} will be greater (less) than F_t, we sell (buy) the foreign currency forward. None of these "adapted" rules results in higher profits than an alternative rule in Table 15.

costs. If the profits are annualized, the rates of return are in the range 0.8 percent to 5.3 percent. These profits are small relative to the risk-free yield on U.S. treasury bills over this period.[27]

In Table 15, observe that the perfect information profits (column 6) vary across currencies. These profits are greatest for Japan (which also has the highest mean squared forecast error) and lowest for Canada (which has the lowest mean squared forecast error). This observation only confirms a definition. Potential profits from forward speculation are greatest when the forward rate is a poor forecaster of the future spot rate.

Statistics for analyzing the unusualness of these speculative profits are presented in Table 16. For the most profitable rules, the H ratio ranges between 0.23 for Canada and 0.51 for Switzerland; the corresponding probabilities (p) range between 0.62 and 0.76. While these estimates of p are larger than 0.5, they are based on a sample of 32 independent observations. Therefore, no estimate of p is significantly larger than 0.5 at the 5 percent confidence level. These rules do not result in unusual profits and therefore we cannot reject hypothesis two.

[27] The returns appear similar to those calculated by Grubel (1966). Over the period July, 1955 to May, 1961, Grubel calculated average annual rates of return between 16 percent and 27 percent for sterling speculation assuming a 10 percent margin. Adjusting our figures for a 10 percent margin implies rates of return in the range 8 percent to 53 percent. The rate of return from sterling speculation is 27 percent (.676 × 4 × 10). Grubel did not calculate any empirical measure of the riskiness of his speculative profits.

TABLE 16
A TEST FOR UNUSUAL SPECULATIVE RETURNS

	Alternative Rules							
	(1)		(2)		(3)		(4)	
Country	H	p	H	p	H	p	H	p
Canada	−.12	.44	.23[a]	.62	.20	.60	.20	.60
United Kingdom	.28[a]	.64	.13	.57	.02	.51	.03	.51
Belgium	.08	.54	.20	.60	.02	.51	.43[a]	.71
France	−.30	.35	.39[a]	.69	.23	.62	.32	.66
Germany	−.11	.45	.18	.59	−.10	.45	.35[a]	.67
Italy	.22	.61	.43[a]	.72	.26	.63	.32	.66
The Netherlands	−.24	.38	.33	.67	−.23	.38	.39[a]	.70
Switzerland	−.12	.44	.51[a]	.76	.19	.60	.42	.71
Japan	.12	.56	−.14	.43	.18	.59	.31[a]	.65

NOTE: H is the H ratio; p is probability.
[a] Most profitable rule for this country.

SUMMARY AND CONCLUSIONS

In this paper, a number of relationships in the international money market have been investigated. A set of simple models for forecasting the future spot rate were proposed and tested on a uniform data base. The most important results are that: 1) forecast errors appear to be serially uncorrelated; 2) forecasting bias or currency preference does not appear to be predictable; and 3) mean squared forecasting error rises in proportion to forecasting horizon. These results are consistent with the view that the market efficiently reflects information concerning future exchange rates.

Another important finding is that a composite forecasting model can significantly reduce forecast errors. The gain from composite forecasting may be the result of information costs, search costs, or government intervention, all of which tend to separate financial markets. More generally, the model provides a framework for analyzing prospective forecasting techniques.

A final test investigated the profit opportunities available to the user of a simple forecast. Profits from forward speculation appeared to be small in relation to a risk-free yield and perfect information profits. The finding that a forecast model, based on publicly available information, cannot be used to earn an unusual profit is consistent with efficient market theory.

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An Evaluation of the Relative Price-Forecasting Accuracy of Selected Futures Markets

Ray Marquardt

The Chicago Mercantile Exchange and the Chicago Board of Trade have been criticized by some people in the public sector and the press. Critics state that, among other things, futures markets give too much profit to speculators and provide no benefit to producers and the public. These critics overlook the fact that the futures market provides a continuous price forecast for the many commodities traded.

Several commercial advisory services, governmental publications, and land-grant colleges make forecasts of future cash prices. However, a search of these "outlook letters" reveals that most sources do not make frequent forecasts. Only a few forecasts are made on a weekly basis; lapses of several months often occur between successive predictions. In addition, few letters make specific forecasts in dollars and cents for a specific time period. The fundamentals of supply and demand are discussed, but the two concepts are seldom brought together to make a specific price forecast. In contrast, the daily trading on the commodity futures market provides a continuous flow of forecast information which both the producer and the purchaser may use in his planning efforts. Thus, the futures market offers an advantage over other types of outlook information; namely, timeliness.

Timeliness is not the only important attribute of a forecast. Accuracy must also be provided if the forecast is to be used effectively in planning production and purchases, and in financing both types of activity.

Large companies can afford to spend a considerable amount of money to make a forecast that is both timely and reasonably accurate. Individual agricultural producers are usually not large enough to make price forecasts based entirely on their own information. Thus, they rely on published outlook letters, governmental publications, and the price on the commodity futures market to serve as their forecasting experts.

Ray Marquardt is a faculty member at the University of Wyoming. This paper was written in 1974.

The review of 10 outlook letters in this study revealed that few actual dollars-and-cents forecasts were available. The hectic and uncertain cash-market conditions that have existed over the past several years have caused many letters to give only vague predictions on the direction of price movements. The commodity futures market gives both direction and magnitude of expected price levels established by the supply-and-demand expectations of many individuals.

The objective of this study was to determine if there is any difference in the relative accuracy of the cash-price predictions made by the commodity futures market quotations and the available commercial, governmental, and university outlook publications.

The conclusions drawn from this study are especially important to agricultural producers, purchasers of agricultural products, and lending institutions. They are also useful to the Chicago Mercantile Exchange and the Chicago Board of Trade since benefits of the futures markets must be identified if they are to maintain a favorable public acceptance and prevent more stringent regulations on trading activity.

RESEARCH PROCEDURES

The two main livestock commodities (live fat cattle and live fat hogs) and the three main grain commodities (wheat, corn, and soybeans) were analyzed in this study. The outlook letter sources evaluated were: "Doanes Agricultural Letter," *Farm Journal,* "Illinois Farmer's Outlook Letter," "Iowa Farm Outlook," "Kiplinger Agricultural Letter," *Nebraska Farmer, Successful Farming,* "U.S.D.A. Livestock and Meat Situation," "Washington Farm Letter," and "Western Livestock Roundup." These sources are identified randomly by number, 2 through 11, in the following analysis.

The analysis consisted of an evaluation of the accuracy of all forecasts made by these sources from January 1, 1970 to December 31, 1973. This means that price movements were analyzed through April, 1974 because 1973 sources contained predictions for 1974 prices.

The number of observations was determined by the number of forecasts made by the outlook letters. An observation occurred only if an outlook letter made a price forecast for one of the five commodities being studied. The price forecasts made by outlook letters were of two types: 1) actual price level or actual predicted change in price in dollars and cents, or 2) a general prediction of the direction of a price change. Thus, the data were analyzed in absolute dollars and cents in Analysis A when such data were available. Analysis B used the prediction of the direction of a price change made by the letters and thus had a much larger sample size.

Analysis A

The deviation between the forecast price and the actual cash price obtained at the specified future date was investigated. The deviations between forecast and actual prices as revealed in the forecasts made by the various commercial, governmental, and university publications were compared with the forecast offered by the closing price on the futures market for the relevant commodity and time period. For example, suppose that on January 2, 1971, Source A said that Choice live steers would increase by $4 per hundredweight (cwt) between January and the middle of June; the quote on January 2, for the June futures was $31 cwt and the cash price on January 2, was $30 cwt. Suppose further that the actual cash price on the day the June contract expired was $32 cwt. The deviations to be compared were:

For Source A: $4 (the forecast increase in price) minus [$32 (the actual cash price in June) minus $30 (the cash price on January 2, which was the date of the forecast)] equals $4 — $2 or $2.

For the Futures Market: $31 (quote for June futures on January 2) minus $32 (the actual cash price in June) or —$1 or a deviation of —$1 from the forecast price.

The value of the deviations were then analyzed by using a paired *t* test to determine if a significant difference existed among the accuracy of the different forecasting techniques.

Analysis B

The direction of the predicted price movement was recorded and compared with the direction indicated by the futures market quotation in the case of nonspecific dollars-and-cents forecasts made by any source. For example, if Source A indicated only that Choice cattle prices are likely to increase between January 2, 1971, and June, 1971, the upward direction was noted. The closing quotation for the June contract was compared to the cash price on January 2, to determine what direction the futures market was predicting that price would move over the same period. All forecasts were categorized into: 1) increase, 2) no change or stable, and 3) decrease price-movement classifications.

The relative accuracy of the different prediction sources was then analyzed by using a chi-square test of independence because in this analysis the data were measured in only nominal levels.

THE FINDINGS

Analysis A

The analysis of all 10 outlook letters for the four-year study period revealed only 77 times when an outlook letter made a forecast of a price change in dollars and cents for one of the five commodities under study (see Table 1). This is one of the safest kinds of forecasts for the layman to interpret, provided that dates are specified for the time the forecast is made. This type of forecast is also easily interpreted by producers because they can apply the effect of the predicted price change to their local conditions better than they can apply a prediction of a specified price at some vague destination. Judging from the few times that outlook-letter forecasts were made, it may be assumed that perhaps producers have difficulty interpreting such forecasts. On the other hand, the five-day-a-week quotations on the futures market, compared with the current cash price at a specified delivery point, offer a frequent price forecast that the producer can apply to his local conditions.

Analysis of the predicted price-change data reveals that although statistically significant differences could not be established, the futures market gave a closer price prediction to actual price changes than did the 10 outlook letters considered as one forecasting source (see Table 1). The futures market gave a closer average deviation of forecasting price change from the actual price change for five of the seven comparisons against individual outlook letters (see Table 1). The observed differences on each of the seven comparisons was not statistically significant at the alpha .10 level, so the sample size was just too small to say that the one technique is a better predictor than the other.

More frequently, outlook letters made predictions of a forecast price level in dollars and cents. Sometimes the exact location and/or time that this price is supposed to occur is not made clear to the reader of the outlook letter. For this paper, price forecasts were interpreted as accurately as possible, and then the paired *t* test was used to analyze the forecasts made on the same date by the outlook letters and futures market (see Table 2). Results indicate that the futures market gave a statistically better forecast than did the 10 outlook letters combined. The difference was significant at the alpha .01 level, so the probability that the observed difference is due only to chance is less than one percent.

The number of cases observed was large (988) but the frequency of usable forecasts on an absolute dollars-and-cents basis is still not large. One must realize that 10 letters were evaluated over a four-year period on five commodities. If each letter had made one forecast for one time period on each commodity on a weekly basis, the number of cases observed would have been 10,400.

Paired *t*-test comparisons of the predictions made by the futures market versus each individual outlook letter showed that the futures market gave a statistically significant better prediction than did eight of the 10 individual letters (see Table 2). The futures market gave a better prediction than did the ninth outlook letter, but the difference was not statistically significant, as the letter made only three predictions on absolute price levels during the four-year period. Only one outlook letter gave better price predictions than did the futures market, and that outlook letter only made 35 predictions on absolute price levels during the period of study.

The bias associated with these methods of analysis should favor the outlook letters. The authors choose when a forecast is made and therefore determine an observation. A futures-market forecast was not compared to an outlook-letter forecast unless the letter had made a specific prediction.

Another series of paired *t* tests was made on these 988 predictions originating from the 10 outlook letters. This analysis was made using the absolute value of the deviation of the forecast price change from the actual price change (see Table 3). The only difference between this analysis and the analysis presented in Table 2 was that the data were analyzed without regard to sign. This analysis was conducted to make certain that several large differences on the plus and negative side of the deviation (of the forecast price change from the actual price change) did not offset each other. The analysis provided nearly identical results as did the data presented in Table 2. The futures market gave a significantly better forecast than did the 10 outlook letters combined. In all but one of the individual comparisons, the futures market gave a closer prediction to actual price changes, although three of those comparisons were not statistically significant.

Analysis B

The outlook letters frequently predicted the direction of a price change even if they did not state an exact price level or state a specific dollars-and-cents change in the price level. These 2,756 different forecasts made by the 10 outlook letters were categorized into: 1) increase, 2) no change or stable, and 3) decrease price-movement classifications. The data were then analyzed by a chi-square analysis and by a comparison of the percentage of correct forecasts made by each method.

Data presented in Table 4 indicate that there is a significant difference between the forecasts made by the futures market and the 10 outlook letters, and the three categories presented at the top of the table. The 10 outlook letters actually made fewer mistakes (32.5 percent) in predicting the direction of the price movement than did the futures market (34.1 percent). This was only because the outlook letters frequently made a prediction of no change in price when a change actually occurred. As a

TABLE 1

SUMMARY OF *t* TEST ON DEVIATION OF FORECAST PRICE CHANGE FROM ACTUAL PRICE CHANGE FOR FAT CATTLE, FAT HOGS, WHEAT, CORN, AND SOYBEANS BY SOURCE OF PREDICTION

Source[a]	Number of Cases	Mean Deviation of Forecast Price Change from Actual Price Change	Standard Deviation of Forecast Price Change from Actual Price Change	Average Difference between Means	Source Which is the Better Predictor	Calculated t Value on Difference between the Two Means[b]
Futures market	77	− .5909	2.454	.1217	Futures market	.62
All 10 outlook letters	77	− .7126	2.785			
Futures market	2	− .3950	1.591	.9300	Futures market	1.24
Outlook letter 2	2	−1.3250	.530			
Futures market	9	.1533	2.929	.8956	Futures market	1.52
Outlook letter 3	9	− .7422	3.094			

Futures market	14	− .2550	.579	−.4936	Outlook letter 4	1.60
Outlook letter 4	14	.2386	1.577			
Futures market	10	−2.6260	2.884	.2740	Futures market	.74
Outlook letter 6	10	−2.9000	3.678			
Futures market	27	− .3778	2.947	.4011	Futures market	.93
Outlook letter 7	27	− .7789	2.829			
Futures market	13	− .5831	1.492	−.0408	Outlook letter 10	.33
Outlook letter 10	13	− .5423	1.876			
Futures market	2	.7600	1.301	−3.34	Futures market	4.99
Outlook letter 11	2	4.1000	.354			

[a] Predicted price-change data were not available for outlook letters 5, 8, and 9.
[b] Difference between means was not significant in any of the comparisons at the alpha .10 level.

TABLE 2

SUMMARY OF *t* TEST ON DEVIATION OF FORECAST PRICE FROM ACTUAL PRICE FOR FAT CATTLE, FAT HOGS, WHEAT, CORN, AND SOYBEANS BY SOURCE OF PREDICTION

Source	Number of Cases	Mean Deviation of Forecast Price Change from Actual Price Change	Standard Deviation of Forecast Price Change from Actual Price Change	Average Difference between Means	Source Which is the Better Predictor	Calculated t Value on Difference between the Two Means
Futures market	988	− .8794	5.497	1.5908	Futures market	17.67[b]
All 10 outlook letters	988	−2.4703	6.076			
Futures market	35	2.0260	3.553	1.0551	Outlook letter 2	2.61[c]
Outlook letter 2	35	.9709	3.740			
Futures market	140	− .0464	5.833	1.5845	Futures market	8.71[b]
Outlook letter 3	140	−1.6309	5.558			
Futures market	231	−1.0385	4.899	1.1212	Futures market	7.90[b]
Outlook letter 4	231	−2.1597	4.934			

Futures market	10	−3.0850	8.606	2.6010	Futures market	2.59[c]
Outlook letter 5	10	−5.6860	10.879			
Futures market	184	−2.0975	5.229	1.5947	Futures market	8.49[b]
Outlook letter 6	184	−3.6922	5.964			
Futures market	110	− .0078	5.737	2.1045	Futures market	5.61[b]
Outlook letter 7	110	−2.1124	7.702			
Futures market	15	−2.7620	7.889	1.0780	Futures market	2.37[c]
Outlook letter 8	15	−3.8400	8.026			
Futures market	3	−2.2767	2.199	.9633	Futures market	1.29[a]
Outlook letter 9	3	−3.2400	3.376			
Futures market	121	−0.5925	4.561	1.6435	Futures market	5.26[b]
Outlook letter 10	121	−2.2359	5.281			
Futures market	139	−1.1212	6.387	2.0513	Futures market	7.52[b]
Outlook letter 11	139	−3.1724	6.978			

[a] Difference between means was not significant at the alpha .10 level.
[b] Significantly different at the alpha .01 level.
[c] Significantly different at the alpha .05 level.

TABLE 3

SUMMARY OF *t* TEST ON DEVIATION OF ABSOLUTE VALUE OF FORECAST PRICE FROM ACTUAL PRICE FOR FAT CATTLE, FAT HOGS, WHEAT, CORN, AND SOYBEANS BY SOURCE OF PREDICTION

Source	Number of Cases	Mean Absolute Value of Deviation of Forecast Price Change from Actual Price Change	Standard Deviation of Forecast Price Change from Actual Price Change	Average Difference between Means	Source Which is the Better Predictor	Calculated t Value on Difference between the Two Means
Futures market	988	3.3805	4.422	.8366	Futures market	10.02[b]
All 10 outlook letters	988	4.2172	5.022			
Futures market	35	3.0471	2.700	.2911	Outlook letter 2	0.97[a]
Outlook letter 2	35	2.7560	2.672			
Futures market	140	3.3298	4.781	.3071	Futures market	1.60[a]
Outlook letter 3	140	3.6369	4.500			
Futures market	231	2.7813	4.161	.4532	Futures market	3.32[b]
Outlook letter 4	231	3.2345	4.304			

Futures market	10	6.2910	6.377	1.6850	Futures market	1.40[a]
Outlook letter 5	10	7.9760	9.143			
Futures market	184	3.7146	4.230	1.2221	Futures market	7.51[b]
Outlook letter 6	184	4.9367	4.978			
Futures market	110	4.0651	4.029	1.4955	Futures market	4.21[b]
Outlook letter 7	110	5.5605	5.711			
Futures market	15	3.9473	7.329	1.0127	Futures market	2.35[c]
Outlook letter 8	15	4.9600	7.339			
Futures market	3	2.2767	2.199	.9633	Futures market	1.29[a]
Outlook letter 9	3	3.2400	3.376			
Futures market	121	2.7040	3.712	.8420	Futures market	3.28[b]
Outlook letter 10	121	3.5460	4.500			
Futures market	139	3.8702	5.194	1.1720	Futures market	4.61[b]
Outlook letter 11	139	5.0422	5.764			

[a] Difference between means was not significant at the alpha .10 level.
[b] Significantly different at the alpha .01 level.
[c] Significantly different at the alpha .05 level.

result, only 49.9 percent of the predictions made by the 10 outlook letters resulted in a correct forecast of the direction of the price movement. By comparison, 62.3 percent of the predictions made by the futures market resulted in a correct forecast (see Table 4). When a forecast letter made a prediction of the direction of the price change, it was correct 60.5 percent (1,374/2,271) of the time compared to a 64.6 percent (1,716/2,655) rate for the futures market. This difference of 4.1 percentage points is statistically significant at the alpha .05 level. Thus, the futures market not only gave more frequent forecasts (five days a week), but also gave more frequent forecasts of the direction of a price change and a higher percentage of accuracy when predicting the direction of price movements.

Again, it must be noted that if this method of analysis is biased, it is probably biased in favor of the outlook letters because they choose the time when a forecast is made. The outlook letters made more frequent predictions for the normal seasonal patterns (e.g., predict that the price of the grains will decline from spring into the harvest season), but made less frequent predictions for periods of relatively more uncertainty.

The forecasting performance of the two sources differed by commodity (see Table 5). The futures market gave the better predictions of the direction of price movements for fat cattle, fat hogs, and corn. The futures market correctly predicted the direction of a price change 70 percent of the time for hogs, 69 percent for cattle, and 60 percent for corn. The percentage of correct forecasts of direction made by the 10 outlook letters was six percentage points below that of the accuracy rate for the futures market for each of these three commodities. This difference was statistically significant at the alpha .05 level in all three commodities.

The futures market and the 10 outlook letters both achieved 66 percent accuracy in correctly forecasting the direction of a price movement in soybeans if a price change was either predicted or observed (see Table 5). However, the outlook letters made more frequent (55 times versus 17 times) forecasts of no change in price when in fact a price change did occur.

The 10 outlook letters were more accurate in correctly forecasting the direction of price change for wheat. The outlook letters were correct 47 percent of the time, if a price change was either predicted or observed, compared to only 41 percent accuracy for the futures market (see Table 5). However, the difference was not statistically significant at the alpha .10 level, so it could have been due to chance.

Paired comparisons of the relative accuracy of the futures market against each of the 10 outlook letters reveals that for eight of the ten

TABLE 4

RELATIVE ACCURACY OF FUTURES MARKET AND 10 OUTLOOK LETTERS IN PREDICTING THE DIRECTION OF PRICE MOVEMENTS OF FAT CATTLE, FAT HOGS, WHEAT, CORN, AND SOYBEANS[a]

Source	Times When the Direction of the Predicted Price Movement Gave the Correct Direction of the Future Cash Price Changes		Times When the Direction of the Predicted Price Movement was Incorrect in Predicting the Direction of Future Price Changes		Times When No Change in Price Was Either Predicted or Observed		Total Observations
	Number	Percentage	Number	Percentage	Number	Percentage	
Futures market	1,716	62.3	939	34.1	101	3.7	2,756
All 10 outlook letters	1,374	49.9	897	32.5	485	17.6	2,756

[a] Calculated chi-square value = 290.4 which is significant at the alpha .01 level.

TABLE 5

RELATIVE ACCURACY OF FUTURES MARKET AND ALL 10 OUTLOOK LETTERS IN PREDICTING THE DIRECTION OF PRICE MOVEMENTS OF VARIOUS COMMODITIES

Commodity and Source	Times when the Direction of the Predicted Price Movement Gave the Correct Direction of the Future Cash Price Changes		Times when the Direction of the Predicted Price Movement was Incorrect in Predicting the Direction of Future Price Changes		Times when No Change in Price was Either Predicted or Observed		Total Observations	Percentage of Times that Forecast was Correct If a Price Change was Either Predicted or Observed
	Number	Percentage	Number	Percentage	Number	Percentage		
Fat cattle								
Futures market	533	66.5	245	30.5	24	3.0	802	69[a]
Outlook letters	376	46.9	223	27.8	203	25.3	802	63
Fat Hogs								
Futures market	641	69.4	271	29.3	12	1.3	924	70[a]
Outlook letters	525	56.8	293	31.7	106	11.5	924	64
Wheat								
Futures market	129	39.8	182	56.2	13	4.0	324	41[b]
Outlook letters	123	38.0	141	43.5	60	18.5	324	47
Corn								
Futures market	215	55.0	141	36.1	35	9.0	391	60[a]
Outlook letters	179	45.8	151	38.6	61	15.6	391	54
Soybeans								
Futures market	198	62.9	100	31.7	17	5.4	315	66[b]
Outlook letters	171	54.3	89	28.3	55	17.5	315	66

[a] Difference between the two percentages for the commodity is significant at the alpha .05 level.
[b] Difference between the two percentages for the commodity is not significant at the alpha .10 level.

comparisons, the futures market gave a higher percentage of correct forecasts of the direction of the price movement if a price change was either predicted or observed (see Table 6). The futures market and outlook letter 3 both correctly predicted the correct direction of the price movement 62 percent of the times that a price change was either predicted or observed. However, the direction of the predicted price movement given by outlook letter 3 correctly correlated with the actual direction of the price movement only 47.8 percent of the time compared with 59.6 percent agreement for the futures market. Outlook letter 3 predicted no change in price quite frequently (about 20 percent of the time they made a forecast) and price actually changed, so this accounted for the better performance for the futures market in this category.

Outlook letter 9 was the only source to provide a higher percentage of forecasts that were correct if a price change was either predicted or observed (see Table 6). In this case, outlook letter 9 was correct 77 percent of the time that it predicted a price change compared to 66 percent for the futures market. However, the direction of the predicted price movement given by outlook letter 9 correctly coincided with the actual direction of the price movement only 41.4 percent of the time compared to 65.5 percent for the futures market. The difference is due to outlook letter 9 forecasting no change in the direction of prices 46 percent of the time it mentioned a price forecast. Thus, the futures market seems to provide a higher percentage of correct forecasts than this letter as well as the other nine letters.

Except for the paired comparison of the futures market and outlook letter 8 (see Table 6), there was no statistically significant difference in any of the paired comparisons on the percentage of times that the forecast was correct if a price change was either predicted or observed.

SUMMARY OF THE FINDINGS

The findings of this study can be summarized as follows:

1. The futures market provides a more frequent and timely forecast than the outlook letters, which only infrequently make specific forecasts by commodity in specific dollars-and-cents terms for a well-specified time period.

2. The futures market was generally a more accurate source of forecasts than were the 10 outlook sources. A paired t test on the deviation of forecast price from actual price for the futures market and the 10 outlook sources indicated that the futures market gave a statistically better forecast on the five commodities than did the 10 outlook letters (see Table 2). When an outlook source made a prediction of the direction of a price

TABLE 6

RELATIVE ACCURACY OF FUTURES MARKET AND VARIOUS OUTLOOK LETTERS IN PREDICTING THE DIRECTION OF PRICE MOVEMENTS OF FAT CATTLE, FAT HOGS, WHEAT, CORN, AND SOYBEANS

Source	Times when the Direction of the Predicted Price Movement Gave the Correct Direction of the Future Cash Price Changes		Times when the Direction of the Predicted Price Movement was Incorrect in Predicting the Direction of Future Price Changes		Times when No Change in Price was Either Predicted or Observed		Total Observations	Percentage of Times that Forecast was Correct If a Price Change was Either Predicted or Observed
	Number	Percentage	Number	Percentage	Number	Percentage		
Futures market	63	71.6	21	23.9	4	4.5	88	75[b]
Outlook letter 2	42	47.7	23	26.1	23	26.1	88	65
Futures market	193	59.6	116	35.8	15	4.6	324	62[b]
Outlook letter 3	155	47.8	94	29.0	75	23.1	324	62
Futures market	446	60.4	261	35.3	32	4.3	739	63[b]
Outlook letter 4	414	56.0	270	36.5	55	7.4	739	61

Futures market	27	69.2	12	30.8	0	0	39	69[b]
Outlook letter 5	20	51.3	13	33.3	6	15.4	39	61
Futures market	147	61.2	84	35.0	9	3.7	240	64[b]
Outlook letter 6	109	45.4	80	33.3	51	21.2	240	58
Futures market	397	60.2	238	36.1	24	3.6	659	63[b]
Outlook letter 7	298	45.2	204	31.0	157	23.8	659	59
Futures market	67	76.1	19	21.6	2	2.3	88	78[a]
Outlook letter 8	49	55.7	29	33.0	10	11.4	88	63
Futures market	57	65.5	30	34.5	0	0	87	66[b]
Outlook letter 9	36	41.4	11	12.6	40	46.0	87	77
Futures market	168	61.8	92	33.8	12	4.4	272	65[b]
Outlook letter 10	140	51.5	99	36.4	33	12.1	272	59
Futures market	151	68.6	66	30.0	3	1.4	220	70[b]
Outlook letter 11	111	50.5	74	33.6	35	15.9	220	60

[a] Difference between the two percentages is significant at the alpha .05 level.
[b] Difference between the two percentages is not significant at the alpha .10 level.

change, it was correct 60.5 percent of the time compared to a 64.6 percent accuracy rate for the futures market (see Table 4). This difference of 4.1 percentage points is statistically significant at the 95 percent confidence level. Thus, the futures market not only made more frequent forecasts, but also gave a higher percentage accuracy when predicting the direction of price movements.

3. The futures market provided relatively more accurate predictions than all 10 outlook letters on the direction of price movements for fat cattle, fat hogs, and corn and at least as good a forecast on soybeans, but did not do as well in forecasting wheat price movements (see Table 5).

Revaluation Versus Devaluation: A Study of Exchange-Rate Changes

William R. Folks, Jr. and Stanley R. Stansell

The purpose of this study is to determine whether the technique of linear discriminant analysis can assist in exchange-risk management. Specifically, a discriminant function, using readily available or estimable macroeconomic values is developed which will classify countries into two distinct groups: 1) countries whose currency value (relative to the value of the dollar) will decrease by 5 percent or more over a two-year period, and 2) countries whose currency value will not show such a decrease.

The authors believe that such a discriminant function, if reasonably accurate, is valuable in corporate exchange-risk management. Under normal operating conditions, U.S.-based corporations with direct investments overseas generally have an excess of assets over liabilities that are exposed to the risk of currency changes. Thus, a reduction in foreign-currency values causes, at least for accounting purposes, a loss in the value of exposed assets. Numerous strategies for adjusting the exchange-risk posture of the firm exist but require some warning for effective use. Some projection of the extent of currency-rate change is also required to prevent adoption of exchange-adjustment strategies which may prove more costly than the losses they were designed to prevent.

The authors hope that the discriminant function developed below will provide an early warning of impending downward exchange-rate changes. Armed with this warning, corroborated possibly by local sources, nonstatistically based projections, and other information, the exchange-risk manager can then provide closer surveillance of the currency under suspicion, take long-range steps to adjust the exchange-risk posture of the firm, and develop contingency plans for short-term measures should the decrease in currency value become imminent.

William R. Folks, Jr. is a faculty member at the University of South Carolina and Stanley R. Stansell is a faculty member at the University of Houston. This paper was written in 1973.

In subsequent sections, the term "devaluing" countries or currencies describes those currencies (relative to the dollar) that lose 5 or more percent of their value. Classification of a currency in this category does not necessarily mean that a formal devaluation (notification to the International Monetary Fund of a change in par value or central rate) has occurred. A loss in value may occur if the country elects to float its currency vis-à-vis the dollar, and if that currency subsequently floats downward by 5 or more percent. Alternately, a revaluation of the dollar would place a currency in the "devaluing" group, if that country did not match the revaluation by one of its own. These diverse methods of adjusting relative currency value have led the authors to define a devaluing country as: one where the direct exchange rate (dollar value of one unit of foreign currency) at the end of a two-year period is 95 or less percent of the direct exchange rate at the beginning of the period. Market rates, rather than par values, are used throughout. This criteria has been used to check all significant rates where the country involved engaged in multiple-rate practices.

Two years was selected as the classification time period in order to meet the following conflicting goals: 1) the time period over which the prediction is made must be short enough to be of use to the manager, and 2) the time period must also be long enough to reduce obscuring effects of political and speculative inputs on the actual timing of the devaluation. While a government intent on fighting devaluation of a currency may fight a rearguard action for several years, an inability to correct the basic economic factors which cause currency weakness must lead to exchange-rate changes.

Although the choice of a 5-percent change in currency value as the method of classification might appear arbitrary, in a floating exchange-rate situation as is now current, the authors feel that a 5-percent change in value over a two-year period is a good estimate of a significant change in currency value. Any change smaller than this amount may not merit the surveillance inclusion that a devaluing country might indicate. In addition, the International Monetary Fund's last arrangement for fixed rates before the February, 1973 dollar devaluation allowed exchange-rate bands of 4½ percent. Thus a 5-percent change would require formal notification to the Fund. In the event of a return to a fixed-rate system with periodic adjustments and a wider band (the crawling peg), use of 5-percent as a measure of exchange-rate changes would indicate approximately those countries for which the peg adjustment would be necessary over a two-year period.

DESIGN OF THE STUDY

The study divides the data into two parts. The discriminant function is developed by using data on those countries that devalued during the years 1963-64 and 1967-68 (see Table 1). For the five countries that devalued in 1963-64, macroeconomic data have been collected for the years 1961-62. Data for five randomly selected countries which did not devalue in 1963-64 are also included. Data for 14 countries that devalued in 1967-68 were collected for the years 1965-66, as well as data over the same period for 14 randomly selected nondevaluing countries. Based on 38 observations of devaluing and nondevaluing countries selected in the first stage, a discriminant function was developed to classify these countries. Details of the variable selection process are given later under *Description of the Variables.* A description of the initial function fitted and its implications are given under *Statistical Methodology.*

Finally, economic data for members of the International Monetary Fund have been collected for the period 1969-70 and an identification of those countries devaluing over the period 1971-72 has been made. The

TABLE 1
COUNTRIES INCLUDED IN ESTIMATION OF THE FUNCTION

Devaluing Countries	Control Group
1961–1962	
Brazil	Australia
Chile	Mexico
Uruguay[a]	Japan
Venezuela[a]	Denmark
Korea	Spain
1965–1966	
United Kingdom	The Netherlands
Iceland[a]	Venezuela
Denmark[a]	Turkey[a]
Finland	Belgium
Spain	Norway
Brazil	Sweden
Chile	Japan
Colombia	Germany
Peru	El Salvador
Uruguay	India[a]
Israel[a]	Italy
New Zealand	Honduras
Ghana	Thailand
Sri Lanka	Tunisia

[a] Misclassified.

final section of the study uses the function developed in *Statistical Methodology* to predict devaluations which occurred in 1971-72. This is the most rigorous possible test of the function. Results are presented under *Results of the Analysis.*

DESCRIPTION OF THE VARIABLES

The selection of macroeconomic variables to be tested for inclusion in the discriminant function was based on three criteria: 1) values used in calculating the variables must be readily accessible or estimable; 2) there should be some logical reason why these economic variables should have a relationship with the exchange rate, although the purpose of the discriminant function is not to reveal relationships among these variables; and 3) variables actually used in the discriminant function are ratios rather than numerical quantities, selected to allow comparability of these values among several countries.

Following is a list of variables included in the initial development of the discriminant function: 1) a definition of the variable; 2) an explanation of why that variable was included in the study; and 3) the source of the variable value. In the formulas defining each variable, the subscript t represents the second year of the two-year data collection period, and $t - 1$ represents the first year. By convention, stocks are measured at the end of the year.

The Reserve Growth Ratio

$$R = \text{Reserves}(t)/\text{Reserves}(t - 1)$$

"Reserves" refers to the official gold and foreign-exchange holdings of the country. The amount of reserves on hand are a direct measure of the country's ability to finance a balance-of-payments deficit. Trends in these reserves indicate present or potential balance-of-payments difficulties.

The Extended Money Supply Ratio

$$M = M2(t)/M2(t - 1)$$

$M2$ designates the extended money supply (money plus quasi-money) at the end of the year in question. An overly large increase in the domestic money supply may indeed lead to both low interest rates and increased demand for goods and services, both locally produced and externally purchased. Both developments may eventually put pressure on a country's balance of payments.

The Price Index Ratio

$$P = \text{Consumer Price Index}(t)/\text{Consumer Price Index}(t - 1)$$

The rate of increase in the local price should indicate potential balance-of-payments problems, since to some extent local prices determine the competitiveness of local production on world markets. Use of a wholesale price index would probably be more appropriate, but the absence of such indices in many countries led to use of a consumer price index.

The Terms of Trade

$$T = \text{Exports}(t)/\text{Imports}(t)$$

Performance in trade accounts is necessary to maintain a sound balance-of-payments position. The ratio, as calculated above, does not include other sources of foreign-exchange earnings, such as payment for invisibles. While these earnings may be important for some selected countries, in general the terms of trade will provide a sufficient proxy for current account performance.

The Investment Service Ratio

$$ISR = \text{Investment Service Obligation}(t)/\text{Reserves}(t)$$

This ratio attempts to measure the ability of a country to meet its foreign-debt service obligations. The numerator of the ratio is the total of all transfers made by the country which result in investment to foreigners. This excludes transfer of capital for repayment of principal on debt obligations or disinvestment of local equity investment. By measuring this value against reserves, a ratio may be developed that will give some summary of the extent to which payment of interest is an important factor in the call on the country's reserves.

Marginal Propensity to Import Ratio

$$I = \frac{\text{Imports}(t)/\text{Gross Domestic Product}(t)}{\text{Imports}(t-1)/\text{Gross Domestic Product}(t-1)}$$

This ratio attempts to measure trends in the marginal propensity to import; technically, the ratio of imports to gross national product. An increase in this ratio over time would indicate an increasing tendency to rely on imports. By neglecting exports, of course, this ratio does give a one-sided view of the economic structure of the country. The authors have substituted gross domestic product in the ratio because of the slowness of most countries to report gross national product to the International Monetary Fund and the close relationship between the two variables.

Central Bank Discount Rate Ratio

$$CBDR = \frac{\text{Central Bank Discount Rate } (t)}{\text{Central Bank Discount Rate } (t-1)}$$

Short-term money market rates may have an important influence on the cross-border speculative and nonspeculative short-term capital movements. A frequently adopted device of currency defense is an increase in the discount rate, as well as other monetary measures designed to tighten the money supply and attract foreign capital. Thus, the discount rate ratio serves as a proxy for the direction of change of money-market rates.

STATISTICAL METHODOLOGY

The statistical technique employed here involves the use of multiple discriminant analysis (hereafter, MDA). This approach has been used: to predict bankruptcy (Altman, 1968); to predict bank capital adequacy (Dince, 1972); in consumer credit evaluation (Myers and Forgy, 1963); and in various manufacturing and financial institutions for predictive purposes (Myers and Forgy, 1963; Walter, 1959).

MDA allows an observation to be classified into one of several a priori groups based on the characteristics of that observation. This study classifies countries into two groups — those which have had significant downward exchange-rate changes relative to the dollar, and those which have not had such changes. The two groups are distinguished by qualitative differences, but the characteristics of the group must be quantifiable in order to use the MDA technique. In this study, various ratios of publicly available economic data are calculated to provide the test characteristics of each group. We would like to select that set of variables (ratios) which is most similar within groups, yet which best discriminates between groups. MDA then derives the linear combination of characteristics that best discriminates between these groups (i.e., between devaluing and nondevaluing countries). The entire characteristic profile and its interactions are considered by MDA, which is an obvious advantage when the number of characteristics is large. (Variables are sometimes very important in a multivariate analysis when they would be insignificant in a univariate analysis.)

Once the coefficients of the characteristics (in this case, the ratios) are obtained from a set of observations, a composite score (usually called a Z score) is calculated and employed as a dividing point between the two groups. Alternatively, the posterior probabilities of falling into a given group can be calculated. This latter technique is employed here. If the assumptions of the analysis are met, and if the characteristics employed are such that they, in fact, discriminate between the groups, the coefficients can then be applied to other data in a predictive fashion. The BMDO7M stepwise discriminant analysis program is used to construct the function.

RESULTS OF THE ANALYSIS

The macroeconomic ratios described under *Description of the Variables* were calculated on the 38 countries listed in Table 1 to provide a data set from which the discriminant function is estimated. (The 1961-62 period and the 1965-66 period are assumed to be similar enough to combine samples from these periods.) Since the purpose of the model is to predict over an entirely different time period, observations from the 1961-62 period are combined with those from 1965-66 to eliminate special factors which might have prevailed in only one period. As a precautionary measure, five control-group countries were selected from the 1961-62 period and 14 from the 1965-66 period to match the number of devaluing countries available during these respective periods.

Since relatively few countries devalue their currency, and since adequate data sets exist for even fewer countries, Table 1 includes in the set of devaluing countries three (Brazil, Chile, and Uruguay) which devalued twice — once in the 1961-62 period, and again in the 1965-66 period. Also included in the control group, are two countries (Spain and Venezuela) which had devalued during other time periods. Japan is included in the control group twice, once in each time period. These overlaps result from both the scarcity of devaluing countries and from the random-selection process. Including the same country twice in the same group probably spuriously increases within-group homogeneity, while including the same country in both groups (even when data are drawn from different time periods) probably reduces between-group differences. Were the model explanatory in nature, these criticisms would be valid. The crucial test of this model lies in its predictive capabilities.

Using MDA, the discriminant function is estimated from data defined previously. The classification matrix is presented in Table 2. The model correctly classifies 82 percent of the sample. The Type I error is large, approximately 26 percent, while the Type II error is significantly smaller at 11 percent. Either error, however, is considerably less than expected by chance (since both groups are of equal size, we would expect a .50 probability of being classified into either group), and is probably less than those incurred by the majority of foreign-exchange managers.

The model produced an F of 3.07 with 6 and 31 degrees of freedom, significant at the 5-percent level. This tends to indicate that the model has significant discriminatory power, although results are biased.

The only variable not included from the original set is the money-supply ratio. This is somewhat surprising; possibly the effects of money-supply changes are adequately measured by other variables such as the price-index ratio. In terms of order of entry into the function using the

TABLE 2
CLASSIFICATION MATRIX

Actual		Predicted		
		Devaluation Group	Control Group	
Devaluation Group		14	5	
Control Group		2	17	
	Number Correct	Percentage Correct	Percentage Error	n
Type I	14	74	26	19
Type II	17	89	11	19
Total	31	82	18	38

stepwise discriminant technique, the price-index ratio was most important. (See Table 3 for the order of entry using the stepwise discriminant technique, a measure of the importance of each variable.)

Of the 38 countries, seven were misclassified; five of these were devaluing countries (Uruguay, Venezuela, Iceland, Denmark, and Israel) erroneously classified as control-group countries. The two control-group countries erroneously classified as devaluing countries were Turkey and India. To some extent, these misses can be explained by a consideration of special circumstances. Israel was drained of foreign exchange in 1967 by the Six Days War. Denmark and Iceland devalued in 1967, not because of existing balance-of-payments difficulties, but rather because of the devaluation of sterling, the currency of their principal trading partner, and the currency used by Danish and Icelandic monetary authorities for support intervention in foreign-exchange markets. The misses on Turkey and India are also interesting since both countries devalued their currencies in subsequent periods. The model spotted a fundamentally unsound situation but erred on the classification because of timing.

TABLE 3
RELATIVE IMPORTANCE OF EACH VARIABLE

Variable Number	Discriminant Coefficient	Standard Deviation	Relative Contribution	Rank by Relative Contribution
1	.03631	26.0928	.94723	2
3	− .04571	29.0885	−1.32964	1
4	.00787	41.3187	.32518	4
5	− .01981	35.8134	− .70946	3
6	− .00325	29.1911	− .09487	6
7	−1.16950	.1229	− .14373	5

Two functions generated by the BMDO7M program from the 38-country data set are presented in Table 4.

These functions are used to calculate the posterior probabilities of a given country being classified into the two groups using Equations 1 and 2:

$$S_{lmk} = C_{mo} + \sum_{j=1}^{r} C_{mj} X_{mkj} \tag{1}$$

where S = value of the mth discriminant function evaluated at case k of group l.

$$P_{lmk} = \text{Exp}(S_{lmk}) / \sum_{i=1}^{g} \text{Exp}(S_{lki}) \tag{2}$$

where P = posterior probability of case k in group l having come from group m.

In order to test the discriminatory power of the function, while avoiding the sampling and search bias previously mentioned, a separate set of 51 countries was selected (see Table 5). Macroeconomic ratios were calculated using 1969-70 data from 11 countries which devalued in 1971-72, and for 40 control-group countries. Of course, our selection was limited to those countries for which publicly available data sets exist. The posterior probabilities are shown in Table 5. Since the 1969-70 data set includes 11 devaluing countries and 40 control-group countries, the expectation is that, by chance, 22 percent of the countries could be classified as devaluing and 78 percent as control-group countries. (See Table 6.)

Surprisingly, when the search bias and sampling bias are removed, the function classifies countries better than it classified when using data in the original estimate of the function. Improvement attributable to the use of

TABLE 4
FUNCTIONS

Variable Number	Devaluation Group	Control Group
1	− .12432	− .06987
3	.20693	.13838
4	.02190	.03370
5	.02677	− .00293
6	.14993	.14505
7	84.58519	82.83147
Constant	−60.13023	−55.62273

TABLE 5
POSTERIOR PROBABILITIES, TEST GROUP DATA, 1971-1972 PERIOD

Country Name	Posterior Probability of Being Classified as a Devaluing Country
Devaluing Countries	
Iceland[a]	.070
Pakistan	.952
Brazil[a]	.024
Chile	.816
Colombia	.961
Israel[a]	.485
Korea[a]	.295
Guyana	.668
South Africa	.556
Sri Lanka	.545
Ghana	.837
Control Group Countries	
Portugal	.316
Tunisia	.038
Austria	.132
Belgium	.102
Denmark	.283
France	.066
Germany	.002
Italy	.350
The Netherlands	.100
Norway	.293
Spain	.074
Sweden	.185
Switzerland	.090
Turkey	.014
Japan	.059
Morocco	.169
Australia	.159
Libya	.000
New Zealand	.403
Singapore	.085
Peru	.002
Thailand	.308
Finland	.065
Greece	.427
Ireland	.369
Canada	.023
Ecuador	.289
Mexico	.018
Venezuela	.194

TABLE 5 (cont.)

Country Name	Posterior Probability of Being Classified as a Devaluing Country
Iran[a]	1.000
Jordan	.400
Egypt	.419
China	.025
El Salvador	.221
Honduras[a]	.981
Jamaica[a]	.646
Mauritius	.016
Philippines	.008
Syria	.334
United Kingdom	.485

[a] Misclassified.

the function can be further examined in two ways. First, calculate the percentage of error reduction as shown below:

$$PER = 44 - 7/51 - 7 = .84 \tag{3}$$

The proportional reduction in wrong assignments resulting from the utilization of the function, is 84 percent, or very substantial.

A further test of the function involves randomly selecting 11 of the 40 control-group countries, preparation of a classification matrix, replication, and comparison of the results of the classificatory ability of the function. Five such replications were performed. (See Table 7.) The classificatory ability of the function again appears to be significantly better than would be expected to occur by chance.

Results of the replicative tests of the function suggest that the MDA technique may be useful in predicting devaluations prior to occurrence.

TABLE 6
CLASSIFICATION MATRIX, TEST GROUP

Actual	Predicted: Devaluation Group	Predicted: Control Group
Devaluation Group	7	4
Control Group	3	37

	Number Correct	Percentage Correct	Percentage Error	n
Type I	7	64	36	11
Type II	37	92.5	7.5	40
Total	44	86	14	51

TABLE 7
CLASSIFICATION RESULTS USING RANDOM SAMPLES OF CONTROL-GROUP COUNTRIES

Replication Number	Percentage of Devaluing Countries Correctly Classified	Percentage of Control-Group Countries Correctly Classified	Percentage of Error Reduction	Z Score
1	64	91	.55	23.8
2	64	91	.55	23.8
3	64	91	.55	23.8
4	64	82	.45	20.3
5	64	100	.64	28.2

Using ratios of historical data, we have illustrated an ability to significantly improve classificatory results. The percentage of error reduction is substantial.

CONCLUSIONS

Results obtained in this study suggest that MDA is a useful technique in terms of its ability to discriminate between potentially devaluing and nondevaluing countries. The macroeconomic ratios employed as predictors apparently contain substantial informational content. The set of ratios used in this study should not in any way be interpreted as the "best" set. They were selected on the basis of traditional economic relationships believed to lead to devaluations. A further study, including both devaluing and revaluing countries, will examine a much larger set of macroeconomic ratios. Results of this study, however, indicate that this readily available statistical technique and data set would improve the ability of the foreign-exchange manager to predict devaluations.

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Section 3: Financial Implications

For years, textbooks, brochures, bulletins, and other readily available publications describing the basics of futures markets have listed financing as one of the major economic roles that the futures market performs. The scenario is described like this: futures markets are capable of reducing price risks; hence, any firm that hedges or prices forward on the futures market ought to have reduced risks; a lender observing this should be willing to lend the firm more money than if it were not hedged; thus, hedging creates the opportunity for a firm to obtain larger loans and greater financial leverage.

In this section, Patterson with tongue in cheek and writing for a class, amplifies humorously, but effectively, the problem of whether a bank or lending agency should give larger loans when the firm is hedged, as opposed to when it is not hedged. In a hypothetical situation, Patterson describes the deliberations within the bank as its loan policy is reviewed and altered.

The financial leverage obtainable by the commercial firm from using the futures market can be quickly calculated. Patterson refers to the borrower being able to obtain a loan, if hedged, of 90 percent of the value of the commodity used as collateral, and if not hedged, 60 percent. If the commodity is valued at $200,000, the borrower could obtain a $180,000 loan if hedged and a $120,000 loan if not hedged. That is, if hedged, the borrower puts up $20,000 of his own money; if not hedged, $80,000 of his own; an increase by a factor of four in his financial leverage due to hedging. There is no upper limit to this increase in financial leverage if loans are at 100 percent of commodity value when used as collateral under a hedging program.

Unfortunately, empirical evidence to support the specific hypothesis that loan size depends upon a hedging program has been difficult to find. One test was conducted by van Blokland in 1974 and no evidence to support the hypothesis was uncovered. This test was small in scale but tended to confirm a rather general feeling that lending officers in small financial institutions are not familiar with futures markets, while their counterparts in large financial institutions, such as major Chicago banks where multimillion-dollar loans to agricultural and agribusiness firms are processed, are familiar with futures markets and may require hedging programs by loan applicants.

In a second study done through a Chicago Mercantile Exchange Graduate Student Research Fellowship, Duke conducted an extensive survey of southeastern commercial banks (1977). Out of 362 banks selected for the study, 145 responded. Of those 145, 40 percent cited at least one customer hedging program, but only 22 percent indicated willingness to participate actively in a customer's hedging program. One could infer that in a much smaller percentage of the cases the size of the loan would be a function of whether or not the customer hedged. About 14 percent of the banks did make funds available for margin maintenance. The survey further indicated a positive correlation between the size of the bank and the likelihood that it would have a hedged loan in its portfolio. The Farm Credit System appeared more committed to encouraging a hedging program than did commercial banks.

Due to the volatile agricultural-price fluctuations of the mid-1970s (the time period between the two cited studies above), and with the introduction of the interest-rate and foreign-currency futures markets, evidence indicates a growing awareness and desire for information concerning this financial role and potential financial leverage. Commodity exchanges are conducting programs for lending officers, popular publications and magazine articles describing the use of futures markets to lenders are appearing, and university extension personnel dealing with lending institutions report an intense desire for knowledge about the use of futures markets. The Duke survey indicated 83 percent of the responding bankers "willing to promote the practice of hedging if they could be convinced of its soundness as a financial tool for agribusiness (and credit) management" (Duke, 1977, p. 51). At least one speech in print (Hauenstein, 1975) indicates how a lender uses a hedging program with one of its clients.

Related academic literature is also emerging. Barry and Willmann (1976) developed a multiperiod risk-programming model to evaluate forward contracting and alternative financial choices when external credit is rationed and market risks are involved. Ikerd (1978) presents a theoretical argument that if price risks are reduced producers will increase production. This has significant implication to lenders and to firms in gaining access to credit. In a bulletin designed for lenders, Leuthold and van Blokland (1979) describe the use of futures markets, how lenders might evaluate hedging possibilities connected with a loan application, and how the lender might participate in the hedging program.[1]

Whether or not loan size will ever become a function of the applicant's participation in a hedging program involves at least a minimum understanding of the commodity futures market by the lending officer, and a demonstration that risks can be reduced for the firm through the hedging operation. The understanding comes through education, and the answer to the latter problem is left to researchers.[2] Efforts in both areas are needed and increasing.

[1] For a discussion on a different, but related, aspect that recognizes futures contracts as financial instruments, see Telser and Higinbotham (1977).

[2] An example of a study testing whether or not forward pricing reduces risks is Leuthold (1975).

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The Worth National Bank of Sioux City

Harlan Patterson

The Worth National Bank is located in Sioux City, Iowa, which is situated on the Missouri River at the heart of the grain and livestock agricultural belt of the U.S. Sioux City's population is approximately 85,000 (metropolitan area population is 130,000). Sioux City businessmen trade by water with ports on the Gulf of Mexico and those on the Great Lakes because of their central location on the inland waterway system of the U.S. The city is also served by a flexible transportation system consisting of five major railroads, two airlines, and a number of short- and long-haul trucking companies.

Six banks and three building and loan associations provide most of the financial services for Sioux City. These six banks held total assets of $316,706,381 at the end of 1970.

BACKGROUND INFORMATION ON THE WORTH NATIONAL BANK

In August, 1883, Sterling B. Worth, Sr., founded the Worth Bank of Sioux City and the bank operated under a charter granted by the State of Iowa for 82 years.

In July, 1965, the management of the bank received a federal charter and the bank's name was changed to the Worth National Bank.

The Worth family has played a dominant role in the management of the bank since it began. Sterling Worth, Sr., relinquished the bank presidency to his son, Sterling Worth, Jr., in 1925. Worth, Jr., held the presidency until 1962, when he became chairman of the board so that his own son, Sterling Worth III, could take over the presidency.

A number of public issues of capital stock had substantially reduced the ownership interest of the Worth family in the bank. At the end of 1970, the Worth family owned only 2,900 of the 10,000 shares outstanding. However, the other five directors of the bank owned another 23 percent

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Ed. note: The people named in this article are purely fictional.

of the shares outstanding. Since these five directors were closely allied to the Worth family, both socially and in business affairs, the Worth family was able to maintain effective working control of the bank, even though it held only 29 percent of the total shares outstanding.

By the end of December, 1970, total assets of the bank were $30,020,800, representing a substantial amount of growth since the end of 1883 when total assets were only $40,000. Over the most recent decade (1960-70), total assets of the bank had grown at an average annual rate of about 4 percent.

The bank's growth over the period 1883-1953 was almost entirely attributable to agricultural loans — i.e., loans to farmers and to agribusiness firms dealing in livestock and grain products. However, the steady development of industry and manufacturing in Sioux City and the surrounding area had somewhat reduced the relative importance of agricultural loans made by the Worth National Bank. For fiscal year 1970, loans to farmers and to agriculture-related firms constituted about 60 percent of the total loan portfolio of the bank. The other 40 percent of total loans in 1970 represented credit to nonagricultural users — particularly to firms involved in metal fabricating, machinery manufacturing, and chemical production.

Despite the decreasing relative importance of agricultural loans, the Worth National Bank still prided itself on being a "farmer's" bank and was closely attuned to the needs of agriculture. The top management of the bank felt that the needs of farmers and agriculture-related industry would be (and should be) the major source of loan demand for the next 25 to 30 years.

THE BOARD OF DIRECTORS MEETING, JANUARY 29, 1971

This attitude about agriculture on the part of the directors and top management of the bank was cause for considerable alarm when the directors met on Friday, January 29, 1971, to review the bank's financial performance for the fiscal year ending December 31, 1970. The decline in the volume of business done with the pork-processing plants in the area was the major issue on the meeting's agenda. For the fifth consecutive year, the total volume of loans made to pork-processing firms had fallen substantially. The decline in this type of loan did not reflect a reduction in the number of pork processors in the banking area served by the Worth National Bank. On the contrary, eight new pork-processing plants of small to intermediate size had been established in the past five years.

The Worth National Bank's policy had been to concentrate marketing and lending efforts toward small- to intermediate-sized meat-processing plants. The bank had never done a substantial amount of direct business with the very large meat processors in the area (such as Swift, and Armour and Co.). These processors had traditionally gone to the major Chicago banks to finance their credit needs. They normally had sizable lines of credit open to them on an unsecured basis at these Chicago banks. The Worth National Bank was just not large enough financially to handle the credit needs of these giants of the meat-processing industry. All seven of the bank's directors concurred that something had to be done to rectify this situation, but disagreed about the underlying cause of the problem.

Each board member had his own idea as to what might be the cause of the problem. One director had read that many firms were now able to fully meet their financial needs through the internal generation of funds (i.e., retained earnings and depreciation allowances) and suggested that the pork-processing plants might fall into this category. Two or three of the directors felt that Elmer Hey, head of agricultural loans to the business department, was the fundamental cause of the problem. They contended that Hey was too old to handle the job and that he had lost his ability "to feel the pulse of the market." Although other arguments were propounded, none of the directors was able to substantiate or tangibly document his contentions.

Seeing that members of the board had reached an impasse, Board Chairman Sterling Worth, Jr., called a special interim meeting of the board of directors to be held Friday, February 12, and asked that Hey be present at the meeting. He also appointed Ernest Abel, the capable and energetic new assistant-to-the-president, to investigate the situation and try to pinpoint the fundamental reason or reasons that the bank's business with the pork-processing firms had declined. Abel was to report to the board at the February 12th meeting.

THE SPECIAL INTERIM BOARD OF DIRECTORS' MEETING, FEBRUARY 12, 1971

The special meeting was held in the Office of President Sterling B. Worth III, with all seven directors, Elmer Hey, and Ernest Abel attending. Sterling Worth, Jr., called the meeting to order and asked Abel to report on his findings. Abel, who had been an assistant vice president in the research department of the Harris Trust and Savings Bank of Chicago prior to coming to Worth National in November, 1970, summarized his findings.

First, he dispelled the notion that pork-processing plants in the Sioux City area generated enough funds internally to handle all of their credit needs. However, pork processors were taking their banking business to banks in Omaha and Minneapolis, yet they were not getting their funds any more cheaply in those cities. Interest rates in the Sioux City area were competitive in every way with the rates in Omaha and Minneapolis. If anything, bank interest rates had moderated more during the last half of 1970 in Sioux City than they had in either of the other two cities. Abel had also found that the Worth National Bank was strong enough financially to have handled over 90 percent of the banking business which had gravitated to Omaha and Minneapolis.

The only significant difference that Abel could find between the Worth National Bank and the banks in Omaha and Minneapolis was the difference in lending policies with regard to collateral hedged on the commodity futures market. The Omaha and Minneapolis banks involved were presently lending 90 percent of the value of commodities used as collateral, when these commodities were hedged on the futures market, and 60 percent of the value of unhedged commodities used as collateral for a loan. The Worth National Bank followed the policy of granting loans equal to 60 percent of the value of commodities used as collateral regardless of whether they were hedged or unhedged.

Abel concluded by saying that personal interviews with a number of top executives from pork-processing firms in Sioux City revealed that these executives were extremely sensitive to the hedging issue. The concensus of opinion among those executives was that the Worth National Bank's policy on hedged commodities was completely out of line with reality and with banks in all major cities.

Sterling Worth, Jr., mentioned he had read that an increasing number of farmers, wholesalers, and commodity processors were using the hedge as a financial tool, but he could not remember the details of the article.

Hey pointed out that the bank had followed this policy of 60 percent of collateral value for commodity loans, regardless of whether the commodity was hedged or not, ever since he had come with the bank in 1924. He emphasized that the Worth Bank had survived the Great Depression whereas many of its more liberal competitors had not. He cited a statistic to make this point clearer — more than 5,000 commercial banks had failed between October, 1929, and the end of 1933.

Robert Storeman, one of the bank's directors and retired president of a local grain corporation, said he could not understand why pork-processing houses would be so attracted by an extra 30 percent of collateral value for hedging their commodities. He stated that processors were charged to hedge their commodities and wondered if maybe this added cost would not offset the attractiveness of the extra loan equal to 30 percent of collateral value.

Charles Holmes, another bank director and president of the Holmes Building and Loan Association, said that processors claimed the hedging operation reduced risks associated with a loan. He felt that lending 90 percent of collateral value rather than the current 60 percent would increase the bank's risks rather than reduce them.

Holmes was also concerned about what the bank would do about interest rates if hedging did change the risks associated with commodity loans. Would rates be raised or lowered to offset the change in risks?

Board Chairman, Worth, Jr., admitted that he did not thoroughly understand all of the mechanics and implications of hedging and the futures market. He added that he felt some good points had been raised by Hey and the directors, and that he, too, had had some of the same questions.

He went on to restate the bank's traditional policy with respect to all loans, including those made to farmers and to agribusiness firms. He cited four factors which he felt were essential in regard to any loan: 1) the integrity and business ability of the borrower; 2) the safekeeping and physical preservation of the commodity used to collateralize the loan; 3) the preservation of the value of the commodity; and 4) the method and timing of repayment made by the borrower.

He said he felt that hedging was intended to preserve the value of the commodity being used as collateral, but that he did not understand exactly how this was possible.

Worth, Jr., said that, in his opinion, preservation of the value of the collateral was not nearly so important to a good loan as the integrity of the borrower. He concluded that even if hedging could, in some way, be used to insure the value of the collateral, he knew of no way to insure against the dishonesty of borrowers.

Hey pointed out that cash and futures commodity prices are in a constant state of flux. They can go down just as easily as they can go up, and these price movements are often quite large. He said he had been a banker for 46 years and had yet to meet a person who could accurately predict the futures price of commodities. Hey noted similarities between banking conditions today and the way they were when he started with the bank and cautioned the directors not to let credit get out of hand as it had in 1927-1929.

The newest board member, Adam Ritt, attorney and senior partner in the law firm of Ritt and Sons, reaffirmed what Hey had said about price volatility in the commodity market. He said he knew of three of his firm's clients who had "lost their shirts" when they tried to speculate in the commodity market. However, he confessed that he did not understand the mechanics of hedging products and thus did not know how this type of commodity market activity was related to the speculative activities of his firm's clients. He asked if any of the other directors or officers could clarify the objectives and mechanics of hedging in the commodity market.

Sterling Worth III, who was a director as well as president of the bank, said he could not add much clarification to Ritt's request for information, but he had heard that the commodity futures markets were highly competitive and, therefore, not "rigged." He said he felt the operations of these markets were legitimate but too complex for the average investor to understand.

Neither the directors nor the two bank officers at the meeting seemed to truly understand the hedging operation, so Worth, Jr., assigned Abel to thoroughly research the subject of hedging in the commodity markets. Abel was to report on his research at the next regularly scheduled board meeting on February 26, 1971. At that time Abel's report would serve as the basis for a vote on the feasibility of changing the bank's existing policy concerning lending on hedged commodity collateral.

THE WORTH NATIONAL BANK'S NEW LOAN POLICY AND IMPLEMENTATION

Ernest Abel gave a thorough report to the bank directors at their February 26, 1971, meeting and clarified the directors' questions about hedging in the futures markets. The directors then voted six to one in favor of changing the bank's policy on loans made on the basis of hedged commodity collateral.

The new policy allowed the head of agricultural loans to the business department to lend up to 90 percent of the value of commodities, at his discretion, when these commodities were hedged in the futures market. For unhedged collateral, the policy remained unchanged — i.e., the bank could lend up to 60 percent of the value of unhedged commodities used as collateral.

On April 1, 1971, Elmer Hey retired as head of agricultural loans to the business department after 47 years of dedicated service to the Worth Bank. He was replaced by his former assistant, Andrew Newmann.

Newmann was 37 years old and had been with the Worth National Bank for only two years, but he had previously worked for a large, nationally known packing house for 12 years and was considered well-qualified for his position. Most of his experience with the meat-packing firm had been in the area of credit analysis and finance.

Loan activity in the department began to show noticeable improvement. Credit extensions made by the department during the months of April through August, 1971, were up 20 percent over 1970 levels. By the end of August, 1971 the Worth Bank had attracted the loan accounts of four local meat-processing and packing firms which had previously gone to Omaha to fill their credit needs. All of these newly-acquired meat-processing and packing houses were older, well-established firms; all had been in operation for at least 20 years; and all were in good shape financially. There was little difficulty involved in evaluating their credit worthiness.

Although pleased with the results of his first efforts, Newmann was aware that if his department and the bank were truly going to forge ahead they could not content themselves with serving only the older, well-established firms. They would have to attract the loan business of some of the newer, untried meat-processing and meat-packing houses in the Sioux City area.

Newmann got the challenge he was seeking on September 7, 1971 when Harold Kanner, president of Kanner Packing House, Inc., came to the Worth National Bank to apply for a loan to be used to finance his firm's expanding inventory of pork bellies.

Kanner Packing House had only been in operation since July, 1968. Kanner had come to Sioux City from Chicago in the spring, 1968. He had previously held executive positions in various Chicago packing houses for 23 years. His last job as a vice-president with Armour and Company would have satisfied most people, but the idea of working for someone else for the rest of his life had lost appeal for Kanner. He sold his home in Chicago and invested proceeds of the sale, plus a large portion of his savings, in the physical properties of a defunct packing house in Sioux City. He was forced to incorporate and periodically make small sales of common stocks in order to acquire working capital.

Kanner Packing House, Inc., specialized in pork products, which worked out quite well since the largest terminal hog market in the world is located in Sioux City. The Kanner operation included full-line production facilities but distribution facilities were sectional. The company's products were sold in areas other than the Sioux City metropolitan area, but seldom beyond a 300-mile radius.

Harold Kanner had established a sound reputation for himself and for his firm in business affairs in three years. After a slow start, the firm's sales had begun to show noticeable improvement. Kanner was optimistic about the future of his company. He presented his company's financial statements for 1969, 1970, and 1971 (see Tables 1 and 2) to Newmann for evaluation of his firm's financial status. All of these financial reports had been audited by Post, Marvick, and Mitchell and Company, an accounting firm in Omaha, Nebraska.

Kanner Company's sale of pork products had increased by 54 percent from fiscal year 1970 to fiscal year 1971. Kanner expected fiscal year 1972 to bring a similar increase over fiscal year 1971. For this reason, he wanted to double his current inventory of frozen pork bellies. Kanner estimated that 465,000 to 470,000 additional pounds of frozen pork bellies would be required to meet the projected increase in sales.

Kanner Company could not afford to finance an inventory expansion of this size. The cash and working capital positions of the Kanner Company were not that strong so Kanner had come to the Worth National Bank with his loan request. He did indicate that his firm would be willing to pledge the bellies purchased as collateral to protect the bank's loan.

Newmann explained the details of the Worth Bank's lending procedure to Kanner. First, the financial statements of the Kanner Company would be analyzed and compared with the Dunn and Bradstreet averages for the meat-packing industry. If the Kanner Company proved strong enough financially, the Worth Bank would lend up to 60 percent on unhedged bellies or up to 90 percent on bellies that were hedged in the futures market. Newmann also indicated that the bank would lend an additional amount equal to the amount of margin that the commodity broker would require for hedging the bellies in the futures market, if the financial performance of the Kanner Company merited it.

Kanner said he would prefer to borrow up to 90 percent of the value of the pledged collateral value, but he had never dealt in a futures market and asked Newmann to explain the hedging process to him. Newmann explained the general mechanics of hedging, then told Kanner that completion of a credit analysis of the Kanner Packing House would take

TABLE 1
INCOME STATEMENTS, KANNER PACKING HOUSE, INC., FOR FISCAL YEARS ENDING JUNE 30, 1971, 1970, AND 1969

Category	1971	1970	1969
Net sales	$4,070,880	$2,640,820	$1,280,580
Cost of sales	3,650,379	2,377,900	1,164,613
Gross margin	420,501	262,920	115,967
Operating, selling, and administrative expenses	309,249	216,314	107,258
Operating income	111,252	46,606	8,709
Interest and debt expense	1,100	1,510	1,722
Profits before income taxes	110,152	45,096	6,987
Federal and state income taxes	52,873	20,280	1,480
Net profits	$ 57,279	$ 24,816	$ 5,507

TABLE 2

BALANCE SHEETS, KANNER PACKING HOUSE, INC., AS OF JUNE 30, 1971, 1970, AND 1969

Assets	1971	1970	1969
Current assets			
Cash	$ 38,000	$ 22,300	$ 15,306
Accounts receivable (net of allowance for doubtful accounts)	210,965	121,298	69,280
Inventory	156,200	91,620	55,884
Prepaid expenses	1,610	1,200	1,312
Total current assets	406,775	236,418	141,782
Plant and equipment (net of accumulated depreciation)	165,637	172,818	180,000
Total assets	$572,412	$409,236	$321,782
Total Liabilities and Stockholders Equity			
Current liabilities			
Accounts payable	$194,322	$122,718	$111,204
Notes payable to banks	14,670	20,200	24,620
Accrued expenses	2,480	3,180	2,816
Federal and state income taxes	2,620	970	630
Total current liabilities	214,092	147,068	139,270
Stockholders equity			
Common stock — without par value (authorized 10,000 shares — issued 5,200 as of 6/30/71)	356,000	261,316	182,512
Retained earnings	2,320	852	
Total stockholders equity	358,320	262,168	182,512
Total liabilities and stockholders equity	$572,412	$409,236	$321,782

about an hour. He advised Kanner to discuss the specific details of hedging with Wilbur Goodsell, a registered commodity broker on the 10th floor of the Worth National Bank Building, and then return to the bank to discuss the loan application.

Goodsell explained the operations of the commodity futures markets and elaborated on hedging in the futures market. He gave Kanner a copy of the standard futures contract for frozen pork bellies and explained the various provisions. He also gave Kanner the daily market-price quotations from the Chicago Mercantile Exchange for frozen pork bellies and cautioned him that these price quotations on pork bellies represented Chicago prices rather than Sioux City prices. Goodsell explained that these prices could be converted into Sioux City prices by making an adjustment for locational difference — the size of this adjustment for frozen pork bellies averaged about 85 cents per hundredweight.

Wilbur Goodsell said that the rules of the Chicago Mercantile Exchange required a minimum margin deposit of $750 to be posted for each pork-belly contract that was bought or sold in the futures market, but that his own firm required a margin of $1,200 per contract to be posted by all new customers in order to protect the customer as well as the broker and allow for more market movement before requiring the customer to post additional margin. Goodsell mentioned that the margin requirement per contract for the Kanner Company would probably be reduced after his firm had built up some trading experience with the Kanner Company.

Harold Kanner expressed a desire to open a trading account on behalf of his firm and received a customer's agreement to be completed before an account could be opened for Kanner Packing House. After completing the customer's agreement, Kanner returned to the Worth National Bank to discuss the loan application with Newmann. Meanwhile, Newmann had evaluated Kanner Company's financial statements relative to others in the industry and was prepared to give Kanner an answer to his loan request.

Section 4: Price Relationships

This section contains one paper each on pricing over time, space, and form. The papers by Bobst and Pickett involve futures markets directly, while the Cox and Wright paper on the grading of feeder cattle (pricing over form) does not. However, this latter paper is concerned with information systems and accurate pricing of a cash commodity, an investigation highly related to futures market studies.

The underlying theories of how prices are expected to vary over time, space, and form in a perfect market context will not be repeated here. For a review of these theories see Bressler and King (1970), or Tomek and Robinson (1972). Much of the relevant theoretical and empirical background in the case of futures markets which is related to this section was cited in the introduction to this volume.

Bobst, investigating price differences over space, determines the effect location may have on basis variability, and hence, the potential hedging risks facing livestock producers. After developing three measures of hedging effectiveness, Bobst tests the hypothesis that no difference exists in the variability of hedging revenues for Southern markets in comparison with futures contract-delivery markets. Results indicate no significant location-basis variability for hogs, but location biases do exist for fed cattle. Implication of these results on hedging effectiveness are analyzed.

Pickett examines the theory of temporal-price relationships for storable commodities and applies it to the frozen pork-belly market. A hypothesized role of this futures market is the temporal guidance of seasonal inventories, with cash-futures price differences reflecting and determining inventory positions. After the development of a supply-of-storage function, several models are estimated where the quantity of frozen pork-belly inventories is regressed on current and lagged cash-futures price spreads as well as lagged quantity. Results of the models with regard to supporting the supply-of-storage hypothesis are mixed. A detailed discussion of statistical and data problems is given, along with an examination of the inability of the hypothesized model to discriminate between alternative explanations of the observed phenomenon.

Cox and Wright investigate the feeder-cattle information system. Inspection of teletype market-news reports reveals a large and incomprehensible list of descriptors for feeder cattle, a factor increasing the risks of cattle buying and feeding. Due to this large variety of names and descriptions, Arizona cattle feeders largely ignore or discount formalized market-news reports. In order to predict future feedlot performance more accurately and improve information flows, the authors construct a set of descriptors that partition feeder cattle according to basic traits. Using a price simulation model to test their proposed revision of feeder-cattle grades, they demonstrate that significant improvements in feeding returns are potentially possible.

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The Effects of Location-Basis Variability on Livestock Hedging in the South

Barry W. Bobst

Live-animal futures contracts have had a spectacularly successful development. Trading volume and open interest in nonstorable commodities such as steers, hogs, and feeder cattle are increasing year by year; yet at the same time, the hedging activity represented in these contracts is very small compared to the potential afforded by the livestock industry. Public relations and educational efforts have been and are being made to arouse interest in potential hedgers. For potential hedgers in business circles, the imprimatur of the Harvard Business School has been placed on hedging in livestock and other commodities by the publication of a book by Arthur (1971). Efforts have also been directed towards farmers with some success, as noted by Futrell (1970).

Live-animal futures contracts provide an alternative marketing procedure for cattle and hog producers. This alternative is best described in the context of the vertical coordination of marketing that takes place between livestock producers and buyers. The simplest means of coordination between livestock feeders and packers is the open market: feeders sell to the highest-bidding packer with no prior arrangements concerning the timing of the sale, quality of livestock offered, or price. Taking the open market as a base, a spectrum of alternative coordinating arrangements can exist, ranging from informal agreements to written contracts that specify one or more of the terms of trade to vertical integration, in which feeding and packing activities are carried out by the same firm and coordination becomes a matter of administrative arrangement. Hedging fits into this spectrum in a variety of ways. For example, hedging can be used in conjunction with open markets, with various kinds of contracts, or even by vertically integrated firms. The potential for hedging in a region, therefore, is an important aspect of efforts to devise vertical co-

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ordination methods which will improve the efficiency of livestock marketing in the region.

Regionality of hedging is stressed because of the geographic structure of livestock feeding in the United States. The traditional heartland of cattle and hog feeding is the Corn Belt, and most livestock futures-contract delivery points have been located there. In the South, cattle feeding has increased greatly in Oklahoma and Texas, the westernmost states in the region. From the standpoint of the potential of hedging in vertical coordination arrangements, the lack of futures-contract delivery points in the region is an important factor. None of the delivery points for live hogs is located in the region. No delivery point for Choice steers was located in the region until August, 1971 when Guymon, Oklahoma, was so designated. The fact that most of the Southern region is remote from contract delivery points means that location-basis variability is an important factor in assessing the potential of hedging in vertical coordination arrangements. The objective of this study has, therefore, been to measure location-basis variability in Southern markets, and to assess the effects of this variability on hedging.

The basic procedure of this study has been to generate measures of hedging-revenue variability for Southern markets and to compare them with similarly generated measures for a central futures-contract delivery market. Revenue variabilities were compared to test the hypothesis of no difference in variability among markets against the hypothesis that differences existed. These were one-sided tests, since if location basis exists, it will result in higher variabilities in the distant markets. Similar tests were conducted to measure the location effect on other aspects of hedging performance. The point of view taken in the research has been that of livestock producers. That is, the hedges that have been postulated have been short hedges intended to avert the risk of price declines on inventories of livestock on feed, and the timing of hedges has been tailored to fit various feeding situations. Thus formulated, the analyses do not represent the situation of long hedgers, although the outcome of a long hedge is the negative of a short hedge with the same timing so that where variance is used as the measure of variability, the measures will be the same. However, the timings of the hedges are not likely to be the same. A long hedger can be envisioned as a packer seeking to avert the risk-of-price increases on forward sales commitments. The timing of such hedges is not likely to be the same as for short hedgers.

For the markets, study period, and hedging systems used in this study, no significant effects of location-basis variability were found for slaughter hogs. However, and again with the same qualifications, significant effects were found for fed cattle in the South and the Southern Plains.

THEORETICAL ISSUES

Location-basis variability can be defined as: the distortion in hedging results that occurs by virtue of the hedger's location at some point distant from a futures-contract delivery point market. Location basis is unhedgeable. At the same time, variation in location basis does not necessarily exist and if so, has its origin in the state of spatial competition in a geographically dispersed market for the commodity in question rather than in the futures market for that commodity. In a perfectly competitive spatial market, with free trade, perfect knowledge, large numbers of buyers and sellers, and so on, price differences between any two points cannot exceed the transfer cost between them in the short run (Bressler and King, 1970). In the long run, entry, exit, and resource revaluation will cause price differences to just equal transfer costs. Short run or long run, the perfectly competitive spatial market implies a stable configuration of price differentials among points in a geographic market — otherwise known as a price surface. Fluctuations in demand or supply at various points in the market cause fluctuations in price which are reflected evenly across the price surface, leaving the transfer-cost generated gradient of the surface unchanged. At the limit, only changes in transfer costs themselves can change the price-surface gradient.

Stability of the price surface for a commodity has two implications of interest in an analysis of hedging in a spatial market. First, the stability of the surface itself suggests predictability. If prices at points A and B bear a certain relationship to one another at one point in time, the same relationship can be safely predicted to hold in the future, given only that transfer costs remain constant. While the absolute level of future prices at A and B may be very unpredictable, the relationship between them is nearly perfectly predictable. The other implication is that prices at points A and B will be perfectly correlated. Thus, where price changes are linear (measured in dollars and cents), price variance will be the same everywhere even though means will vary along the price surface.

In addition, with the perfect correlation among prices, location-basis variability will not exist in a perfectly competitive spatial market. This can be seen by examining the variance components of a short-revenue hedging equation. Omitting brokerage fees, the hedging-revenue function is formulated as follows:

$$R_{ijgt} = P_{igt} + H_{jm} - C_{mt} \qquad (1)$$

where R_{ijgt} is hedging revenue in market region i, hedge length j, for commodity grade g which is sold on date t; P_{igt} is the cash price at market i for grade g on date t; H_{jm} is the futures contract price in which the hedge was placed on a date specified by hedge length j in the contract maturing in period m; and C_{mt} is the price at which the contract was repurchased on date t. All variables are measured in the units appropriate to the commodity. For livestock, this is dollars per hundredweight.

Mean and Variance of Hedging Revenue

Consider the mean and variance of hedging revenue over a period in which contract m is the nearby futures contract. Mean hedging revenue will be the algebraic sum of the means of the prices in Equation 1. That is:

$$\overline{R}_{ijg} = \overline{P}_{ig} + \overline{H}_{jm} - \overline{C}_{m}, \; t = 1, 2, \ldots T, \qquad (2)$$

where T is the total number of sales dates for which contract m is the nearby contract. At the limit, T is infinitely large, since sales can conceivably be continuous. The realities of marketing institutions, however, limit price observations to a daily or weekly basis. Variance of hedging revenue is the algebraic sum of the variances and covariances of its components. The equation is as follows:

$$V(R_{ijg}) = V(P_{ig}) + V(H_{jm}) + V(C_m) + 2CV(P_{ig}, H_{jm}) - 2CV(P_{ig}, C_m) - 2CV(H_{jm}, C_m), \; t = 1, 2, \ldots T, \qquad (3)$$

where V stands for variance and CV stands for covariance. This variance equation stands for any given market region i. For the location-basis variable to be nonexistent in a perfectly competitive spatial market, the variances in any two market regions must be equal. This can be shown by decomposing the covariance terms in Equation 3 in light of the previous conclusions about spatial price relationships, viz., prices along the price surface are perfectly correlated and have equal variance.

The covariance between any two variables (say 1 and 2) can be decomposed as follows:

$$CV(1,2) = r(1,2)\,V(1)\,V(2), \qquad (4)$$

where $r(1,2)$ is the correlation coefficient between the variables and $V(1)$ and $V(2)$ are their respective standard deviations. In addition, if

$$r(1,2) = 1, \qquad (5)$$

and

$$r(1,x) = y, \qquad (6)$$

then

$$r(2,x) = y$$

also, where x is any variable and y is any value that the correlation coefficient can assume, from -1 to $+1$.

Let 1 and 2 above stand for two market regions in which hedging has taken place over the same market period T for the same commodity grade *g*. When inspecting hedging-revenue variance, Equation 3 in the light of the relationships developed in Equations 4, 5, and 6, Market 1 can be substituted for Market 2, and vice versa, in every term in which they occur with no change in value. Each component of variance in one market equals the corresponding term in the other. Thus, in a perfectly competitive spatial market, hedging-revenue variances will be the same everywhere and location-basis variability, in the sense of a dispersion of hedging results from one area to another, will be nonexistent. This is so, even though mean hedging revenues will vary from area to area along the price-surface gradient.

Imperfect Spatial Competition

In the real world, knowledge is imperfect, requisite large numbers of buyers and sellers are not present in all areas, rigidities in commodity transport exist, and quality differences represented by commodity grades are not perceived in the same way at all places and times. Leads and lags in price adjustments among markets can exist. Under these conditions of imperfect spatial competition, location-basis variability may occur. With less than perfect correlations between futures contract-delivery markets and distant markets, and possibly different variances as well, hedging-revenue variances may be higher in distant markets than at the contract-delivery market; however, this is an empirical question. The existence of significant location-basis variability cannot be inferred a priori from an imperfect state of spatial competition. The question of how much imperfection there is must be addressed.

Alternative Measures of Location-Basis Variability

The foregoing discussion leads to two alternative measures of location-basis variability: first, comparisons of cash-market correlation coefficients between contract-delivery markets and distant markets; and second, comparison of hedging-revenue variances through estimates of Equation 3 for various markets. The latter procedure was chosen for purposes of this study. A comparison of cash-market correlations has the virtue of simplicity, but would not capture the time dimension of hedging. Equation 3 shows that hedging-revenue variance is affected by the relationship between cash and futures prices at two different points in time. Covariance terms relate local price to the futures price at which the hedge is placed, and to the futures price at which the hedge is lifted or covered. A contemporaneous correlation between local cash prices and cash prices in the delivery market would ignore the lagged relationship, and a lagged correlation would ignore the contemporaneous relationship. For these reasons, a direct comparison of variances seems the better of these alternatives.

A third analytical alternative exists, which is to use a portfolio-type procedure of the sort suggested by Ward and Fletcher (1971), and applied empirically by Heifner (1969), and Holland, Purcell, and Hague (1972). Work on optimal and minimum-risk hedging strategies is certainly necessary, and location-basis variability analysis of the type implied by the second alternative, is no substitute for microanalysis of hedging for local markets. However, data problems crop up when portfolio-type analyses are applied for interregional comparisons of the sort that have been the objective of this study. This type of analysis requires knowledge of the production function for feeding in each area of application. As Ehrich (1969) points out, available (secondary) cost data may not represent the minimum-cost situation for a region. Also, the upgrading of livestock while on feed introduces a bias unless the degree of upgrading is known and taken into account. Thus, intimate knowledge of local conditions is necessary for the successful application of a portfolio-type procedure. Under these circumstances, the simpler model, which is specifically directed toward measurement of location-basis variability without at the same time trying to solve hedging management problems in a number of regions, was adopted.

Hedging Error and Bias

The analytical procedure suggested by Equations 1, 2, and 3, has some capabilities beyond the measurement of location-basis variability. The procedure has some capacity for measurement and analysis of what is referred to in this report as hedging error, and of the more familiar subject of futures price bias. Hedging error is essentially an ex ante concept that evaluates the outcome of a hedge from the point of view of expectations at the time the hedge was placed, and is closely related to the textbook concept of the perfect hedge. Bias takes an ex post view of the outcome of a hedge and is essentially a comparison of hedging revenue with the revenue that would have been received had hedging not been undertaken.

In the familiar example of the perfect hedge, the commodity in question is sold short, convergence between cash and futures prices in the delivery month are exact, and the commodity is sold and the contract is covered to achieve an outcome just equal to the price at which the commodity was sold short. Two modifications to the perfect hedge concept are necessary. First, there is the implicit assumption that the expected revenue equals the sale price. This not only implies location at the par delivery point, but also implies that the hedger has no price expectations of his own other than what is reflected in the futures price. As Hieronymus (1971) indicated, hedging is performed with some price expectation in mind, otherwise known as basis trading. The second modification is that convergence between cash and futures prices is seldom exact, nor do the price changes in the two markets necessarily exactly parallel each other. Futures prices in the nearby contract and cash prices will be highly, but not perfectly, correlated.

Basis expectation can be quantified in the following manner:

$$E(R_{ijgt}) = H_{jm} + Z_{igt}, \tag{7}$$

where $E(R_{ijgt})$ is expected hedging revenue; H_{jm} is the hedging price as previously defined; and Z_{igt} is the basis differential which relates the futures price to the hedger's own situation. The basis differential has spatial, grade, and time dimensions, and may also reflect the hedger's own price forecast. Expected hedging revenue, therefore, contains an objective component (the futures contract price) and a subjective component (the hedger's estimate of the basis differential).

Hedging error is defined as the difference between received and expected hedging revenue, or:

$$U_{igt} = R_{ijgt} - E(R_{ijgt}). \tag{8}$$

Substituting Equations 1 and 7 into Equation 8, the hedging-error function reduces to:

$$U_{igt} = P_{igt} - C_{mt} - Z_{igt}. \tag{9}$$

Note that length of hedge does not affect hedging error. Hedging error, as expressed in Equation 9, is composed of the realized basis $(P_{igt} - C_{mt})$ less the anticipated basis Z_{igt}. In the par delivery market, realized basis will be zero for the delivery grade if convergence is exact. This meets the condition for a perfect hedge, so hedging error will be zero if the anticipated basis was also zero. For nonconvergence and for other cash markets, realized basis will be different from zero, but hedging error may or may not be zero, depending on the level of the anticipated basis.

Thus, hedging error cannot be estimated in its entirety without knowledge of the anticipated basis. Since anticipated basis is fundamentally in the mind of the hedger, it cannot be estimated except on a case-by-case basis. However, the realized-basis component can be estimated from market data. Estimates of this component are useful in that they give a measure of the error against which a hedger must work in his particular market. The realized-basis component of hedging error will be referred to as U'_{igt} and is:

$$U'_{igt} = P_{igt} - C_{mt} \tag{10}$$

with variance,

$$V(U'_{ig}) = V(P_{ig}) + V(C_m) - 2CV(P_{ig}, C_m), t = 1, 2, \ldots T. \quad (11)$$

A comparison of Equations 11 and 3 shows that realized-basis variance is a major component of hedging-revenue variance and that both can be expected to be affected by location.

The role of the individual in anticipating basis change is an intriguing aspect of the hedging-error function. Equation 9 shows that hedging error will always be zero if the anticipated basis is of an appropriate value. That is, a really clever forecaster can overcome the difficulties imposed by imperfect convergence, location, and grade-basis variability, at least in principle. Of course, the ability of our hypothetical clever forecaster to know fairly precisely the outcome of a hedge does not mean that he will necessarily place that hedge, which brings us to the bias.

Bias is usually defined as the persistent deviation of futures prices at different points in time. A downward bias is said to exist when prices persistently tend to rise over the life of a contract; upward bias is the reverse of this. Bias can also be approached from the point of view of the hedger. In this case, an ex post evaluation of hedging results compares hedging revenue with the revenue that would have been received without hedging. In the context of the price models developed here, this is:

$$B_{jgt} = R_{ijgt} - P_{igt}, \quad (12)$$

where B_{jgt} is the measure of bias. Substituting Equation 1 into Equation 12 reduces the bias equation to the difference between futures prices; that is,

$$B_{jgt} = H_{jm} - C_{mt}. \quad (13)$$

Note that bias is not affected by location. Bias, if present in a futures market, affects hedgers in all locations equally.

Summary: Theoretical Issues

Three measures of hedging effectiveness have been developed in this section: first, hedging-revenue variance, the measure of primary interest in the empirical portion of the study, has been argued to be the same everywhere in a perfectly competitive spatial market. However, market imperfections may give rise to locational differences. Other things remaining equal, if hedging-revenue variances differ significantly among locations, location-basis variability can be said to be present. Obviously, the various cash-market price variances must be among the things remaining equal.

The second measure of effectiveness developed is hedging error, where expected hedging revenue is taken as the basis of comparison. While not observable in its entirety, hedging error's realized-basis component can be measured from market data. Since location enters into the realized-basis component, variance may differ by location.

Third, the concept of basis was examined, only to find that location is not a factor. Bias, therefore, lies outside the scope of this study.

LOCATION-BASIS VARIABILITY FOR SLAUGHTER HOGS

Three preconceived ideas were carried into the research on location-basis variability for slaughter hogs. First, daily price observations would have to be the data base if useful measurements were to be obtained, because of the frequency of price changes for hogs. Lags in price change between markets, which might be apparent in daily data, might well be covered up in weekly averages. Second, the market data used should be available and familiar to farmers, to whom the results will eventually be transmitted in one form or another. For this reason, Omaha was chosen as the reference delivery point market over Peoria, Illinois, which is the par delivery market. During this study, Omaha prices seemed more available to southern producers, at least through the newspapers, than Peoria prices. Third, the study was restricted to 1971 because of the illiquidity of the live-hog futures market until the last few years, and due to the large amounts of data to be handled when working with multiple markets on a daily basis.

Markets and Grades Selected

Three Southern hog markets were selected for use in the study: the western Kentucky (purchase area) buying stations; the Southeast direct market (southwestern Georgia and adjacent areas of Alabama and Florida); and the North Carolina auctions. By southern standards, these are regions of concentrated slaughter-hog production and marketing. Their markets also have the virtue of having daily price reports made for them. Prices in Kentucky, the Southeast market, and at Omaha were reported on the basis of USDA grades. Delivery specifications for the live-hog contract are also on the basis of USDA grades. Prices for North Carolina, however, were reported on the basis of a state grade, called "North Carolina Top Hog." Prices were not reported for any lower grades in North Carolina. While a state grade does not necessarily conform to U.S. grade standards, "North Carolina Top Hogs" are reported to be essentially comparable to U.S. 1's and 2's weighing 200 to 220 pounds (Holland, Purcell, and Hague, 1972).

Hedging Systems

Two hog production and marketing systems were postulated for purposes of calculating hedging results. The systems differ by the length of run of the hedge. The longer-run system was a farrow-finish system, in which a hedge was placed when pigs were farrowed and lifted 174 days later when the finished hogs were assumed to be marketed. The second system was envisioned as a specialized feeding enterprise in which 50-pound feeder pigs are fed to market weight. The hedge was assumed to be placed at the time the feeder pigs were purchased and lifted 106 days later when the finished hogs were marketed. The lengths of the hedges, 174 and 106 days respectively, were derived from National Research Council growth-rate standards and expected lengths of time necessary to achieve a market weight of 225 pounds (National Research Council, 1970). Variation around the mean growth rate would cause a dispersion of weights and grades around this mean weight so that individual lots of hogs might fall into any of the reported grade and weight ranges.

Method of Calculation

Hedging revenues were calculated for the two hedging systems for each reported grade in the selected markets for 1971. Equation 1 describes the calculation process employed. Calculation was oriented on the marketing date, with hedges placed 174 and 106 days prior to that date. If any indicated hedging date fell on a weekend or holiday, the hedge was placed on the next available date on which hog futures contracts were traded. Hedges were assumed to be lifted on the same day hogs were marketed, or on the next available date in the few cases where holidays did not coincide.

Marketings which took place in a contract-delivery month were assumed to be hedged in that contract up to the 15th of the month. Marketings which took place after the 15th were assumed to be hedged in the next contract, as were marketings in noncontract months. That is, marketings for January, 1971, and for February, through the 15th, were assumed to be hedged in the February contract. Marketings for February 16, through April 15, were hedged in the April contract, and so on. The 15th of a contract month was used as the cutoff point rather than the 20th, when contracts normally expire, in order to avoid liquidity problems which might arise nearer the expiration date.

Daily closing prices of futures contracts and the midpoints of daily trading ranges reported for cash-market hogs were the prices used in the calculations. Means, variances, and covariance components for hedging revenues, and realized-hedging errors were calculated according to Equations 1 and 10 respectively. These statistics were adjusted for missing cash-price data. No attempt was made to interpolate missing data from nearby prices.

Results

Hedging-revenue results are summarized in Table 1.

Reported grade and weight ranges are not uniform among markets. The lightest-weight, highest-grade range reported in the Kentucky market is the same as the mediumweight, medium-grade range at Omaha. Also, the weight ranges in the Southeast market are somewhat larger than at Omaha. This raises a question of differences in variances of cash prices between markets, which can be answered empirically. Inequality of variances can occur because of differences in market level; that is, between auctions, terminals, and so forth. However, the perfectly competitive spatial market model discussed previously would suggest equal variances. Differences in market level cause differences in exchange costs which, like transfer costs, will be reflected in price differentials.

With respect to location-basis variability, the focus of attention is on the variances presented in Table 1. To review the conditions of the hypothesis of location-basis variability, if hedging-revenue variances can be shown to be unequal, then location-basis variability is presumed to be present. Bartlett's test of equality of variances has been used to test the null hypothesis of equality in cash-market price variances and in hedging-revenue variances. Results of these tests are presented in Table 2.

The figures shown in the top portion of Table 2 are the Bartlett's test statistics for equality of variances of the variables shown on the rows for the grade and weight classes shown in the columns. The figures in the lower portion of the table show the critical values of F against which the test values should be compared. F-ratios greater than the critical values indicate significant differences among the variances compared in the test. No test statistic exceeds its critical value. Cash-price variances within grades, and hedging-revenue variances are not significantly different from one another. This means that there is no indication of significant location-basis variability. Of course, the test that was employed called for identical grades in all markets. This was not possible, but the wider reporting ranges in the Southern markets would, if anything, increase variance differences with respect to Omaha so that the test results are strengthened rather than weakened by the reporting differences.

The implications of the results of the variance tests are fairly clear. Location-basis variability was not a significant factor for Southern market hedgers in 1971. As far as basis was concerned, they could hedge as effectively as their colleagues in the Omaha area. As shown by the hedging-revenue means in Table 1, mean revenues were less in the Southern markets, but so were cash-market means. Mean hedging revenues corresponded to the spatial price surface.

TABLE 1
HOG PRICE AND HEDGING-REVENUE SUMMARY STATISTICS BY GRADE, FOUR MARKETS, 1971

Market/Grade	Cash Market Price[a]		Hedging Revenue[a] Farrow-Finish		Hedging Revenue[a] Feeder-Pig-Finish	
	Mean	Variance	Mean	Variance	Mean	Variance
Omaha terminal market (252 observations)						
U.S. 1–2 (200–220 pounds)	19.31	2.39	20.36	2.57	19.25	4.58
U.S. 1–3 (200–240 pounds)	19.03	2.45	20.09	2.61	18.97	4.78
U.S. 2–4 (240–270 pounds)	18.36	2.45	19.41	3.01	18.29	5.20
Kentucky buying stations[b] (254 observations)						
U.S. 1–3 (200–240 pounds)	18.56	2.72	19.61	2.83	18.48	4.77
U.S. 2–4 (190–240 pounds)	18.14	2.79	19.20	2.88	18.07	4.81
U.S. 2–4 (240–260 pounds)	17.73	2.85	18.79	2.89	17.66	4.84
Southeast direct (251 observations)						
U.S. 1–2 (200–230 pounds)	18.46	2.52	19.51	2.97	18.41	4.81
U.S. 2–3 (190–240 pounds)	17.83	2.62	18.88	3.06	17.77	4.88
U.S. 2–4 (240–270 pounds)	17.33	2.66	18.39	3.10	17.28	4.90
North Carolina auctions (242 observations)						
North Carolina top hog	17.96	2.71	19.03	2.98	17.91	4.79

[a] Dollars per cwt.
[b] A fourth grade of heavy hogs is reported for Kentucky but not included here.

TABLE 2
BARTLETT'S TEST OF EQUALITY OF VARIANCE OF CASH HOG PRICES AND HEDGING REVENUES BY GRADE, FOUR MARKETS, 1971[a]

Test Item	Lightweight, High-Grade Hogs	Mediumweight, Medium-Grade Hogs	Heavyweight, Low-Grade Hogs
		(F-ratios)	
Cash prices	1.60	0.54	0.70
Farrow-finish hedging system	1.06	0.80	0.17
Feeder-pig-finish hedging system	0.31	1.05	0.19
		Critical values	
$F_{.05(3,\infty)}$	2.60		
$F_{.05(2,\infty)}$		2.99	2.99

[a] The procedure for Bartlett's test of equality of variances is summarized in Ward and Fletcher (1971).

Inspection of the variances of the two hedging systems shows that timing of the hedge had a great effect on the variability of results. Location, however, had no bearing.

A question does arise about the effectiveness of hedging in any location when hedging-revenue variances are compared to corresponding cash-market variances. Variances tend to be slightly larger for the farrow-finish hedging system and considerably larger for the feeder-pig-finish system. However, such comparisons are implicitly ex post in nature. As previously pointed out, hedging effectiveness also needs to be evaluated ex ante, from the point of view of the expectations held at the time hedges were placed. The realized-basis component of hedging error provides a partial measure of ex ante hedging effectiveness. Data for this component are presented in Table 3.

The means of the realized-basis statistics of Table 3 primarily reflect spatial differentials and are of little concern here. Comparing variances in Table 3 with the corresponding values in Table 1, note that variances of realized basis were substantially less than hedging-revenue variances, and they were substantially less than corresponding cash-market price variances. They, too, showed no location effect. While total hedging-error variances may have differed from realized-basis variances, depending on the skills of the hedgers who might have been in the market in 1971, the data indicate that price risk from the ex ante point of view could have been shifted away from hog producers in 1971. In summary, hedging of slaughter hogs in 1971 appeared to have been effective ex ante but ineffective from the ex post point of view. In any case, location-basis variability did not appear to be present.

LOCATION-BASIS VARIABILITY FOR FED CATTLE

Somewhat different problems are confronted when analyzing location-basis variability for fed cattle as opposed to hogs. In the first place, the frequency of price change is much less for cattle. Weekly prices were considered adequate to capture the detail of price change for fed cattle, where daily prices were employed for hogs. Consequently, a longer time span was covered, but this was offset by a profusion of feeding systems. Eleven different lengths of hedge were required for four sex-grade combinations. In addition to these factors, a structural change took place in the Choice steer futures contract during the study period. The par delivery point was shifted and a discount delivery point was established in one of the distant markets under study.

TABLE 3
REALIZED-BASIS STATISTICS FOR HEDGING REVENUES BY GRADE, FOUR MARKETS, 1971

Market/Grade	(Dollars per cwt.) Mean	Variance
Omaha terminal market		
U.S. 1–2 (200–220 pounds)	−0.78	1.48
U.S. 1–3 (200–240 pounds)	−1.05	1.53
U.S. 2–4 (240–270 pounds)	−1.73	1.85
Kentucky buying stations		
U.S. 1–3 (200–240 pounds)	−1.52	1.49
U.S. 2–4 (190–240 pounds)	−1.94	1.48
U.S. 2–4 (240–260 pounds)	−2.35	1.44
Southeast direct		
U.S. 1–2 (200–230 pounds)	−1.61	1.45
U.S. 2–3 (190–240 pounds)	−2.25	1.46
U.S. 2–4 (240–270 pounds)	−2.74	1.47
North Carolina auctions		
North Carolina top hog	−2.11	1.47

Markets, Grades, and Study Period

Market selection was guided by location of cattle feeding within the Southern region and by accompanying availability of price reports. Three markets were selected: Kentucky, Georgia, and the Southern Plains area of Texas and Oklahoma. Omaha was selected as the reference delivery-point market. Prices in Kentucky and at Omaha were reported on the basis of terminal market sales. Prices in the Georgia region (reported from Thomasville) were on a direct, at-plant basis for Choice steers and from auction sales for other grade-sex combinations. Prices in the Southern Plains region were reported F.O.B. feedlots, assuming a 4 percent shrink. Four grade-sex combinations were reported from all markets: Choice steers, Good steers, Choice heifers, and Good heifers. Where different weight ranges were reported for the same grade of cattle, as was the case for Choice steers in the Southern Plains, prices for the lighter weight range were used.

The study period selected was January, 1969, through June, 1972, a total of 21 successive contract periods. This time span encompassed a structural change in the Choice-cattle futures contract. With the August, 1971 contract, the par delivery point was shifted to Omaha. Prior to that, Omaha had been a delivery point, but at a 75 cents per hundredweight discount. At the same time, Guymon, Oklahoma, which is in the Southern Plains area, was designated a delivery point at a $1 per hundredweight discount. The discontinuity in hedging results caused by the structural changes was taken into account by shifting the time focus of the study to a contract-period basis and using pooled within-contract variances for purposes of hypothesis testing. The Southern Plains area was treated as a distant market throughout the study period despite the establishment of a delivery point there. Justification for this lay in the fact that the delivery point was in effect only for the last six contracts and because, as shown by Crow, Riley, and Purcell (1972), the delivery discount appears to be so unrealistically large as to render the point ineffective.

Hedging periods were derived from postulated feeding systems which were differentiated by sex, grade, and breed of feeder cattle. Times on feed were derived for these different types both as weaned calves and as backgrounded yearlings from National Research Council rate-of-gain standards. Hedging periods were assumed to be equal to times on feed. That is, hedges were assumed to be placed in the week cattle were placed on feed and lifted the week they attained target finishing weights. These data are summarized in Table 4.

Hedging revenues were calculated according to Equation 1 for all the grade-sex-hedge length combinations shown in Table 4. Hedging-revenue

TABLE 4
FEEDING-HEDGING PERIODS FOR SELECTED FEEDER-CATTLE TYPE

Grade, Sex, and Breed Types	Weights		Average Rates of Gain[a]		Feeding Periods	
	Starting	Finishing	Weaned Calf	Background Yearling	Weaned Calf	Background Yearling
	(Pounds)		(Pounds per day)		(Weeks)	
Choice steers						
English crossbred	600	1,100	2.40	2.87	30	25
English straight	550	1,050	2.32	2.87	31	25
Okie #1	550	1,050	2.32	2.87	31	25
Good steers						
Large-breed crossbred	600	1,100	2.41	2.87	29	25
English straight	500	950	2.34	2.87	27	22
Okie #2	550	1,000	2.37	2.87	27	22
Choice heifers						
English crossbred	600	900	2.20	2.65	19	16
English straight	550	850	2.20	2.65	19	16
Okie #1	550	850	2.20	2.65	19	16
Good heifers						
Large-breed crossbred	550	800	2.10	2.65	17	13
English straight	450	750	2.04		21	
Okie #2	450	750	2.04		21	

[a] Source: National Research Council (1970).

variances were calculated according to Equation 3. Moments were taken about individual contract means. Variances were then pooled for the 21 contracts represented in the data. This procedure avoided any difficulties that might have arisen from the structural shift in the futures contract. This procedure also served to focus on the variability within contracts, which is the relevant component for location-basis analysis. Due to the wide range of cattle prices during the study period, taking moments about the overall mean would have included among-contract variances so large as to mask the within-contract components.

Procedures used to calculate hedging revenues were similar to those used for hogs. Marketings in the contract month were assumed to be hedged in that contract up to the week containing the 20th of the month (the expiration date) and in the succeeding contract thereafter. Marketings in months without contracts were hedged in the nearby contract. Thus, hedges were placed in each contract for a two-month period.

Results

Summary statistics for fed-cattle hedging revenues are presented in Table 5. The cash-market and hedging-revenue means presented are overall means, while the variances are pooled within-contract variances. The number of weeks of observations is also included. No attempt was made to interpolate for missing prices. Missing prices were especially troublesome for the Georgia market, where quantities of cattle offered were often considered too small to establish a meaningful price. Even so, sufficient observations were available to estimate variances for every contract except the December, 1970 contract for Choice heifers in Georgia.

As in the case of hogs, location-basis variability is presumed to be significant if the hypothesis of equality of hedging-revenue variances for a specific grade and length of hedge is rejected, given that cash-market price variances among markets are equal. Bartlett's test of equality of variances was first applied to cash-market prices. If the hypothesis of equality of cash-market price variances was accepted for a given grade of fed cattle, tests of equality of variances were then performed for the hedges postulated for the grade. On the other hand, rejection of the hypothesis of equality of cash-market price variances halted the test procedure. If cash-price variances are not equal for a particular grade, nothing definite can be said about the relationships among hedging-revenue variances. Results of this analysis are summarized in Table 6. The hypothesis of equality of cash-market price variances could be accepted only for Choice steers. F-ratios for the other grades were beyond the critical limits of the F-distribution test statistic. Thus, for fed cattle other than Choice steers, the

TABLE 5
SUMMARY STATISTICS FOR FED-CATTLE HEDGING REVENUES
FOUR MARKETS, JANUARY, 1969 — JUNE, 1972

Prices, Hedging Revenues	Omaha	Kentucky	Georgia	Southern Plains
		(Dollars per cwt.)		
Choice steers				
Number of weeks	178	181	159	179
Cash price				
Mean	31.13	31.12	31.75	31.01
Variance	.73	.87	.76	.94
31-week hedge				
Mean	28.62	28.59	29.11	28.45
Variance	.39	.62	.63	.59
30-week hedge				
Mean	28.65	28.63	29.15	28.49
Variance	.41	.60	.67	.58
25-week hedge				
Mean	28.84	28.83	29.37	28.68
Variance	.47	.67	.80	.64
Good steers				
Number of weeks	181	181	171	177
Cash price				
Mean	28.68	28.21	28.71	29.08
Variance	.57	1.00	.31	.63
29-week hedge				
Mean	26.24	25.76	26.19	26.64
Variance	.37	1.04	.57	.43
27-week hedge				
Mean	26.32	25.84	26.29	26.73
Variance	.40	1.02	.63	.47
25-week hedge				
Mean	26.39	25.92	26.38	26.81
Variance	.41	1.00	.61	.45
22-week hedge				
Mean	26.56	26.08	26.54	26.98
Variance	.45	1.15	.74	.44
Choice heifers				
Number of weeks	181	179	133	180
Cash price				
Mean	30.23	30.23	30.14	29.66
Variance	.77	.81	.49	.68
19-week hedge				
Mean	28.31	28.29	27.81	27.73
Variance	.65	.71	.99	.63
16-week hedge				
Mean	28.52	28.51	28.05	27.94
Variance	.61	.67	.84	.65

TABLE 5 (cont.)

Prices, Hedging Revenues	Omaha	Kentucky	Georgia	Southern Plains
	(Dollars per cwt.)			
Good heifers				
Number of weeks	180	181	173	170
Cash price				
Mean	27.56	27.04	27.40	28.38
Variance	.57	.90	.29	.58
21-week hedge				
Mean	25.51	24.98	25.30	26.33
Variance	.48	.90	.79	.54
17-week hedge				
Mean	25.80	25.27	25.58	26.61
Variance	.61	.97	.72	.62
13-week hedge				
Mean	26.08	25.55	25.88	26.88
Variance	.56	.90	.67	.66

analytical procedure breaks down. Tests of hedging-revenue variances were therefore performed only for hedges postulated for Choice steers. As indicated in Table 6, F-ratios for these tests were significant, indicating differences in hedging-revenue variances among markets.

These results appear discouraging from the standpoint of hedging in the South and Southern Plains. A basis for hedging seems to exist in Choice steers, which is the most important class of fed cattle and is also the deliverable grade for the futures contract. Cash-market price variances appear to be equal, which is in conformity with the theoretical prerequisite for hedging in distant locations, a spatially competitive market. However, as was mentioned before, lags in price adjustment among market locations, which do not necessarily show up in cash-price variances, will show up in

TABLE 6

BARTLETT'S TEST OF EQUALITY OF VARIANCES OF FED-CATTLE PRICES AND HEDGING REVENUES, BY GRADE, FOUR MARKETS, JANUARY, 1969 TO JUNE, 1972

Test Item	Choice Steers	Good Steers	Choice Heifers	Good Heifers
	(F-ratios)			
Cash prices	1.10	16.85[a]	2.94[a]	15.61[a]
31-week	3.89[a]			
30-week	3.28[a]			
25-week	3.63[a]			

[a] Indicates significance at 5-percent level. The critical value of $F_{.05}(3, \infty)$ is 2.60.

hedging-revenue variances where timing of price change is more critical to the outcome. Such conditions apparently exist in the market for Choice steers, since hedging revenues are significantly different from one another. For the other sex-grade combinations, even the more gross aspects of the underlying requirement for spatial competition are not met. The inequality of cash-market price variances for the markets as a whole, would seem to negate the possibility of hedging in distant markets on equal terms with the contract-delivery market.

Further Tests

The analysis leaves several questions: first, tests of equality of variances test the hypothesis that all the variances being examined are equal. Rejection of the hypothesis leaves open the possibility that a subset of markets have equal variances. Thus, especially important is the conclusion of significant location-basis variability for Choice steers in the Southern Plains region, since this is the most important of the regions being studied. Individual F-ratio tests would seem to be called for to examine this question. A second question to be explored is an alternative to the test for location-basis variability as conceived so far. It can be argued that hedging is a viable procedure if it succeeds in shifting price risk away from the hedger, even if hedging is more effective in some other market area. This approach calls for ex post and ex ante comparisons of hedging results with price variances in individual markets.

Table 7 presents individual F-ratio tests for Choice steers. These tests indicate the significance of differences of price- and hedging-revenue variances in the Southern and Southern Plains markets relative to Omaha. The F-ratios in the first row of the table indicate no significant differences in cash-market price variances, although the ratio for the Southern Plains

TABLE 7
INDIVIDUAL F-RATIOS OF CASH PRICE AND HEDGING-REVENUE VARIANCES FOR CHOICE STEERS IN THREE MARKETS COMPARED TO OMAHA, JANUARY, 1969 TO JUNE, 1972[a]

Test Item	Kentucky	Georgia	Southern Plains
		(F-ratios)	
Cash price	1.20	1.03	1.29
31-week hedge	1.59[b]	1.61[b]	1.52[b]
30-week hedge	1.47[b]	1.64[b]	1.42[b]
25-week hedge	1.45[b]	1.71[b]	1.36[b]

[a] Source: Table 5. The test statistic is F = Var (i)/Var (Omaha) for price and revenue variances. The critical value of F is approximately 1.33 at the 5-percent significance level for Kentucky and the Southern Plains and 1.35 for Georgia.
[b] Indicates significance at the 5-percent level.

market is very close to the critical value of F. Ratios in the next three rows of Table 7 test differences between hedging variances. These were all significantly greater than comparable variances at Omaha. These results indicate that the conclusions drawn from Table 6 apply to the study markets individually as well as in the aggregate. There is, however, a tendency for the F-ratios to fall as hedging periods become shorter. The question of location-basis variability for even shorter hedging periods will be considered later in this report.

Table 8 presents individual F-ratio tests for comparisons between the Southern Plains market and Omaha for the nondeliverable grades. Table 8 shows that cash-price variances are not significantly different, nor are any of the hedging-revenue variances significantly different between these two markets. As will be shown later, grade-basis variability renders these hedges less effective than Choice steer hedges. Still unclear is whether grade-basis variability is masking location-basis variability through an interaction effect or if, in fact, location basis is only significant for Choice steers in the Southern Plains market.

Table 9 provides an alternative set of measurements of hedging effectiveness. In Table 8, hedging-revenue variances are expressed as percentages of cash-price variances for the indicated grade and sex at each market. Thus, the lower the index or percentage, the greater is the reduction in revenue variance relative to cash marketing. While formally less satisfactory than measurements against pooled among-market variances, these indexes do provide some indications of the potential for shifting price

TABLE 8

INDIVIDUAL F-RATIOS OF CASH PRICE AND HEDGING-REVENUE VARIANCES FOR NONDELIVERABLE GRADES IN THE SOUTHERN PLAINS COMPARED TO OMAHA, JANUARY, 1969 — JUNE, 1972[a]

Test Item	Good Steers	Choice Heifers	Good Heifers
		(F-ratios)	
Cash price	1.10	0.89	1.03
29-week hedge	1.17		
27-week hedge	1.20		
25-week hedge	1.10		
22-week hedge	1.03		
21-week hedge			1.11
19-week hedge		0.97	
17-week hedge			1.02
16-week hedge		1.06	
13-week hedge			1.19

[a] Source: Table 5. The critical value of F is 1.33 at the 5-percent level of significance.

TABLE 9
RATIOS OF HEDGING-REVENUE VARIANCES TO CASH-MARKET PRICE VARIANCE, FOUR MARKETS, JANUARY, 1969 TO JUNE, 1972

Hedge Type, Length	Omaha	Kentucky	Georgia	Southern Plains
	(Percentage of cash-market price variance)			
Choice steer				
31-week hedge	53	70	83	63
30-week hedge	56	69	89	62
25-week hedge	64	77	105	67
Good steer				
29-week hedge	64	104	186	68
27-week hedge	69	102	204	75
25-week hedge	73	100	200	72
22-week hedge	78	116	240	69
Choice heifers				
19-week hedge	84	88	202	92
16-week hedge	79	82	172	95
Good heifers				
21-week hedge	85	100	272	92
17-week hedge	107	108	248	106
13-week hedge	98	101	229	113

SOURCE: Table 5.

risk at these markets. The indexes for Choice steers show that hedging is more effective at Omaha, although there seems to be some convergence of results at Omaha and the Southern Plains as hedging periods are shortened. A similar convergence effect for these markets appears in the indexes for good steers. In fact, the index for the 22-week hedge is lower in the Southern Plains than at Omaha. Indexes for Choice heifers are lower at Omaha than in the Southern Plains, and for Good heifers the indexes indicate about equal ineffectiveness. Grade-basis variability is apparent in the indexes for both these markets. Index values rise as grade and sex diverge from the contract delivery specification of Choice steers.

Results for Kentucky indicate that hedging is only moderately effective for Choice steers, less effective for Choice heifers, but little different from Omaha, and ineffective for Good steers and heifers. Results for Georgia indicate that hedging is generally ineffective there. However, the explosive results for Choice heifers and for Good steers and heifers probably exaggerate the degree of ineffectiveness. Table 5 shows that price variances for these grades were all substantially below comparable variances in other markets. These variances are probably understated and reflect reporting procedures used for the auction markets where they were registered. Prices were apparently reported on the basis of fairly broad ranges within which considerable price variation could take place with no reported price change. Since cash-market prices have been measured by their midpoints in this study, a change in range had to occur before a price change was recorded. Thus, the breadth of reporting range for the Georgia auctions caused an underestimate of price variances and a consequent exaggeration of the variance ratios. However, the fact that such price ranges can persist indicates a tenuous tie with the national market, so that hedging is probably ineffective in these grades in any case. Results for Choice steers would indicate this. Prices for this grade were reported on a direct basis and were much more responsive to national market-price fluctuations. Even so, the leads and lags in adjustments of location variability occurred, and, as the indexes indicate, hedging of Choice steers was only marginally effective for Georgia.

The hedging effectiveness indexes of Table 9 are essentially ex post in nature as they relate hedging results to prices obtained. As has been shown, ex ante measures which relate hedging results to expectations are also appropriate measures of hedging effectiveness. Table 9 also shows that only a portion of this relationship, which was called hedging error, can be observed from market data. Quantifiable measures of the component (realized basis) were expressed in Equations 10 and 11, and their use has been demonstrated in the section on hogs. Realized-basis statistics were calculated for fed cattle, and the results are presented in Table 10.

The realized-basis means presented in Table 10 represent mean differences between cash prices and Choice cattle futures prices for the nearby contract. They give some measure of spatial price differentials. However, these means are not adjusted for the change in par delivery market. Realized-basis variances are pooled within contract variances and are unaffected by the structural change. As before, direct comparisons of variances among markets can be made only where cash-price variances are not significantly different among markets. This condition holds only for Choice steers. The hypothesis of equality of realized-basis variances for Choice steers was rejected, as was the case for Choice steer hedging-revenue variances. The two tests should then reach the same conclusion, since realized-basis variance is an important component of hedging-revenue variance. Variance ratios must be relied upon for comparisons of the other grades (see Table 11).

The variance ratios shown in Table 11 are computed in the same manner as the ratios in Table 9, except that realized-basis variances are the numerators in these ratios. They are to be interpreted in much the same

TABLE 10
REALIZED-BASIS MEANS AND VARIANCES BY GRADES, FOUR MARKETS, JANUARY, 1969 TO JUNE, 1972

Grade and Class of Fed Cattle	Omaha	Kentucky	Georgia	Southern Plains
	(Dollars per cwt.)			
Choice steers				
Mean	−0.52	−0.53	0.02	−0.65
Variance[a]	.39	.56	.62	.51
Good steers				
Mean	−2.96	−3.43	−3.01	−2.57
Variance	.33	.95	.56	.35
Choice heifers				
Mean	−1.42	−1.44	−1.72	−2.00
Variance	.39	.50	.70	.46
Good heifers				
Mean	−4.05	−4.60	−4.24	−3.12
Variance	.36	.73	.53	.43

[a] Bartlett's test statistic is 2.95, which is significant at the 5-percent level, indicating that realized-basis variances are different among markets.

way as before; that is, the lower the ratio, the more effective the hedge is in shifting price risk (in this case from the ex ante point of view). It will be noted that the ratios for Choice steers at Omaha and the Southern Plains are very nearly the same. Thus, when compared on the basis of their own price variances, hedges in these markets are equally effective. This seems to contradict the result from Table 10. The individual F-ratio between these markets' realized-basis variances is 1.32, which lies on the acceptance side of, but close to, the boundary expressed by the critical

TABLE 11
RATIOS OF REALIZED-BASIS VARIANCES TO CASH-MARKET PRICE VARIANCES BY GRADES, FOUR MARKETS, JANUARY, 1969 TO JUNE, 1972

Grade and Class of Fed Cattle	Omaha	Kentucky	Georgia	Southern Plains
	(Percentage of cash-market price variances)			
Choice steer	53	64	82	54
Good steer	58	95	182	56
Choice heifer	51	61	142	67
Good heifer	64	81	181	74

SOURCE: Tables 5 and 10.

value of F being about 1.33 (see Table 7). This ratio is almost equal to the cash-price variance ratio of 1.29 (see Table 7). Thus, when individual market cash-price variances are used as denominators (see Table 11), the resulting ratios are virtually equal.

Realized-basis variance ratios for the nondeliverable grades are generally reduced from comparable ratios presented in Table 9. That is, hedging effectiveness appears greater for these grades when viewed in the ex ante sense than in the ex post sense of Table 9. Relative effectiveness among markets remains unchanged, but hedging in the nondeliverable grades seems to gain in effectiveness relative to choice steers when viewed ex ante. These comparisons throw an interesting light on the covariance term, $CV(P_{ig}, H_{jm})$, from Equation 3. This term is present in hedging-revenue variances but not in realized-basis variances. Values of this covariance term vary by location, grade, and length of hedge. The absence of this term seems to be primarily responsible for the relative increase in hedging effectiveness for the nondeliverable grades in Table 11.

SPECIAL ANALYSIS FOR CHOICE STEERS

There is evidence to suggest that the timing of hedges may be important in determining the magnitude of location-basis variability. First, there are the results of Heifner's study (1969), hedging potential for fed cattle. Heifner found no significant difference in hedging effectiveness between Omaha and the Southern Plains for Choice steers. No other markets overlap between the two studies. Heifner postulated hedges of four months duration, which are shorter than the periods used for Choice steers so far in this study. Second, there is the apparent convergence of variance ratios for Choice steers, shown in Table 9, as hedges are shortened. For these reasons, an examination of the effects of shorter hedging periods seemed useful. Therefore, a set of long (30 weeks), medium (21 weeks), and short (13 weeks) hedges were postulated. Hedging-revenue results were calculated for these hedging periods for the four study markets. Timing of the 21-week hedge was very close to that assumed by Heifner. The difference between 4 months and 21 weeks is more apparent than real, since Heifner assumed that hedges were lifted prior to the beginning of a delivery month, while in this study hedges were allowed to continue for another 3 weeks, until the expiration of the contract. Thus, the timing of hedge placements are very close, within a week of one another.

Hedging-revenue results and tests of equality of variances for these hedging periods are shown in Table 12. Results for cash-market prices and for the 30-week hedge are the same as in Table 6. The additional information to be gained from the table relates to the 21-week and 13-

TABLE 12
CHOICE-STEER PRICE AND HEDGING-REVENUE SUMMARY STATISTICS, FOUR MARKETS, JANUARY, 1969 TO JUNE, 1972

Item	Omaha	Kentucky	Georgia	Southern Plains	F-ratio, Bartlett's Test
			(Dollars per cwt.)		
Cash price					
Mean	31.13	31.12	31.75	31.01	
Variance	.73	.87	.76	.94	1.10
30-week hedge					
Mean	28.65	28.63	29.15	28.49	
Variance	.41	.60	.67	.58	3.28[a]
21-week hedge					
Mean	29.07	29.06	29.60	28.92	
Variance	.55	.73	.87	.56	4.96[a]
13-week hedge					
Mean	29.64	29.62	30.20	29.49	
Variance	.54	.73	.86	.75	2.66[a]

[a] Indicates significance at the 5-percent level. The critical value of $F_{.05}$ is 2.60.

week hedges. Here again, the equality of variances of hedging-revenue variances was rejected for both of these hedging periods. Individual F-ratio tests were conducted with Omaha as the basis of comparison. Results of these tests are presented in Table 13, where hedging-revenue variance ratios can be seen to be significant for all but the 21-week hedge in the Southern Plains. This is the hedge length that comes closest to reproducing the hedging situation postulated by Heifner, and this is the only length of hedge, of all those studied, for which location-basis variability is nonsignificant for Choice steers in the Southern Plains.

Examination of covariances and correlations between cash and futures prices provides some insights into how the differences in hedging-revenue variances originate. As shown in Equation 3, two such covariances are components of hedging-revenue variance. First, there is the covariance term, $CV(P_{ig}, H_{jm})$, which relates cash prices to the futures prices when hedges were placed. Hedging-revenue variance varies directly with this covariance term, as shown by its positive sign in the equation. The covariance term can be further decomposed to a correlation between cash and hedging prices (Equation 4) which likewise has a direct relationship with hedging-revenue variance. The second covariance term in which cash and futures prices enter, is the term $CV(P_{ig}, C_m)$, which relates cash and futures prices at the time hedges are liquidated. This covariance term

TABLE 13

INDIVIDUAL F-RATIOS OF CHOICE-STEER CASH PRICE AND HEDGING-REVENUE VARIANCES, THREE MARKETS COMPARED TO OMAHA, JANUARY, 1969 TO JUNE, 1972[a]

Test Item	Kentucky	Georgia	Southern Plains
Cash price	1.20	1.03	1.29
30-week hedge	1.47[b]	1.64[b]	1.42[b]
21-week hedge	1.34[b]	1.60[b]	1.03
13-week hedge	1.33[b]	1.57[b]	1.38[b]

[a] Data are from Table 12. See Table 7 for test procedures.
[b] Indicates significance at the 5-percent level.

varies by location, but not by hedging period, and is inversely related to hedging-revenue variance, like its constituent correlation coefficient. The covariance between hedging and covering futures prices, $CV(H_{jm}, C_m)$, varies by hedging period but not by location, and so is of no interest in explaining differences between locations.

Table 14 presents the covariance and correlation statistics of interest for the Choice-steer hedges under study. Since differences between Omaha and the Southern Plains are of particular concern, attention is directed to the first and last columns of the table. Hedging covariances for the Southern Plains are larger in absolute terms than the covariances for Omaha. In the 30-week and the 21-week hedges, the Southern Plains covariances are three or more times as large as at Omaha, and in the 13-week hedge they are more than twice as large. Obviously the numerical differences are quite small, but the hedging-revenue variances themselves are also small. Then too, such numerical differences as do exist between covariances are multiplied by a factor of two in their effect on variances. Signs of the covariances are important. When positive, they are adding to hedging-revenue variance, and when negative, they are reducing variance. Thus, the effect of the covariance differentials is to increase hedging-revenue variance in the Southern Plains, relative to Omaha in the 30-week and 13-week hedges, and to reduce it in the 21-week hedge. Hedging covariances are positive or negative, depending upon the direction of change of futures prices at the time hedges are placed in relation to the direction of change of the ultimate cash prices. Thus, we can see to what extent negative price forecasts in the 21-week hedge are responsible for the convergence of hedging revenues in the Southern Plains and Omaha for this hedging period.

Curiously, the higher the correlation between the prices at which hedges are placed and ultimate cash prices, the higher hedging-revenue variance will be and vice versa. The covariance term through which this phenomenon acts upon hedging-revenue variance is absent from the realized-basis

TABLE 14
COVARIANCES AND CORRELATIONS OF CHOICE-STEER PRICES WITH HEDGING AND COVERING FUTURES PRICES, FOUR MARKETS, JANUARY, 1969 TO JUNE, 1972

Item	Omaha	Kentucky	Georgia	Southern Plains
		(Dollars per cwt.)		
Hedging covariances				
30-week hedge				
$CV(P_{ig}, H_{30})$	.011	.029	−.007	.034
$r(P_{ig}, H_{30})$	.029	.071	−.019	.082
21-week hedge				
$CV(P_{ig}, H_{21})$	−.021	−.007	−.006	−.076
$r(P_{ig}, H_{21})$	−.046	−.015	−.012	−.146
13-week hedge				
$CV(P_{ig}, H_{13})$	.029	.041	.035	.068
$r(P_{ig}, H_{13})$	.058	.077	.069	.122
Covering covariances				
$CV(P_{ig}, C_m)$	.588	.586	.471	.632
$r(P_{ig}, C_m)$	.760	.687	.576	.718

variance measure. Absence of the covariance term causes the convergence of the ex ante measures of location-basis variability that were noted in the previous section. Thus, a troublesome component of the relationship can be avoided by confining measures to an ex ante point of view. However, the portfolio-type analyses of hedging strategies which are now popular take a fundamentally ex post point of view of hedging outcomes. From a hedging analysis standpoint, therefore, the ex post measures of variability on which this study has concentrated cannot be ignored.

Little is known about the behavior of Choice-cattle futures prices over the life of a contract, but the negative relationship for the 21-week hedge seems unusual. If this is a statistical fluke and the relationship would normally be positive, then location-basis variability could be expected to be significant for all hedging periods in the Southern Plains. On the other hand, if this should happen to reflect some phenomenon of futures-price behavior, a new dimension would have to be considered in the timing of hedges. Nothing has been said heretofore about the variances and covariances of futures prices themselves. Within-contract variances and covariances for the various hedging periods considered are presented in the Appendix. Variances for the various hedging lengths indicate that futures-price variance tends to rise gradually, but steadily, over the life of the contract. Of course, prices were also rising. Covariances show a complex pattern by falling to almost zero in the 22-week hedge and rising thereafter. Again, it is not known whether this represents any consistent pattern of price behavior.

CONCLUSION

The significance or nonsignificance of location-basis variability for hedges placed in one of the live-animal futures markets does not by itself answer the question as to whether hedging ought to be undertaken by producers in a local market, but establishes whether they have an equal opportunity to hedge when compared with producers in other markets. Where location-basis variability is significant, it does not rule out hedging altogether. Optimum- or minimum-risk hedging strategies may call for a certain proportion of hedging of the inventory of livestock on feed, although this proportion will be less than if location-basis variability were not present. From the producers' point of view, location-basis variability puts additional limits on the ability of hedging to shift price risk away from the enterprise. From the futures markets' point of view, location-basis variability reduces the supply of hedges forthcoming from livestock producers. Findings of this study indicate that location-basis variability is insignificant for slaughter hogs in the Southern markets selected for study, but is significant for fed cattle in the Southern and Southern Plains markets. Taking into account the general growth in livestock hedging, these findings would suggest that hedging of live hogs in the South will tend to grow in proportion to hedging in other areas, notably the Corn Belt, but that growth in hedging of fed cattle will be limited.

Since the conclusion of significant location-basis variability in the Southern and Southern Plains fed-cattle markets has considerable potential impact, we should review the procedure by which this conclusion was reached. The formal analytical procedure was two-phase: 1) the hypothesis of equality of variances of cash-market prices was tested, and accepted or rejected for the grade of fed cattle being tested; 2) if accepted, the hypothesis of equality of variances of hedging revenues was tested by grade and length of hedge. If rejected, the test procedure stopped, as inequality of price variances was taken as an indication that the spatial market was not sufficiently competitive to allow basis-free hedging. Thus, rejection of the phase-one hypothesis was taken to be sufficient evidence that location-basis variability was significant. This conclusion could also be reached by rejection of the phase-two hypothesis of equality of hedging-revenue variances.

Readers familiar with statistical procedures will recognize the potential in this analysis for making what is known as a Type II error (accepting a hypothesis as being true when it is actually false). Thus, a Type II error may have been committed when hog-price variances were accepted as being equal among markets, or when Choice-steer price variances were accepted as being equal. The absolute magnitude of the probability of making a Type II error is never known, but we do know that the probability decreases as sample size increases. So, while Type II errors may have been committed in this analysis, the probability is low because samples were comparatively large. Some 260 daily observations were used for hogs, and about 180 weekly observations were used for cattle. In statistical parlance, these samples provided large numbers of degrees of freedom and consequently made the tests quite powerful.

The possibility of making a Type I error (the rejection of a true hypothesis) is always present in statistical analysis, but the probability of occurrence can be controlled. Otherwise known as the level of significance, the probability for this study was arbitrarily set at 5 percent, which is a very conventional level. The consequences of adopting other levels should be explored. At a higher level of significance, such as 1 percent, several hypotheses that were rejected in this study would have been accepted; namely, most of the hypotheses concerning location-basis variability in Choice steers. This would most likely have caused a Type II error. At a lower level of significance, say 10 percent, perhaps some hypotheses would have been rejected that were accepted here. For this study, the 5-percent level of significance was preferred.

This seeming digression on statistical procedures has been presented to show that the relatively small, but significant, degree of location-basis variability in Choice steers in the Southern Plains can be altered by manipulating the data and statistical procedures. This would be unwise. The data suggest that the fundamental state of spatial competition in the market area is healthy, as indicated by the price variances. Needed is the elimination of the lags in price adjustment which are causing the basis variability to occur. Establishment of a delivery point in the region may accomplish this, particularly if the discount is adjusted to accurately reflect price differentials between Omaha and the Southern Plains. However, more resources may have to be invested in price reporting and studying price formation to eliminate the problem.

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APPENDIX

MEANS, VARIANCES, AND COVARIANCES OF CHOICE-STEER FUTURES, BY LENGTH OF HEDGE, JANUARY, 1969 TO JUNE, 1972

Hedging Period	Mean	Variance	Covariance, with Cover Price
		(Dollars per cwt.)	
Cover price	31.64	.83	
31-week hedge	29.11	.15	.056
30-week hedge	29.15	.19	.086
29-week hedge	29.19	.21	.097
27-week hedge	29.28	.25	.115
25-week hedge	29.35	.21	.091
22-week hedge	29.52	.20	.004
21-week hedge	29.58	.28	.035
19-week hedge	29.73	.34	.065
17-week hedge	29.87	.32	.133
16-week hedge	29.93	.26	.139
13-week hedge	30.15	.33	.112

The Supply of Storage for Frozen Pork Bellies

John C. Pickett

A number of recent authors (Brennan, 1958; Samuelson, 1966; Stein, 1961; Telser, 1958; Tomek and Gray, 1970; and Weymar, 1968) have examined temporal price relations for various agricultural commodities. This study is an application of the theory developed by these authors to frozen pork bellies which are traded on the Chicago Mercantile Exchange.

Temporal price relations are concerned with the structure of prices for successive time periods. These prices may be the current spot price and the past and future spot prices. Also, these prices may be represented by the current spot price and the corresponding prices for futures contracts. In the case of frozen pork bellies, the futures contracts which are currently traded are February, March, May, July, and August. On any given trading day, a spot price exists along with a price for each futures contract.[1] The relationship of these spot and futures prices over time is the essence of temporal price analysis.

Futures markets perform two important functions; they act as a guide for inventory levels, and establish forward prices. Both functions are so closely intertwined that evidence of their separate performance has not been stressed (Tomek and Gray, 1970). This paper examines the first function and assumes that the participants determine the second by their actions in the market as they react to existing and anticipated inventory levels.

As a consequence of the importance of inventories on futures prices, futures markets have originated and have had their highest development occur in situations where stocks of annual crops are held continuously (Tomek and Gray, 1970). Frozen pork-belly stocks are held continuously, in cyclical quantities, but are not a typical annual crop. Two crops are generally produced each year resulting from the biologically imposed breeding-maturing requirements. Since there are two crops each year and

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[1] If the old contract has matured and the new contract has not begun to trade, then the one or more contracts may not be quoted on a particular day.

consumption occurs throughout the year, a major role of the pork-belly futures market is the temporal allocation of the seasonal inventories throughout the consuming year. The accumulation and diminution of commercial inventories are guided by the relationship between the cash and futures prices. As these inventory adjustments are frequently accompanied by the sale and purchase of futures contracts, the price relationships between the spot and various futures contracts closely reflect the inventory positions.

THEORETICAL MODELS

The Price-Spread Model

Samuelson (1966) has applied the tools of spatial competitive relations to equilibrium commodity prices over time. Consider an agriculture commodity whose harvest occurs one day during the year but whose consumption is spread evenly throughout the year. The essential question is: What set of prices will have to exist in order to allocate the one-time harvest of the crop among the consumers who demand the commodity continuously throughout the year? The intuitive answer is obvious. The price will have to rise continuously from one harvest to the next, inducing an individual to store a portion of the crop until it is required by the consumers. Figure 1 shows the crop available and successive harvest periods. Figure 2 is the inverse of Figure 1, and shows the movement of prices for successive harvest periods. Figure 3 shows the supply-and-demand curves which can generate the price path traced in Figure 2. Figure 3 is a typical two-market, back-to-back diagram. The one-time harvest supply is S_1 and the demand throughout the year is represented by D_1 and D_2. Market 1 represents the harvest market or time period, while Market 2 represents the

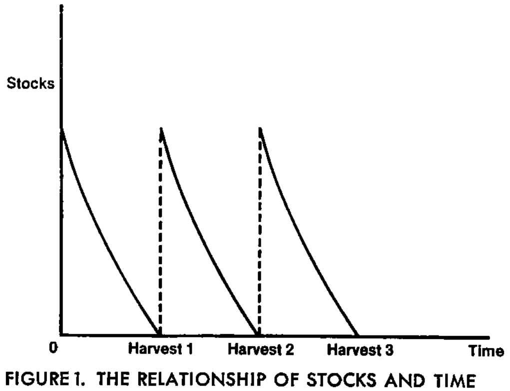

FIGURE 1. THE RELATIONSHIP OF STOCKS AND TIME

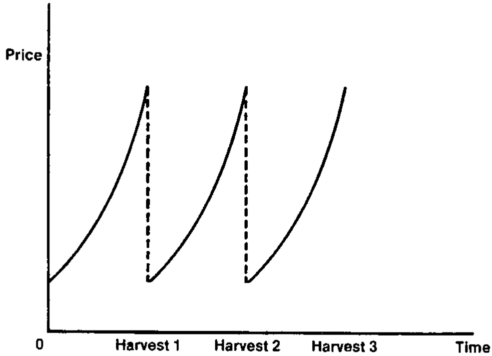

FIGURE 2. THE RELATIONSHIP OF PRICE AND TIME

post-harvest market or time period. T_{12} is the cost of storing the commodity from Time Period 1 to Time Period 2.

Carryover of the commodity from Market 1 to Market 2 will occur only if $A_2 \geq A_1 + T_{12}$. (Note: the horizontal axis in Figure 3 for Market 2 is below the horizontal axis for Market 1 by cost of storage, T_{12}.) Equilibrium between the two markets (time periods) will occur at the price indicated in Figure 3, where $A_2 = A_1 + T_{12}$. If the price in Market 2 does not exceed the price in Market 1 plus storage costs, no carryover will occur. If the price in Market 2 does exceed the price in Market 1 by more than storage costs, storage will be stimulated, lowering the price in Market 2 and raising the price in Market 1 until equilibrium is reached. This distributes the harvest from one time period to the next.

Later time periods can be depicted by similar diagrams with $T_{34} > T_{23} > T_{12}$ which represents higher storage costs for longer storage periods (additional days, weeks or months). The A_2 price in Figure 3 is just one point on the curve in Figure 2. Each point on Figure 2 can be generated by a Figure 3 with the higher storage costs representing longer storage periods. Hence, imagining a whole series of diagrams like Figure 3 in succession from harvest-to-harvest will generate the pattern of prices traced in Figure 2. Price changes within the crop year are related to storage costs. Prices drop in the next harvest period when the new crop is available, and the price level from crop year to crop year can vary according to demand-and-supply conditions each year.

Figure 4 is constructed from Figure 3 in order to determine the amount of carryover. Curve ES_1 is the excess supply curve of Market 1 and is generated by subtracting D_1 from S_1 (Figure 3) at all prices. ES_1 will be zero where $D_1 = S_1$, the market clearing price in Market 1. Curve ES_2 is the excess supply curve of Market 2 and is generated from D_2 and S_2

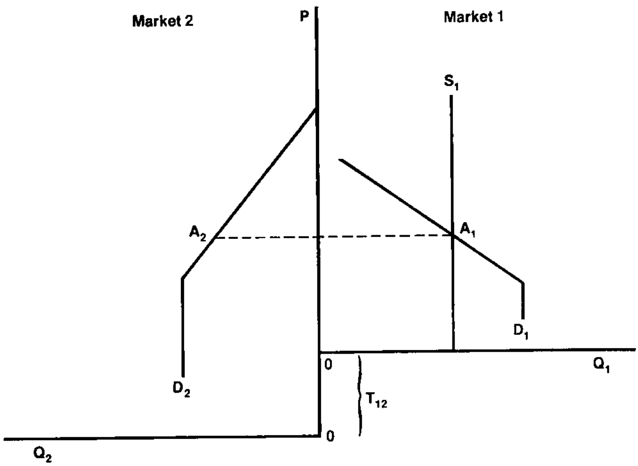

FIGURE 3. BACK-TO-BACK SUPPLY AND DEMAND CURVES

similar to the process for ES_1. Since Market 2 represents a post-harvest time period, $S_2 = 0$, which results in ES_2 being the negative of D_2. The point where ES_1 and ES_2 intersect in Figure 4 represents the equilibrium price between Market 1 and Market 2 and the quantity of carryover stocks between the two time periods if there are no storage costs, or $T_{12} = 0$.

Since storage costs are involved, Figure 5 is constructed from Figure 4. The vertical axis measures the price spread, or storage costs, from Market 1 to Market 2. Curve *NN* is constructed by subtracting ES_1 from ES_2 at each quantity point, the vertical distance between the two curves. Curve *OAT* measures the constant storage costs required to transfer the commodity from Time Period 1 (Market 1) to Time Period 2 (Market 2). Distance *OA* equals T_{12}. The amount of stocks which will be carried over is determined by the quantity $ES_2 - ES_1 = T_{12}$. The equality holds at point *K* and the amount of carryover is *OL*.

Figures 3 through 5 can be used to trade the effects of a change in supply and/or demand in either market on the size of the carryover stocks. For example, if supply increases in Market 1, then ES_1 shifts to the right, *NN* shifts up, resulting in larger stocks being carried over given constant storage costs.

A refinement of the storage cost curve, *OAT,* would allow a maximum amount of carryover stocks. This maximum would be determined by the existing storage capacity. Additional quantities could not be stored at any price which is depicted by the vertical portion *TU*.

Actual storage costs can be allowed to vary as the size of the carryover stocks vary. This is a more attractive assumption, since at low carryover

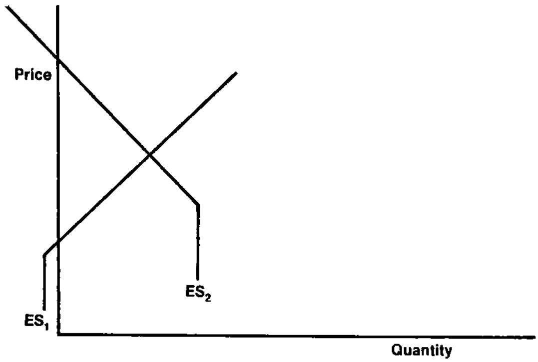

FIGURE 4. EXCESS SUPPLY CURVES

quantities warehouse operators would be willing to lower their prices as the demand for storage space declines. At high levels of carryover stocks, additional storage space could be obtained by using the more expensive storage facilities and converting storage space, normally used for another commodity, to the high storage price commodity. Figure 6 demonstrates the original fixed-price storage curve, *OATU*, and the variable-price storage curve, *BC*. Working, in a classic analysis, conceived this functional relationship as a storage supply curve (Tomek and Gray, 1970).

The objective of the supply-of-storage theory is to explain intertemporal price differences between spot and forward prices or between spot and expected future spot prices (Weymar, 1968). The cash price depends on the supply-and-demand conditions at any moment in time, and the supply-and-demand conditions in adjacent time periods. A future price for a

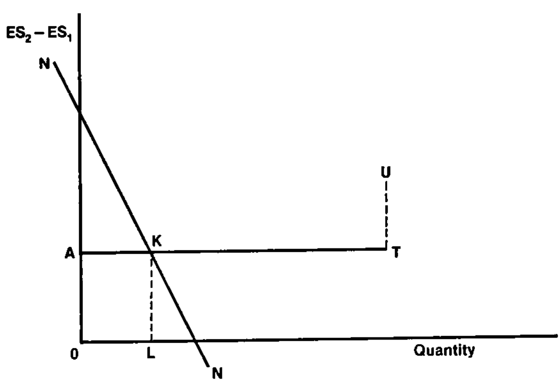

FIGURE 5. PRICE SPREAD AND CARRYOVER STOCKS

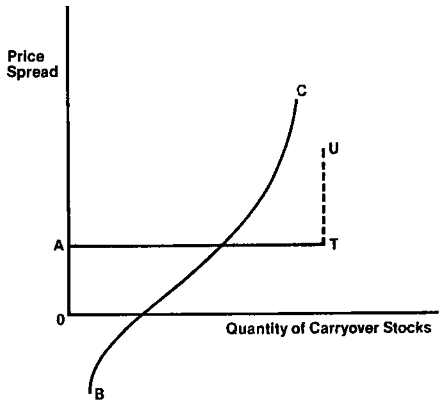

FIGURE 6. FIXED AND VARIABLE STORAGE COSTS

particular delivery month depends on the supply-and-demand conditions expected to prevail between the current period and the delivery month. Thus, the level of prices for all delivery months, including the nearest month and the cash price, respond to changes in information concerning the relevant supply-and-demand conditions. The interrelationships between successive prices may also change, but mainly in response to the level of current inventory (Tomek and Gray, 1970).

As demonstrated in Figure 6, the spread between the future price and the spot price is a function of inventory levels. This spread is the price of storage and is normally positive. A positive storage price reflects the carrying charges of inventory from one time period to the next. An inverse carrying charge is said to exist when this price spread is negative. An inverse carrying charge indicates that a scarcity exists for current inventory, causing the cash price to exceed the future price plus storage costs. In Figure 6, a negative price spread occurs at low inventory levels.

The Holding Cost Model

Consider a commodity that has no organized futures market such as inventories for manufactured goods. What benefits do these inventories provide to their owners? There are two types of yields that may accrue from holding such inventories:

THE STOCKOUT YIELD

Inventories eliminate the possibility that an order cannot be filled because the production run cannot produce the amount that is ordered within the designated delivery period.

THE COVERAGE YIELD

A second yield is produced by reducing the frequency of price changes for the finished goods. Stability of finished-goods prices is encouraged by altering the price only when raw-material prices deviate significantly from the prices of finished goods. An inventory of raw materials requires that a large quantity of that inventory be put into the production process before the replacing inventory prices cause the finished-goods prices to be altered. This yield is nothing more than stating that a large inventory makes average raw-material prices change more slowly than a small or nonexistent inventory which reduces both frequency and size-of-price changes for the finished goods.

The marginal inventory holding cost (MC_s) is equal to the storage costs (C_s), minus the stockout yield (R_s), minus the coverage yield (R_c) (Weymar, 1970).

$$MC_s = C_s - R_s - R_c \tag{1}$$

Storage costs include the normal warehousing, insurance, and interest costs of holding a unit of inventory. Figure 7 shows the relation of storage costs and inventory levels while Figures 8 and 9 show the relation of stockout yield and coverage yield and inventory levels. Note that in Figure 9 coverage yield becomes negative for large inventory positions, since price rigidity in the face of competitor price reductions produces a negative yield for the large inventory. If MC_s is calculated at each price by Equation 1, Figure 10 will result. Note that at large inventory levels, $MC_s = C_s$ since R_s approaches zero and R_c becomes zero then negative for larger inventories.

The functions in Figures 6 and 10 are equivalent. The discussion preceding each figure develops the function in a different manner, but the results are the same. The equivalence of both arguments is important here. The former back-to-back, supply-and-demand curves are used to generate excess supply curves which show the amount of inventories carried from one time period to the next. In the latter discussion, the marginal storage cost has three separate components each of which varies as the inventory level varies. The marginal storage-cost function is obtained by the linear combination of the three components at each inventory level.

Implicit in the analysis has been the economic motivation of the individual who holds stored inventory as either the price spread varies or as the inventory yield varies. The economic function performed by the holder of seasonally produced commodities is to provide storage services to the market. He is being paid the storage costs T_{12}, T_{23}, and so on. The holder of commodity inventories for which no futures market exists requires such inventories for manufacturing activities. His return is reflected in the

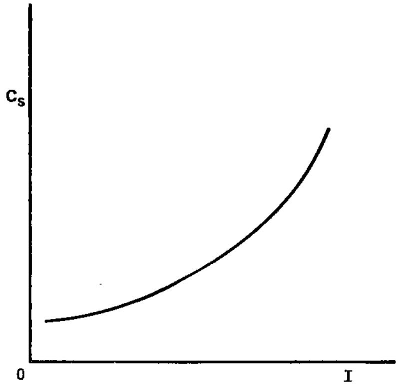

FIGURE 7. STORAGE COSTS

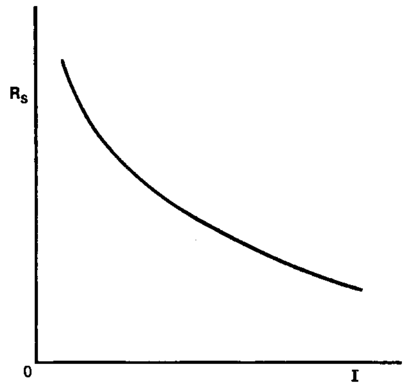

FIGURE 8. STOCKOUT YIELD

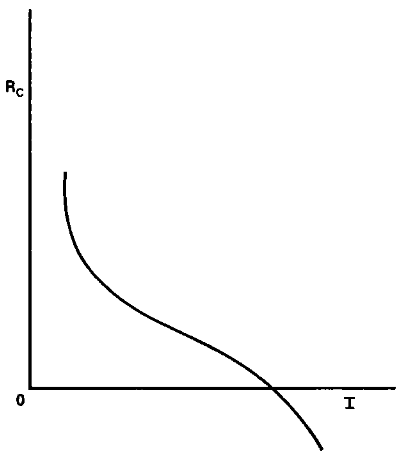

FIGURE 9. COVERAGE YIELD

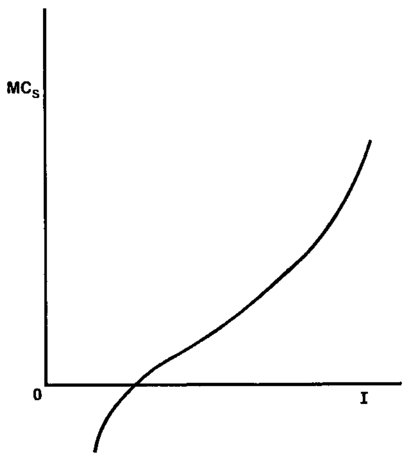

FIGURE 10. MARGINAL COST OF STORAGE

profits of his manufacturing activities. Storers and processors are not the only holders of inventory. Speculators and dealers, acting in a speculative capacity, will hold inventory if they expect the price to appreciate at a rate fast enough to cover carrying costs and yield a satisfactory return (Weymar, 1968). The total inventory is then held by processors and speculators, given the price spread, or the expected rate of price appreciation.

Either of the two theoretical formulations can be used as the model when an empirical estimation of a supply-of-storage function is undertaken. One of the formulations must be chosen before estimation can be undertaken and the supply-of-storage function actually estimated.

STATISTICAL ANALYSIS

Assumptions

A fundamental problem — what assumptions are necessary before the storage function can be estimated — must be resolved before empirical estimates can be discussed. Assuming that the storage function is relatively stable, and the demand curve varies, a supply function can be generated by plotting the price spread against inventories. Assuming that neither the supply nor the demand curve is stable, the plot-of-price spreads against inventories produces a series of discontinuous points unrelated to each other, because different supply-and-demand curves generate each observed point. If different supply-and-demand curves hold for each point, then it is impossible to estimate one supply-of-storage function, unless a system of simultaneous equations is constructed. If the demand curve is stable and the supply curve varies, then the plot-of-price spreads against inventory generates a demand for storage function. This paper assumes that the supply-of-storage function is stable and the demand curve varies along this supply function. Empirical research indicates that the components of the cost of storage have been relatively stable over time; hence the supply of storage is stable (Brennan, 1958).

Estimating procedure requires specification of one of the two theoretical models. The availability of data has forced the use of the price-spread model here. The vertical axis of Figure 10 is identified as costs, while the price-spread model identifies this axis as the spread between the future and the cash price. There is difficulty in obtaining not only estimates of the storage costs and stockout and coverage yields, but also in the functional relationship between quantities and inventory positions. Absence of the components of the marginal holding-cost function leads to the necessity that the price-spread model is the theoretical model being estimated. Price spreads are readily obtainable from published sources.

Data

Two types of data are needed to estimate the supply-of-storage function. The first is price data necessary to construct the price spreads. These data are obtainable from the Chicago Mercantile Exchange *Annual Yearbook* which contains daily price quotations for each futures contract and the cash price for different weight frozen bellies. Data points used in estimating procedures are the weekly Friday closing price for each futures contract and the weekly Friday closing price for 12-14 pound cash frozen bellies recorded in dollars and cents. Originally, the contract specifications called for delivery of 12-14 pound bellies but currently, delivery can be made in 10-14 pound bellies. The cash price quotation used is frozen 12-14 pound bellies. Periodically, the market is closed on Friday. The weekly closing price for both the futures contract and cash is then the last trading day of the week.

The second data requirement is inventory positions. These data are contained in both the *Annual Yearbook* and *Cold Storage Report*. The *Annual Yearbook* contains inventory positions in two geographical locations — warehouses are located inside Chicago or outside Chicago. Total holdings in each location are available on an end-of-week basis in units of 1,000 pounds, and are used as the data for inventory positions. The number of warehousing facilities contained in the sample varies during the time period 1965 to 1970. When a change in the number of warehousing facilities occurs, no significant change can be detected in the inventory positions. Therefore, no adjustment is made on the inventory positions for the number of facilities included in the sample.

End-of-month figures for frozen pork-belly stocks are published by the U.S. Department of Agriculture in *Cold Storage Report*. The inventory positions contained therein are representative of total frozen-belly holdings in the U.S. These positions are not used in the analysis for two reasons: 1) the number of data points is reduced by a factor of four when compared to the weekly positions available in the *Annual Yearbook*, resulting in a loss in degrees of freedom in the estimated equations; and 2) some portion of total holdings of frozen bellies reported in *Cold Storage Report* are not deliverable against the futures contracts traded on the Chicago Mercantile Exchange because they are not held in approved warehouses as are the warehouses identified in the *Annual Yearbook* totals.

In addition, inventory positions do not specify the amount held in each weight class. Contracts specify delivery of 10-14 pound bellies that should be the inventory positions which are related to the price spread. Other weight classes are acceptable for delivery, but a price concession is made for weight groups other than that specified under the contract-delivery conditions. Since storage positions for 10-14 pound bellies could not be separated from storage positions of all weight classes, there was no recourse from using the storage of all weight classes.

The economic magnitude reflected in the inventory positions conforms to the variable measured along the horizontal axis in the price-spread model — carryover stocks. The observed inventory positions are: the beginning inventory, plus production or flow into stocks during the period, minus consumption or withdrawals from stocks during the period. The quantity of stocks is the variable that measures the amount to be carried from one time period to a later time period.

The time period for the analysis is from the week ending June 5, 1964, to May 15, 1970. The starting date marks the beginning of inventory positions for both inside and outside Chicago in the *Annual Yearbook*. The ending date is the last date of the maturing May, 1970 futures contract.

The interval between data points is one week. An interval shorter than one week would not have inventory positions available from the *Annual Yearbook*. An interval of one day would serve two functions: 1) to introduce inconsistencies in the data interval resulting from holidays and weekends, and 2) to magnify the effects of not only speculative inventory positions but also the effects of speculative activity in the price of futures contracts. Fortnightly or monthly data intervals were not used because of the loss in degrees of freedom.

An understanding of the methodology followed in constructing the price spreads depends on the institutional arrangement for quoting prices for future contracts. At any given point in time, a price is quoted for February, March, May, July, and August maturing contracts. The cash price could be subtracted from each quoted price to construct a spread between a fixed date in the future for which a known price exists and the cash price. For any given week, a price spread is constructed between the Friday closing price for each futures contract and the Friday cash price. In moving through time, a set of price spreads is constructed for each contract for each week. As the old contract matures and the new contract begins to trade, the new futures contract price is substituted for the old. This procedure results in a set of price-spread observations for each contract from 1964 to 1970. The set of price-spread observations does contain missing observations for those weeks where the old contract has matured but the new contract has not yet begun to trade.

The nonavailability of data in appropriate form presents an additional problem. The price-spread model related the amount of carryover stocks to a price spread between only two time periods. The inventory figures used in the analysis can be related to a maximum of five different price spreads. For example, visualize a table that includes time for rows, and the price spread for each of five futures contracts, and the inventory position representing columns. This inventory position can then be related to each of the price spreads. An inventory position for a January date can be used to deliver against any contract during the year. To conform precisely to the model, the inventory positions held to settle each of the maturing contracts would need to be available. However, data are not available in this form so the total inventory position must be related to the price spread of each contract maturity.

Statistical Estimates

Construction of the price spread for each contract maturity throughout the time period is a straightforward procedure when utilizing Equation 2:

$$P = P_f - P_c \qquad (2)$$

where P_f is the futures price and P_c is the cash price. Discussion of Figure 3 indicated that, as the time period between harvest and consumption lengthens, the storage costs of transferring the commodity between time periods increases. As the price spread is now expressed in Equation 2, no adjustment is made to differentiate a contract that has only one month until maturity and one that has 11 months until maturiy. This absolute price difference will automatically change, not only as inventory positions are altered, but also as the maturity date approaches the current date. In order to eliminate the effect on the price spread of the time to maturity, price spread is adjusted to reflect the average price spread per week to maturity. This adjustment is accomplished by Equation 3:

$$P = (P_f - P_c)/(t + 1) \qquad (3)$$

where t = number of weeks until the contract matures.

One is added to the denominator to eliminate the infinite value for the price spread in the last week before contract maturity and to allow for the possibility that the last trading day will occur sometime during the following week but not on the Friday of the following week.

An investigator has no knowledge a priori whether or not the average price spread per week is a correct adjustment procedure for statistical purposes. Each of the estimated equations which follow were reestimated using the unadjusted price spread of Equation 2 instead of the adjusted price spread of Equation 3. In every case the results were better using Equation 3, as evidenced by a R^2 approximately double that of R^2 using Equation 2 and higher F-values in all cases when Equation 3 was used. All following discussions of price spreads are in reference to the spread calculated by Equation 3.

A supply function always has an implicit time dimension associated with it. By a time dimension, one is implying that alternative quantities will be placed on the market at different prices per same time period such as quantities placed on the market during a week, month, quarter, or annually. The supply of storage for frozen pork bellies has a time dimension of one week, and more than one supply-of-storage function exists during a calendar year. These multiple storage functions are a result of the number of observations which exist for the futures prices. The precise definition of a storage function requires that a price spread be constructed between the cash price and all futures prices. A set of all futures prices does not exist. Only futures prices which are represented by the traded futures contracts exist at any moment. Therefore, a price spread can be constructed between the known cash price and the known (traded) futures contracts. At any given point in time, a price spread can only be constructed for those futures prices represented by the trade futures contracts — February, March, May, July, and August.

The fixed number of known quoted futures prices allows for the generation of a number of supply-of-storage functions revealing shifts in the function within a calendar year and between years. For example, a storage function can be estimated from the first complete set of data using the March, 1965 futures contract price. A second storage function can be estimated using the May, 1965 futures contract price. Additional storage functions can also be estimated using the July, and August, 1965, February, 1966 contract prices and continuing until May, 1970. Note that not one but a series of storage functions are being estimated.

Methodology

The price-spread model, which provides the theoretical foundation for the empirical investigation, fundamentally asks the question: What determines the quantity of a commodity that is carried over from one time period to a later time period? The model defines the determining factors as the price spread between the two time periods, and the cost of storing the commodity. The model can be expressed in functional form as:

$$Q = f(PC) \tag{4}$$

where Q = carryover stocks or inventory
P = price spread as defined in Equation 3
C = storage costs.

Equation 4 symbolically shows that carryover stocks depend on the price spreads. Omitting C from this equation results in the uncomplicated notation of the supply-of-storage function.

Differentiation must be made between this supply-of-storage function and a storage function expressed as Equation 5:

$$P = f(Q). \tag{5}$$

Either equation may be the correct expression of the direction of dependence between price and quantity. No general rule or set of criteria is available to choose between the two expressions. The choice depends on the model underlying the analysis. The price-spread model states that the amount of inventories carried over from the current time period to a future time period depends on the difference in prices between the two time periods.

The methodology for the statistical analysis is as follows: 1) indicate the plots of stored inventory and price spreads; 2) demonstrate the results of the simple linear-equation model; 3) show why a model which includes lagged variables may improve the estimate of the storage function; 4) demonstrate the results of the linear model which includes lagged variables; and 5) outline some statistical problems contained in the results.

PLOTS OF RAW DATA

The first step in analyzing the data is to plot the quantities of stored bellies against the price spread which existed for each maturity date. Figure 11 is the pictorial representation of the data. At first glance there does not seem to be any relation between inventories and price spreads. An obvious relation would be indicated when the pattern of points seems to trace a straight or some type of curved line. The pattern seems to be best represented by a horizontal line parallel to the quantity axis. This is similar to line *AT* in the theoretical model as drawn in Figure 6.

Remember that Figure 11 contains all the data points generated during the sample time period. If the storage function has been slowly shifting during the sample period, the plot of the raw data would not be expected to reveal a perfect supply-of-storage function. The plot of raw data might suggest that the intersection of the cost-of-storage curve and the supply-of-storage function is being observed. Actually, a set of equilibrium points is observed because both the cost-of-storage and the supply-of-storage function jointly determine the inventory carried from a current time period to a future time period.

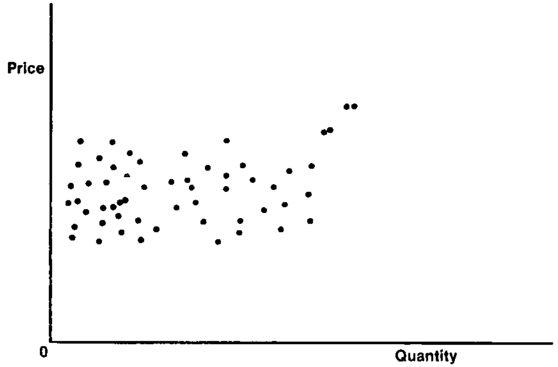

FIGURE 11. PLOT OF PRICE AND QUANTITY OBSERVATIONS

SIMPLE LINEAR EQUATION

Since the plot of all data points is best represented by a straight line parallel to the inventory axis (labelled Q) an equation of the form $Q = \alpha + \beta P + \epsilon$ was estimated. The estimated equation over all the data is:

$$\underset{(637)}{Q = 34134} + \underset{(1734)}{9503P} \qquad R^2 = .02 \quad F = 15.3 \quad \text{Durbin-Watson} = .03. \tag{6}$$

The standard error of each coefficient is shown in parentheses beneath the coefficient.

As indicated in the preceding discussion, there are 27 subperiods in the data. Each represents the price spread for a mixed maturity futures contract. There are five futures contracts traded during the time period of the data—February, March, May, July, and August. Equations of the form of Equation 6 were estimated for each subperiod. Presentation of only the R^2 values for each subperiod is sufficient to point out that the estimated equations explain less than 18 percent of the variation in the quantity of stored inventory in any one case, excluding the May contracts. Table 1 presents the R^2 value by year and futures contract maturity. The extremely low R^2 values alone are grounds for rejecting the underlying price-spread model as the theoretical foundation for the analysis. The four R^2 values greater than 50 percent for the May contract are significant to the analysis for two reasons: 1) the price-spread model does explain more than one-half of the total variation for the four May contracts, and 2) the four May contracts produce an R^2 considerably higher than the other contract months for four consecutive years which may indicate that the price-spread process determining stored inventory positions differs for future contract-delivery months.

INCLUSION OF LAGGED VARIABLES

The values in Table 1 may indicate either that the theoretical model is incorrect, or that independent variables have been omitted which would help to explain the variation in the dependent variables. Given all the other professional articles which employ the price-spread model and the strength of Samuelson's original work, rejection of the price-spread model as the basis for this investigation seemed ill-advised. (Variables are assumed to have been omitted from the equation.)

The next question to examine is to identify the variables (factors) that would explain additional variation in the dependent variable. A number will immediately come to mind, such as the price of competing meat products, supplies of competing meat products placed on the market,

TABLE 1
R^2 VALUES FOR EACH SUBPERIOD ESTIMATED FROM EQUATION 6

Months	1965	1966	1967
February		.038	.0002
March	.0004	.122	.046
May	.472	.298	.556
July	.079	.022	.057
August	.016	.065	.084
Months	**1968**	**1969**	**1970**
February	.00009	.176	.002
March	.003	.001	.014
May	.515	.588	.534
July	.041	.030	
August	.016	.041	

income levels of consumers, and consumption of pork bellies as measured by bacon slice. These and other variables are not included for two reasons:

1. A desire to avoid the identification problem caused by including some variables that reflect both the supply-and-demand relationships. For example, if a variable for consumption (bacon slice) is included with the price spread, the estimation will reflect combined effects of supply and demand which cannot be separated. The statistical results would be difficult to interpret.
2. The relation between these omitted variables and the included variables. All other variables act to position the supply-and-demand curves in the two time periods that interact to produce two prices. This paper is not interested in defining the position of the supply-and-demand curves for the commodity in each time period, but does seek to clarify the amount of the commodity that is transferred between time periods. All the effects of the omitted variables are reflected in the two prices, and if the variables are included, the identification problem will result.

There are two types of omitted variables — lagged-price spreads, and lagged quantity of stored inventory. Justification for including lagged-price spreads depends on the decision process followed by those individuals who store bellies. The process is indicated to be that past prices are considered by individuals supplying storage before storage of bellies is provided. The market evaluates or weighs the set of current and past price spreads before storage is provided.

The lagged quantity of stored inventory is included on the grounds that there is a distinct time lag in the ability of the market to accumulate or dispose of bellies. Accumulation of bellies is dependent upon hog slaughter and consumption, which in the short run responds to hog prices and bacon prices, and in the long run responds to the breeding-slaughtering cycle which itself is dependent upon hog prices. The disposal of bellies requires some time period, because an increase in quantities has to act to decrease bacon prices which increases consumption. If the market in the aggregate attempts to dispose of bellies in large quantities, then the price will decline, inducing some sellers to alter their decisions and hold or become buyers. The inability of the aggregate market to accumulate or dispose of belly stocks in a short period is reflected in inclusion of the lagged-inventory position as an independent variable.

The next question to answer is: How many lagged-price spreads to include as independent variables? Market participants generally consider all past prices in their decision process when the recent past is weighted heavier than the distant past. All past prices cannot possibly be included as independent variables, since there is a maximum of only 52 observations on each subperiod.

The procedure used to determine the maximum number of past prices was spectral analysis. Spectral analysis is a complicated procedure to convert the time domain to a frequency domain. One aspect of spectral analysis is a coherence function that measures the correlation between two variables in the frequency domain. Conversion from the frequency domain back to the time domain allows estimation of the relative importance of each of the past prices.

Examination of the coherence function produced a maximum of six immediate past prices which were relevant in explaining the variation in stored inventory. Since the data interval is one week, the current price spread plus the preceding six weekly price spreads, are the price spreads included as independent variables.

The lagged-inventory positions are limited to the one for the immediate past. This follows from the Koyck lag technique on a distributed lagged equation. Inclusion of lagged-dependent variables as independent variables in excess of the one in the immediate past period would present the estimating equation in an autoregressive form. In autoregressive form, current values of a variable can be estimated for all the past values of that variable. An autoregressive scheme is not assumed by the price-spread model, but could be formulated into the price-spread model.

Inclusion of lagged prices and inventory can be expressed in functional form as Equation 7. The subscripts note the relevant time period associated with each variable.

$$Q_t = f(P_t, P_{t-1}, P_{t-2}, P_{t-3}, P_{t-4}, P_{t-5}, P_{t-6}, Q_{t-1}). \qquad (7)$$

RESULTS OF THE INCLUSION OF LAGGED VARIABLES

The estimating equation is in the form of Equation 8. This is a linear equation which is a consequence of attempting various nonlinear equations to find the best fit. None of the nonlinear forms produced fit consistently higher than the linear equation:

$$Q_t = \alpha + \beta_1 P_t + \beta_2 P_{t-1} + \beta_3 P_{t-2} + \beta_4 P_{t-3} + \beta_5 P_{t-4} + \beta_6 P_{t-5} + \beta_7 P_{t-6} + \beta_8 Q_{t-1} + \epsilon_t. \tag{8}$$

The desire is for all hypothesized variables defined in Equation 7 to be supported by statistical analysis. Initial estimates of Equation 8 for all subperiods were initiated. Examination of the t- values associated with each regression coefficient indicated that in most cases some of the independent variables were not significant. A reestimation was made including only those variables that were significant at the 10-percent level. The estimated equations are shown in Table 2, identified by the sample subperiods. Standard errors have been omitted.

Interpretation of Results

Consider the first equation for March, 1965. Of the seven possible prices and the lagged-dependent variable, only the price spread lagged four weeks is statistically significant. The sign of the coefficient is negative, yet the price-spread model for the supply function hypothesizes a positive relation between price spreads and quantities. The sign of the constant or intercept is positive and the model hypothesizes a positive sign. The R^2 is extremely low and the F-value indicates the equation should be rejected, which means that either the model or the functional form (linear) of the equation should be rejected. A relevant observation is the insignificance of the lagged-dependent variable. The statistical omission of this variable suggests that the one-week lagged quantity does not enter the market's decision-making process.

The second equation is a better estimate for discussion. All prices and the lagged quantity (inventory) are statistically significant. The correct interpretation of the regression coefficients is: once the equilibrium that exists between price spread and inventory is disturbed, the effect of a one-unit change in price in the current period on the inventory is to reduce inventory by 3,273 units if the price change is positive, and by −3,273 units if the price change is negative. The adjustment back to equilibrium does not cease, since the effect on inventory is 26,980 units resulting from the price-lagged one period, 47,164 units from the price-lagged two periods, and so on until the effect on inventory from the price-lagged six periods is 29,591 units. The total effect on inventory is the sum of all the

TABLE 2
REGRESSION RESULTS

Time Period	Constant	P_t	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	P_{t-5}	P_{t-6}	Q_{t-1}	R^2	F	DW
March, 1965	10,692					−5,573				.04	.67	1.66
May, 1965	−3,667	−3,273	26,980	47,164	41,976	37,358	33,249	29,591	.89	.99	22.05[a]	.53
July, 1965	8,286	−5,370	−1,074	−214	−42	−8			.22	.13	2.09	1.88
August, 1965	8,365		−11,327	11,528	2,766	664	159	−13,306	.24	.15	1.44	2.01
February, 1966	2,739							5,241	.72	.72	26.95[a]	1.49
March, 1966	1,796		4,666	3,499	9,653	−3,587	−2,690	−2,017	.71	.71	16.48[a]	1.50
May, 1966	1,232		7,399	7,029	6,677	6,343	6,025	5,724	.95	.97	6.54[a]	.28
July, 1966	3,372			4,705	3,497	2,098	10,671	−8,091	.67	.62	10.60[a]	1.97
August, 1966	3,194	5,835	−9,359	234	159	13,261	9,017	−9,233	.68	.67	11.10[a]	1.99
February, 1967	2,102								.74	.55	25.70[a]	1.52
March, 1967	3,602						−5,416	−3,845	.71	.51	12.80[a]	1.58
May, 1967	2,983	−5,091	1,533	1,441	1,354	1,273	13,799	12,971	.94	.99	27.32[a]	.64
July, 1967	2,705					−13,653	−9,830	7,315	.72	.56	13.00[a]	1.53
August, 1967	6,408		9,413	5,836	−43,177	−26,769	−16,597	−10,929	.62	.58	14.50[a]	1.42
February, 1968	6,020	6,864	3,157	−13,578	−6,245	−31,887	−14,668	33,025	.46	.52	6.30[a]	1.68
March, 1968	4,667	−16,920	24,859	13,672	−9,829	−5,405	−2,973	−1,635	.55	.38	5.00[a]	1.76
May, 1968	−817	−8,099	2,049	1,762	1,515	16,851	14,492	26,885	.86	.99	8.63[a]	.56
July, 1968	4,949	5,817	2,094	−5,081	3,956	1,424	−28,296	23,864	.36	.33	2.78[a]	1.94
August, 1968	4,316				46,028	−37,838	−9,837	41,980	.26	.16	1.53	1.94
February, 1969	10,972						−9,172			.06	1.40	2.23
March, 1969	9,923		−17,261	1,898	−24,647	2,711	−298	32	−.11	.10	1.18	1.93
May, 1969	−3,070	−5,738	−9,476	9,768	26,384	22,690	36,388	31,294	.86	.99	749.30[a]	.56
July, 1969	4,335	4,917	1,868	−4,677	1,935	735	4,991	1,896	.38	.31	2.93[a]	1.80
August, 1969	6,008	−7,386	10,924	−10,027	−17,655	11,366	63,359	−27,490	.27	.35	2.22[a]	1.90
February, 1970	5,719					7,486	2,844	−6,524	.38	.20	2.40[a]	1.93
March, 1970	5,716			12,772	−7,995	−2,878	−1,036	−373	.36	.20	2.58[a]	1.83
May, 1970	2,340	4,891	9,070	7,709	6,553	5,570	10,011	8,510	.85	.98	6.93[a]	.39

[a] Equation is statistically significant.

regression coefficients. In this equation the total effect on inventory is 213,045 units distributed among the lagged prices as indicated by the regression coefficients.

The effect on inventory does not cease after the sixth-lagged price. The lagged inventory is significant. The coefficient is $1 - \lambda = .89$, therefore $\lambda = .11$. The effect on current inventory of inventory-lagged one period is .89 of the preceding inventory figure. A large $1 - \lambda$ value indicates that inventory quantities are adjusting slowly. A small value for $1 - \lambda$ signifies inventories are adjusting rapidly. The Koyck lag technique demonstrates that the effect of lagged inventory on current period inventories at the cessation of the free lag is dependent upon the magnitude of $1 - \lambda$.

A pictorial representation of the lag structure for the May, 1965 equation is shown in Figure 12. The graph line connecting the points portrays the effect of lagged prices on inventory. The tail of the graph depicts the effect of the lagged inventory on current inventory. A value of $1 - \lambda$ close to one makes the line approach the horizontal axis slowly, indicating that the process generating the movement back to equilibrium is lengthy. A small $1 - \lambda$ indicates that the movement back to equilibrium occurs quickly. Of considerable importance to the analysis, is the observation of the magnitude of $1 - \lambda$ for each equation. A preceding section of this paper noted that both the original price and inventory data contain the combined effects of hedging and speculative decision making. The largest speculative activity in bellies occurs in the February, July, and August futures contracts. The estimated $1 - \lambda$ values of these three months are

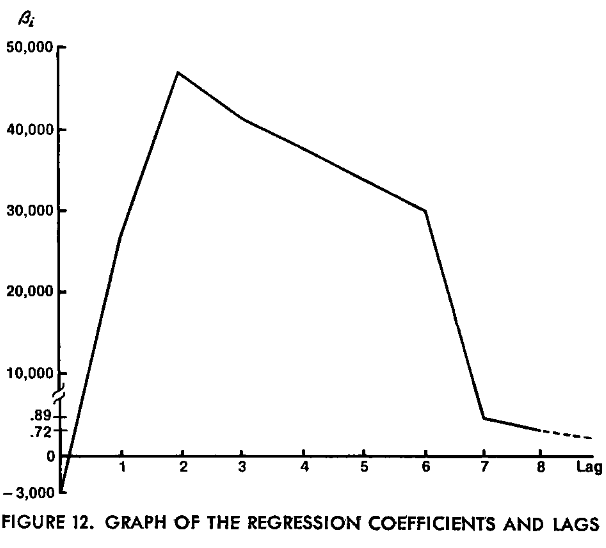

FIGURE 12. GRAPH OF THE REGRESSION COEFFICIENTS AND LAGS

typically lower than the values for the March and May contracts. Since it is impossible to disentangle the hedging and speculative activity in the data, and knowing which trading months usually receive the most speculative interest, the $1 - \lambda$ values indicate that the movement back to equilibrium is faster in those months when speculative activity is concentrated. In the two months that do not receive much speculative attention, especially May, the adjustment is much slower. The important conclusion is that the time required to restore equilibrium is short when speculative activity is large.

Returning to the discussion of Figure 12, the combined effect of all prices on the stored inventory can be represented by the sum of the regression coefficient associated with each price variable. This sum is represented by the area beneath the line connecting each regression coefficient. In estimating a supply function, any increase in price should have a combined effect of increasing the quantity supplied. Table 3 presents the sum of the regression coefficients for each subperiod. The entries for the May equations are those which result from a reestimation of these subperiods as presented in the following subsection, *Statistical Problems.*

An inverse relationship is indicated between price and quantity in 9 of the 27 subperiods. An increase in the price spread produces a reduced supply of stored inventory. Two possible explanations are available to explain these temporarily perverse storage functions: 1) speculative activity may completely dominate the hedging activity, or 2) the current period's supply of stored inventory which has been committed for sale exists in such a small quantity that a large price spread will not induce carryover because uncommitted stocks do not physically exist. Neither explanation can be proven either true or false. These equations which produce an inverse relationship between stored quantity and price must not be considered as the correct functional relationship between quantity and price.

The equation for February, 1969 does not contain a significant lagged-dependent variable. A hypothesized explanation is that speculative activity

TABLE 3
TOTAL EFFECT OF ONE-UNIT CHANGE IN PRICE ON THE QUANTITY SUPPLIED

	1965	1966	1967	1968	1969	1970
February		5,241		−23,332	−9,172	3,806
March	−5,573	9,524	−9,261	1,769	−37,565	470
May	200,840	10,790	21,805	38,509	26,578	15,156
July	−6,709	3,470	−16,141	3,778	11,665	
August	−9,516	9,914	−81,584	40,333	23,091	

does not consider the past pattern of stored inventory as an important variable when formulating future price expectation. Therefore, the lagged-dependent variable will not be statistically related to the dependent variable. Since the lagged-dependent variable has been found to be significant in the other estimated equations, this equation is probably not representative of the actual storage function for this period. The March, 1965 equation also does not contain the lagged-dependent variable.

The equation for March, 1969 has a negative sign on the lagged-dependent variable. This sign should be positive. A negative sign is indicative of an explosive model; $1 - \lambda = -.11$ produces $\lambda = 1.11$. Current inventory positions will be an increasing function of past inventory figures which is not an acceptable result given the structure of this market. The model should be rejected as an explanation for the supply of storage during this subperiod. In examining each of the remaining equations, three general observations can be made. First, there is no consistent pattern to the statistically significant variables which explain the quantity of inventory. There is no evolutionary pattern through time, and there is no pattern for a given future month between successive years. One would hypothesize a priori that the prices should enter into the decision process in an indeterminate pattern. Decision makers would observe a pattern and, by engaging in speculative activity, eliminate it. As a result, one observes that the statistically significant prices vary among the subperiods in a random pattern.

Second, in these equations where all variables are significant (especially May) there is no pattern as to the size of the regression coefficients. The contribution one lagged price makes in explaining the inventory varies among the subperiods in a random manner.

Third, the constant term is positive except in only three subperiods, indicating that the supply function is positioned as the theoretical model hypothesizes.

STATISTICAL PROBLEMS

Examination of the F-statistic indicates that the March, July, and August, 1965, August, 1968, and February and March of 1969 equations should be rejected. Those equations which are accepted are indicated by an asterisk on the F-value. Rejection of these equations implies that the equation, and therefore the model, is incorrect for these subperiods. Three of the six rejected equations are also rejected for not possessing a lagged-dependent variable or having a lagged-dependent variable of incorrect sign.

A serious problem arises with the evidence of serial correlation in all of the May equations. One assumption necessary for the ordinary least-squares estimating technique is that the disturbances in one period are independent of disturbances in any other period. Evidence of serial correlation means that the disturbances in one period are dependent upon disturbances in earlier periods. The result of serial correlation is that the α's and β's are efficient but the sampling variance is incorrect. The consequence of an error in the estimate of the sampling variance occurs when one is attempting to predict. The prediction will be biased.

Why has serial correlation arisen? There are two possibilities: 1) exogenous variables have been omitted from the equation, or 2) the functional form of the equation has been misspecified. With respect to the first possibility, the price-spread model has expanded to include lagged variables but not other variables which may generate an identification problem. For the second possibility, no other functional form has eliminated the presence of serial correlation.

No reason can be found to explain why the presence of serial correlation occurs only in the May equations. If variables have been omitted, serial correlation would be expected to occur in the other contract maturity dates. If the functional form is incorrect, the incorrect specification would be expected to appear in the other contract maturity dates as well.

A statistical procedure exists — the grid search method — for removing the serial correlation, although specification of either the omitted variables or functional form as the cause would be preferred. All significant variables have been adjusted initially by Equation 9 with ρ taking the values $+.99, +.98, \ldots, +.02, +.01$.

$$X_t - \rho X_{t-1} \tag{9}$$

The equations have been reestimated for each value of ρ. Choice among all the estimated equations is made on the basis of minimum standard error of the residuals. The R^2 value is recorded, but is meaningless when this adjustment in the original variables is made. The Durbin-Watson statistic has improved considerably. These equations seen in Table 4 should be substituted for the May equations presented in Table 2.

SUMMARY

In order to summarize the results of this study, characteristics of the estimated equations must be interpreted in light of the deficiences of the data used in the analysis:

1. The observations on prices contain the effects of pure speculative decisions as well as the effects of the storage decisions. Speculative activity affects prices which, in turn, affect the amount of stocks carried over. Therefore, speculative activity is affecting the estimated relationship between inventory positions and the price spread.

TABLE 4
REGRESSION RESULTS OF REESTIMATED MAY EQUATIONS

Time Period	Constant	P_t	P_{t-1}	P_{t-2}	P_{t-3}	P_{t-4}	P_{t-5}	P_{t-6}	Q_{t-1}	R^2	SER	F	DW	ρ
May, 1965	−3,210	−979	25,024	44,939	39,546	34,801	30,625	26,884	.88	.98	1,084	432	1.98	.70
May, 1966	1,728		2,088	1,962	1,844	1,743	1,630	1,532	.94	.92	774	146	1.31	.94
May, 1967	3,236	−1,716	1,358	1,262	1,174	7,023	6,531	6,173	.93	.95	948	152	1.54	.90
May, 1968	3,701	−2,069	4,988	4,639	4,314	9,721	9,041	7,875	.93	.93	1,125	88	1.79	.92
May, 1969	1,952		−1,991	1,256	4,994	4,644	9,158	8,517	.93	.92	1,107	72	1.99	.93
May, 1970	3,261		2,601	2,392	2,201	2,025	3,092	2,844	.92	.92	874	113	2.16	.92

2. The price spread can only exist between a known future price and the cash price. The known future price only exists for those dates for which a futures contract is traded. A price spread constructed between all future prices and the cash price would be preferable, but the market does not provide this information.
3. The Chicago Mercantile Exchange delivery specifications state deliverable stocks have to be stored after December 1, in order to be deliverable at par during the next year. The inventory figures do not specify the quantity of new bellies and old bellies. Thus, the inventory figure may not be representative of the amount deliverable at par. Certainly, the old bellies are not held for delivery against the futures contract at the cessation of trading of the August contract, yet the quantity of inventory is specified as being related to the price spread which contains the future price observation. Ideally, researchers prefer to relate the quantities and price spreads of equivalent variables.
4. The measured inventory can be delivered against any contract during the year. These data do not allow identification of the amount of inventory being held to a certain future date in response to a certain price spread that exists between the two dates. Ideally, the number of pounds of inventory being transferred to a certain date in the future, and the price spread which exists between the two dates would be preferred.

These deficiencies in the data are referred to as measurement errors. The price-spread model requires certain narrowly defined data but the data which must be collected contain information in excess of what is required. As a consequence, the price-spread model is being used to test hypotheses with data that contains the effects of speculation and does not relate quantities and price spreads with a fixed time dimension.

The price-spread model hypothesizes that the amount of inventory transferred from the current time period to a future time period is a function of the price spread between the two time periods and the cost of storing the commodity between the two time periods. The model was expanded to include lagged-price spreads and lagged-quantities of inventory as independent variables. The ordinary least-squares technique was employed to estimate a linear function between inventory and the independent variables for each of the 27 subperiods that existed during the time period for which data were collected.

The statistical tests undertaken on the 27 estimated equations reject 6 as being the correct functional form to explain the variation in the dependent variable. The rejected subperiods are March, July, and August, 1965, August, 1968, and February and March, 1969. These rejections imply that the price-spread model is not an adequate theoretical model for explaining the variation in stored inventory. Other functional forms were estimated in an attempt to reformulate the relation, but in all cases the F-value indicated the function was to be rejected. Thus, the price-spread model does not provide the theoretical relation between stored inventory and the independent variables for these six subperiods.

The supply-of-storage theory hypothesizes a positive relationship between changes in price spreads and changes in stored inventory. Nine of the 27 subperiod equations produce a negative total change in stored inventory resulting from a unit change in the price spread. Five of the nine subperiods are the same subperiods whose estimated equations have been rejected earlier on grounds of an insignificant F-value. There remain four subperiods whose estimated supply-of-storage function is perverse.

Perverse supply curves can exist in economic theory. The theory of the supply of storage does not hypothesize a negative relation between stored inventory and the independent variables. There are only two justifications for the negative relationship. First, speculative activity dominates the formation of the futures price which affects the measured price spread. Second, the errors in measurement include the effect of speculative activity. These two reasons combined tell us the price-spread model is incomplete. A function needs to be designed to account for the effect of speculation on the futures prices, allowing the statistical procedures to separate the speculative effects on futures prices from the effects of price spread on the quantity of stocks carried over. In the hypothesized model, both effects are comingled and separation is impossible, so the equations should be rejected as representing the appropriate supply-of-storage functions.

Twenty-seven equations were originally estimated and 10 have been rejected. The remaining question is: What information is provided about the supply of storage for frozen pork bellies from the remaining 17 equations? The supply of storage is generated by decision makers observing a set of current and past price spreads and the inventory positions lagged one period. The decision process engaged by individuals who supply storage is complex, as observed by the absence of any perceivable pattern in which the lagged-price spreads enter into each of the estimated equations. If some order of entry could be detected, one could hypothesize that the decision makers first examine this price spread, second, another price spread, and so on. Since there is no apparent order, the conclusion can be drawn that while price spreads do explain the amount stored as the theory states, the process determining which price spreads influence the storage decision is unknown.

In addition, the absence of any pattern in which prices enter the decision process is confirmed by the lack of any pattern for the size of the regression coefficients as the supply functions are estimated sequentially. This suggests two conclusions:

1. The market process is dynamic and stable. Being dynamic means that the equilibrium price spread and inventory position is constantly changing as the supply-and-demand curves for each market time period shift. Stability implies that once the market is in a disequilibrium position the market moves back towards a new equilibrium position. The perverse shape of some of the estimated supply functions indicates a temporarily unstable market, but this never exists longer than two consecutive subperiods.
2. If during any subperiod of any one futures contract a perceivable pattern is observed, the market participants will react to the pattern, and thus eliminate it. All patterns will be eliminated by the actions of the market participants with the consequence of the preceding observation.

Examination of the coefficient of determination indicates that approximately one-half of the total variation in the amount held in storage can be explained by the price spreads and lagged-inventory positions. This is an acceptable result considering the effect of speculative activity on price spreads which cannot be isolated on this model, and the deficiencies in the data. The results also imply that Samuelson's theoretical model can be empirically verified with these data.

An additional insight into the effects of speculative activity can be gained by observing the $1 - \lambda$ values and the coefficient of determination for those contract maturity months which traditionally attract speculation, and those maturity months which do not typically receive speculative interest. Contracts maturing in May receive the least speculative activity. The May equations first estimated produce an extremely high R^2 value implying that the price-spread model is almost a perfect theoretical base for the supply-of-storage function. In the remaining contract maturity months which attract speculative activity the R^2 values decline as expected since the price-spread model does not attempt to consider the effects of speculation on the amount of inventory transferred to a future time period.

The $1 - \lambda$ values can be interpreted as an indicator of the speed at which the system returns to equilibrium after a one-unit change in the price spread. This coefficient for the May equations indicates that the time required to restore equilibrium is longer than for the other contract maturities. The absence of speculative activity in this month indicates that the market's accumulation and disposal of bellies requires a considerable number of weeks before a complete inventory response can be observed, raising the perplexing and yet unresolved question: Why does the presence of speculative activity, as observed by low R^2 values and an a priori knowledge of the months which attract speculation, produce a short time period in which inventory positions respond to changes in price spreads, while the absence of speculation produces a longer time period required for inventory positions to respond to changes in price spreads?

The estimated supply functions show that the process generating the amount of stocks carried over from one time period to the next is quite complex. The independent variables enter the sequence of equations in some indeterminate order, and the regression coefficients assume values of an unpredictable magnitude. These two observations suggest that there is not one supply function which is representative of the supply of storage for frozen pork bellies. Each of the estimated functions does indicate that some set of past price spreads is the appropriate group of independent variables.

The influence of the lagged-dependent variable is of particular importance. The rate at which equilibrium is restored depends upon the month in which the futures contract matures. The May supply function requires a longer period than the other four months and this has also been observed for the six May subperiods used in the analysis. The process generating the supply functions differs between May and the other subperiods, but this process generating the May equations has been more uniform throughout the data period than any of the other subperiods.

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The Feeder-Cattle Information System

P. Thomas Cox and M. Anthony Wright

This paper analyzes the feeder-cattle information system and proposes some revisions in the current categories of feeder-cattle grades. The analysis proceeded in four steps. First, upon inspection of the teletype market-news reports from all over the United States, a large amount of informational noise was discovered consisting of nonstandard grading descriptors and inconsistent weight ranges. Second, a survey of the purchasing practices of Arizona cattle feeders found that they do not rely heavily upon the formalized market-news reports because of the noise present. Most feeder cattle are purchased after informal telephone discussions with order buyers. Third, on the basis of physiological and economic criteria, feeder cattle were partitioned into types on the basis of sex class, frame size, degree of muscling, and weight. These traits are important when predicting feedlot performance. Fourth, a price simulation, reflecting the situation facing feedlots with single-time capacities of 12,000, was run utilizing price data from 1957 to 1975. The simulation's objective was to test in a market situation the efficacy of the proposed revision of feeder-cattle grades. It demonstrated that there were significant differences between the feeder-cattle type and their respective internal rate of return earned over the time period of the study.

BACKGROUND

Over the past few years the American beef-cattle industry has withstood several hard shocks. Ration cost increased tremendously following the Russian wheat deals. Feeder-cattle prices climbed to all-time record highs and immediately thereafter plunged to disastrous lows. The attrition rate of bankrupt firms seems only to increase. For example, over one-third of Arizona cattle-feeding firms went out of business in 1976 alone. With such price volatility, the cattle feeder faces an uncertain world clouded with

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risks. While most scientific studies are aimed at adjustments in the final product — slaughter beef — this paper is an attempt to alleviate the risk and uncertainty in feedlot industry by concentrating upon the input side of the production equation. Choosing the correct kind of cattle to feed can be a problem for the Southwestern cattle feeder. There are many different breeds, sizes, weights, and sexes available for feeding. This variety represents the first kind of risk that the cattle feeder faces. The second kind of risk is more subtle. Since the feeder cattle that are available come from across the country and since the prospective purchaser is not physically present when the cattle are offered for sale, the purchaser must rely upon verbal descriptions for his evaluation of the feeder cattle. The descriptions found throughout the country are not always isomorphic with the cattle themselves. Further, there is no systematic and complete set of feeder-cattle descriptors that are based upon traits predictive of feedyard performance.

The objective of this paper is to explore the feeder-cattle information system. This is accomplished in four basic steps: 1) a survey of the existing system is made to discover both the underlying trends and the informational noise that presently exist; 2) the opinions of Arizona cattle feeders about the system and the frequency of its use are determined through a random stratified sample; 3) the paper constructs an efficient, semantically sound set of descriptors that partition feeder cattle on the basis of traits predicting their future feedyard performance; and 4) a price simulation is performed using realistic historical data that attempts to test the efficiency of the proposed feeder-cattle descriptive system. Hopefully, by close attention to the input side of the production equation, some of the risk accompanying cattle feeding will decrease and profitability will increase.

TELETYPE FEEDER-CATTLE INFORMATION SYSTEM

Feeder-cattle market information is made available to the public by means of radio, press, television, mail, teletype, and telephone. The information collected from any one market or market area flows to the Southwestern cattle feeder in a generalized pattern depicted in Figure 1. The two major means of communication are the teletype and telephone. The telegraph is a more formal approach that gives basic daily and weekly summary information on supply and demand. The leased wire and radio system of the market-news services is shown in Figure 2. The telephone is a more informal, but crucial, link between the market and prospective buyers and sellers. Over the phone, order buyers can discuss in detail the

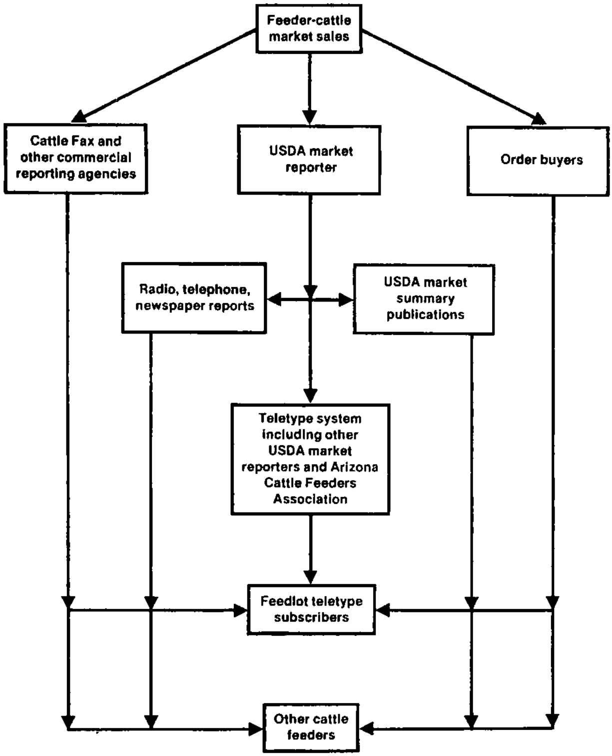


FIGURE 1. FLOW OF FEEDER-CATTLE INFORMATION

cattle currently offered for sale prior to the execution of any purchase orders. While being unsystematic in the presentation of information, the telephone market link compensates with information crucial to the purchase of any one lot of cattle.

In 1974, the Arizona Cattle Feeders' Association (ACFA) instituted a teletype information service that is linked to the system depicted in Figure 2. The ACFA's service carries the U.S. Department of Agriculture's livestock news reports, Cattle Fax marketing service, and current quarter-hourly futures prices in livestock and foodstuffs. Either by a telephone call to the association's office or by direct printout at some of the larger feedlots, up-to-the-minute reports on Arizona and U.S. cattle sales are available. Currently there are 25 teletype terminals in major Arizona and southern California feedyards. The subscribers are listed in Table 1 and consist mainly of the largest feedlots where placements usually are in excess of 25,000 head per year.

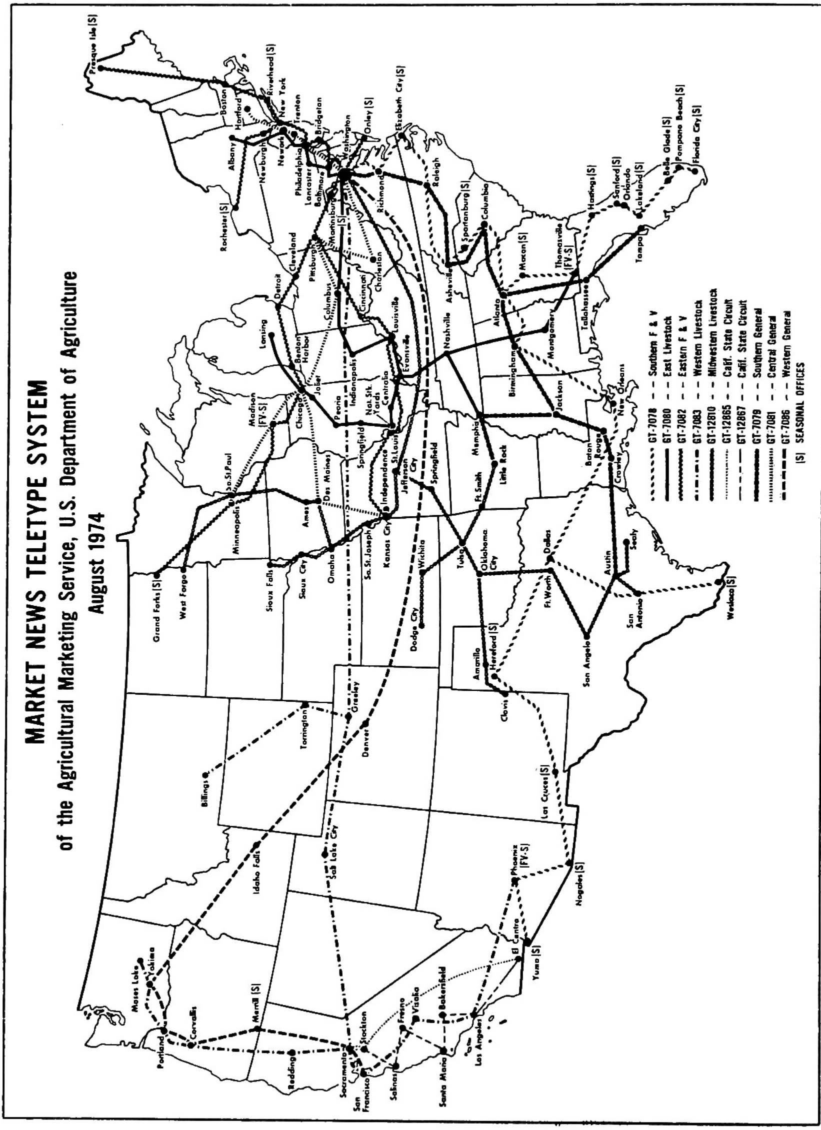


FIGURE 2. MARKET INFORMATION SYSTEM

TABLE 1
SUBSCRIBERS TO THE ARIZONA CATTLE-FEEDERS' ASSOCIATION'S TELETYPE INFORMATION SERVICE (DECEMBER, 1976)

Arizona
Red River Feed Yard (Red River Land Co.)
Hughes and Ganz Feedlot (Arizona-Colorado Land & Cattle Co.)
— Queen Creek feedyard
— Phoenix office
McElhaney Cattle Co.
Spur Industries (Santan feedlot)
Circle One Livestock Co.
Pinal Feeding Co.
Benedict Feeding Co.
Clayton Livestock Co.
Producers Livestock Marketing Association
Lazy T-7 Cattle Co.
Arizona Feeds
C & E Cattle Co.
T & C Feeding Co.
Cowden Livestock Co.
Clements and Norton Feeding Co.
Southern California
Alamo Cattle Feeders
Central Valley Feed Yard
Colorado River Feed Yard
Fairlane Feeding Corp.
Orita Land & Cattle Co.
San Pascal Land & Cattle Co.
Skiles Cattle Co.
Stockman's Club of the Imperial Valley
3-D Cattle Co.
Clements and Norton Feeding Co. (Blythe feedlot)

Informational Noise in Teletype Reports

The Arizona Cattle Feeders' Association was contacted to obtain the daily market reports from their teletype information service. The objective was to sample the incoming information on feeder cattle available for placement in Southwestern feedlots. Two typical reports can be seen in Table 2. The report begins with the city of the report's origin and date. The next item to be printed is the name of the market site or the title of the special report. For example, the topic of the Greeley report is the Winter Livestock Commission Company's auction at La Junta, Colorado. Similarly, in the Amarillo example, the weekly summary is given. A list of the states, sites of report origins, market places, and special reports encountered in our sampling is given in Table 3. The next informational unit is the gen-

TABLE 2

EXAMPLES OF FEEDER-CATTLE MARKET-NEWS REPORTS

GREELEY, COLO AUGUST 25, 1976 FED-STATE

WINTER LIVESTOCK COMMISSION COMPANY — LA JUNTA, COLO — CATTLE AUCTION TUESDAY, AUGUST 24, 1976

SALE VOLUME 1153; WEEK AGO 1436: YEAR AGO 2092.

AT AUCTION — ALL CLASS STEADY EXCEPT SLAUGHTER COWS STEADY TO 1.00 LOWER. STEER YEARLINGS 19 PCT OF SUPPLY, HEIFERS 30 PCT, CALVES 49 PCT, COWS 17 PCT, BULLS 3 PCT.

FEEDER STEERS — PACKAGE CHOICE 560 LBS 38.75, PACKAGE 670 LBS 40.30, GOOD AND CHOICE 525-750 LBS 37.25-38.10, GOOD 500-650 LBS 34.25-36.25.

FEEDER HEIFERS — CHOICE 525-575 LBS 35.00-35.80 625-650 LBS 35.70-35.80 35.70-35.80, GOOD AND CHOICE 500-700 LBS 32.00-35.00, GOOD ALL WEIGHTS 28.25-32.00, AGED HEIFERS 700-900 LBS 25.00-29.50.

STEER CALVES — CHOICE 300-375 LBS 43.75-44.00, 425-450 LBS 40.00-41.50.

HEIFER CALVES — CHOICE 300-400 LBS 36.00-38.00, 400-475 LBS 34.00-36.75, GOOD AND CHOICE 300-475 LBS 31.50-35.10, GOOD ALL WEIGHTS 28.00-31.50.

AMARILLO, TEXAS AUGUST 25, 1976 FEDERAL STATE
AMARILLO LIVESTOCK AUCTION SUMMARY AND WEEKLY 51
SALABLE RECEIPTS: 9,196 LAST WEEK: 8,564 LAST YEAR: 4,810

COMPARED TO LAST WEEKS CLOSE: TRADE MODERATELY ACTIVE, DEMAND GOOD BOTH DAYS. FEEDER STEERS FIRM TO 1.00 HIGHER, HEIFERS STEADY TO 1.00 HIGHER. SLAUGHTER COWS CLOSED STEADY TO WEAK AFTER REGAINING MONDAYS DOWNTURN. LIMITED SUPPLY SLAUGHTER BULLS STEADY TO 50 HIGHER, SALES RECORDED ON TUESDAY. RECEIPTS MAINLY GOOD AND CHOICE 400-800 LB FEEDER CATTLE AND CALVES, LIBERAL SHOWING CHOICE FEEDER STEERS 500-850 LB

ON OFFER MONDAY. SLAUGHTER COWS AND BULLS AROUND 5 PERCENT OF TOTAL SUPPLY

FEEDER STEERS: CHOICE 250-400 LB 38.00-43.50, CLOSING 39.75-43.50, FEW LOTS TO 45.00 TUESDAY. CHOICE 400-500 LB 39.00-43.25, 500-600 LB 38.00-40.00, LOT 508 LB 40.70, 600-700 LB 38.00-40.00, 700-850 LB 38.00-39.75, MIXED GOOD AND CHOICE INCLUDING BULLS 250-400 LB 36.00-40.00, 400-650 LB 36.00-38.50, GOOD 475-650 LB HOLSTEINS 28.50-31.00, LOT 817 LB 32.00. MIXED GOOD AND CHOICE 450-650 LB BULLS 33.00-36.50.

FEEDER HEIFERS: CHOICE 250-400 LB 32.00-35.00, 400-500 LB 32.00-34.00, 500-600 LB 31.00-34.60, CLOSING 32.50-34.60, 600-800 LB 32.50-35.00, COUPLE LOTS 696-705 LB 35.50-35.80. MIXED GOOD AND CHOICE 250-400 LB 29.00-32.00, 400-600 LB 29.25-32.50, 600-750 LB 29.00-33.25.

eral tone of the market including the supply-and-demand situation. Finally, the general classes of the feeder cattle sold, grade descriptors, weight ranges, and price quotations are given.

Although the two examples seen in Table 2 appear to be equivalent in form, there are some subtle differences in the way cattle are described. Note that the Amarillo market reports very lightweight (250 to 400 pounds) Choice animals as "steers," while in Greeley these animals of similar weight and grade are called "calves." In all likelihood, these animals would be identical in respect to grade, weight, age, and sex; but the information communicated via the teletype printout does not contain sufficient data for this determination as the term calf refers to an age class while the term steer refers to a sex class. Conceivably these animals could be of different ages and sex, while being similar in weight and quality grade.

The Greeley and Amarillo reports were chosen specifically because of their similarity. Yet a small disjunction in the use of feeder-cattle descriptors between the markets has caused noise and uncertainty that need not be present. If we look at the reports from all of the markets, we can see, as in Table 4, each market reporting with a slightly different terminological system. In short, each market reported the sale of feeder cattle at inconsistent quality grades and weight ranges. This informational noise vastly increases the difficulty of equating value and price between regional markets of cattle unseen by the prospective buyer.

The lists of quality descriptors found in Table 5 are particularly descriptive of the noise confronting the interstate purchase of feeder cattle. First, the noise consists of a large number (134) of highly subjective categories giving the superficial appearance of uniqueness. For example, what is the difference between Choice, Some Prime, and Choice, Few Prime? If we characterize the data by state (Table 4), we can see the interstate disparity in use. Although the mean number of descriptors per state is 9.6, the range is from 55 to 2. How can a prospective purchaser of feeder cattle make rational decisions when confronted by this noise and confusion? Of course, one answer to this question is the use of the informal person-to-person telephone communication, which we will discuss more later in this paper.

As we look closer at the descriptors, certain grammatical and semantic patterns emerge that greatly simplify the information system. We shall save an in-depth discussion of these patterns until later in the paper and shall now view only some very simple patterns. For example, the descriptor Choice, a USDA grade name, appears 29 times in 35 market cities. Other indicators of the degree of muscling (fleshy, thin, etc.) appear in 37 of 134 descriptors. Terms indicating frame size and sex class are also present.

TABLE 3
FEEDER-CATTLE MARKETS SAMPLED IN TELETYPE SURVEY

State	City of Origin	Report Title
Arizona		Arizona Direct
	Phoenix	Feedlot and Range Trade
California		California Direct
	El Centro	Southern California Area Feedlot Sales Weekly Summary
	Los Angeles	Feedlot and Range Sales (weekly)
	Martinez	California Feedlot and Range Sales
	Redding	Red Bluff Livestock Auction
		North California Feedlot and Range Sales
		Shasta Livestock Auction
	San Francisco	Central Coast Counties' Feedlot and Range Summary, California Feedlot and Range Sales
	Stockton	Stockton Livestock Market
		Northern San Joaquin and Southern Sacramento Valley and Coastal Area Range and Feedlot Summary
		Northern San Joaquin and Southern Sacramento Valley Direct cattle sales
	Visalia	Northern San Joaquin and Southern Sacramento Valley
		Western Stockman's Market of Visalia
Colorado	Brush	Brush Livestock Commission Co.
		Livestock Exchange
	Ft. Collins	Farmers and Ranchers Livestock Commission Company
	Greeley	Greeley Producers' Feeder Cattle Auction
	La Junta	La Junta Livestock Commission Co.
		Winter Livestock Commission Co.
		A Weekly Review of Selected Colorado Cattle Auctions
	Sterling	Sterling Livestock Commission Co.
Florida		Florida Cattle Auctions
		Florida Cattle and Calves
		(for markets at Lakeland, Madison, Okeechobee, Webster)
Georgia		Georgia Cattle Auctions
Iowa	Sioux City	Weekly Feeder Cattle Summary
		Knondaz Feeder Auction

TABLE 3 (cont.)

State	City of Origin	Report Title
Kansas	Wichita	Feeder Auction
	Dodge City	McKinley-Winter Feeder Cattle Auction
		Garden City Feeder Cattle Auction in Garden City, Kansas
Minnesota	South St. Paul	Daily Midwest Livestock Summary
		Feeder Cattle Auction
Missouri		Central Missouri Livestock Auction
	Kansas City	Weekly Feeder Cattle Summary
	St. Joseph	
Montana	Billings	Billings Livestock Commission Co.
		Public Auction Yards
		Montana Feedlot and Range Sales
Nebraska	Ericson	Ericson Livestock Commission Co.
	Grand Island	Grand Island Livestock Auction, Inc.
	Norfolk	Norfolk Livestock Auction, Inc.
	Omaha	Feeder Cattle Auction
		Lexington Livestock Market
New Mexico	Clovis	Clovis Livestock Market
		Ranchers and Farmers Livestock Auction Co.
North Dakota	West Fargo	
Oklahoma	Oklahoma City	Feeder Cattle Auction
Oregon	Portland	Oregon Feedlot and Range Sales
South Dakota	Sioux Falls	Semi-Weekly Feeder Cattle Auction
Texas	Amarillo	Amarillo Livestock Auction Summary Weekly
		Amarillo Livestock Auction Report
		Texas Panhandle and Western Oklahoma Range and Feedlot Weekly Summary
	Fort Worth	
	San Angelo	Cattle and Calf Auction
	San Antonio	Weekly Livestock Review
		Northeast Texas Livestock Auction Sulphur Springs, Corsicana, Madisonville, Terrell
		Central Texas Livestock Auction Brenham, Giddings, Lampasas, El Campo
		Bjenham Cattle Auction
		Giddings Cattle Auction

TABLE 3 (cont.)

State	City of Origin	Report Title
Utah	North Salt Lake	Idaho, Utah, Eastern Nevada Feedlot and Range Sales Producers' Livestock Auction in Salina, Utah
Washington	Moses Lake	Quincy Livestock Commission Washington Feedlot and Range Sales Moses Lake Livestock Auction Stockland Livestock Exchange, Inc.
Wyoming	Torrington	Torrington Livestock Commission Co. in Torrington, Wyoming Sandhills Feeder Cattle Association Sale at Sioux County Livestock Auction Co. at Harrison, Nebraska Alliance Livestock Auction Co. in Alliance, Nebraska Lusk Livestock Exchange, Lusk, Wyoming Wyoming-Western Nebraska and Southwestern South Dakota Weekly Feedlot and Range Sales Summary Stockgrowers Livestock Auction Worland, Wyoming Wyoming-Western Nebraska Direct Sales Report

At the other extreme, 91 distinct miscellaneous descriptions appear only once.

Some Reasons for the Variance in Feeder-Cattle Descriptions

Enumerating the exact causes of the variance in descriptions is very difficult because of the lack of historical information on the subject. We can, however, identify some underlying reasons for this variance, but no one reason can explain everything. Some of the factors we shall be looking at are: state cattle-herd size, federal grading system, regional tradition, and reporting style.

HERD SIZE

State herd size might be a partial explanation for the interstate classificatory disparity found in the feeder-cattle information system. The basis of this relationship is very simple. The more cattle a state has, the more likely the same state would have divergent cattle types and breeds. Table 6 demonstrates this relationship. For example, the two states that have the largest number of unique descriptors (Texas and Missouri) also have the

TABLE 4
SUMMARY OF DESCRIPTORS USED IN SELECTED STATES

	Twenty-five Most Frequently Used Descriptors[a]																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total/others	Totals
Arizona			X	X																							2
California	X	X	X	X			X											X	X								7
Colorado	X	X	X				X				X								X				X			4	11
Florida	X	X						X																			3
Georgia	X	X						X																			3
Iowa	X		X			X			X																	3	7
Kansas	X	X	X	X	X			X				X	X						X							5	14
Minnesota	X	X	X			X	X																			1	6
Missouri	X	X		X	X		X		X						X	X	X		X	X	X			X	X	41	55
Montana		X		X	X					X												X				1	6
Nebraska	X																									2	3
New Mexico	X	X		X		X																					4
North Dakota	X																									2	3
Oklahoma	X	X		X								X														2	6
Oregon	X								X					X													3
South Dakota	X	X		X	X	X							X							X						3	10
Texas	X	X	X	X	X	X		X		X							X	X			X					7	18
Utah	X	X					X					X														3	7
Washington	X	X		X		X	X			X		X							X							6	14
Wyoming	X		X			X									X		X									5	10
Totals	18	14	8	10	5	7	6	4	3	3	1	4	2	1	2	1	3	2	5	2	2	1	1	1	1	85	192

[a] See Table 5 for a list of the descriptors.

TABLE 5

QUALITY DESCRIPTORS REPORTED AT SELECTED FEEDER-CATTLE MARKETS

1. Choice
2. Good
3. Good and choice
4. Mixed good and choice
5. Mostly choice
6. Choice and prime
7. Standard and good Holsteins
8. Standard
9. Choice, fleshy
10. High choice and prime
11. Choice, some prime
12. Choice, few prime
13. Mostly good Holsteins
14. Choice, thin fleshed
15. Choice to prime
16. Good to low choice
17. Mostly good
18. Standard and good
19. Fleshy
20. Fleshy and partly fattened
21. Good and low choice
22. Mixed choice and prime
23. Aged
24. Part choice, some prime
25. Mostly thin and moderately fleshed
26. Mostly choice, few good
27. Standard and low good
28. Mixed good and choice fleshy
29. Low good
30. Good and few choice
31. Good Holsteins
32. Short-bodied exotic crossbreed
33. High good and choice, thick moderately fleshed
34. Choice moderately fleshed
35. Choice rather fleshy
36. Mostly choice to prime
37. Grain fed aged
38. Grain fed
39. High standard, low good
40. Standard Holsteins
41. Utility Holsteins
42. Bulk choice
43. Choice and mixed good to choice
44. Mostly choice thin and moderately fleshed
45. Choice framey
46. Fleshy and early maturing
47. Mostly choice moderately fleshed
48. Mostly standard Holsteins
49. Few prime
50. String high choice
51. Hay feed
52. Standard to mostly good Holsteins
53. Very fleshy
54. Mostly choice fleshy
55. High good and choice, thin and moderately fleshed
56. Choice, few good
57. Good and rather fleshy
58. Framey
59. Moderately flesh and fleshy
60. Moderately fleshed
61. Holsteins
62. Fleshy or early maturing
63. Late maturing
64. Choice including prime
65. Choice including few prime
66. High good and choice
67. Thin fleshed
68. Mostly good thin and moderately fleshed
69. Late maturing
70. Good with end choice
71. Mixed good and choice thin
72. Good thin
73. High choice
74. Moderately fleshed choice and prime
75. Thin to moderately fleshed choice and prime
76. Choice and prime mixed color crossbreeds
77. Small end choice, standard and low good
78. Choice with prime end
79. Choice and high choice thin
80. High choice, few prime
81. Black white-faced, moderately fleshed
82. Partly fattened

TABLE 5 (cont.)

83. Good thin and moderately fleshed Holstein
84. Good and choice thin and moderately fleshed
85. Thin and moderately fleshed
86. Early maturing or mixed crossbreeds
87. Baby calf
88. High good and choice thin and moderately fleshed
89. Choice moderately fleshed, fleshy and partly fattened
90. Thin big-framed
91. Thin
92. Choice thin and moderately fleshed
93. Framey black white-faced
94. Framey moderately fleshed
95. Fleshy or short-bodied
96. Choice mature steer
97. Mostly choice, few prime
98. High standard and good
99. Standard and good dairy breed or crosses
100. Reputation steers
101. Few good including Holstein
102. Mostly low choice
103. Good to mostly choice
104. Odd head good
105. Odd head choice
106. Standard and good thin
107. Standard and low good Holstein
108. Good, largely Holsteins
109. Mixed good and choice moderately fleshy
110. Green
111. Green choice and prime
112. Fairly fleshy
113. Choice rather thin
114. Mostly choice thin
115. Two-year-olds off grass, Montana
116. Choice with end off prime, moderately fleshy
117. High choice and low prime
118. Early maturing
119. Choice and prime thin
120. Reputation calves
121. Choice partly fattened
122. Stretchy
123. Largely choice
124. Low choice thin
125. Choice, usually fleshy
126. Mixed choice
127. Tending thin
128. Black white-faced, short couple fleshy
129. Choice moderately fleshed to fleshy
130. Mixed good and choice Holsteins
131. Fleshed choice and prime
132. Good and choice Holsteins
133. Cross-breed
134. Mixed good and choice Holsteins

largest number of calves. To further test the relationship between the number of feeder cattle available for sale and the number of descriptors used per state, a least-square regression was computed. The curvilinear equation, $lnY = 1.41 + .3017X$, where lnY is the natural log of the number of descriptors and X the number of the state calf herd on January 1, 1975 (ERS, 1976), had a slightly better fit than a simple linear equation. Only a weak positive relationship existed with Pearson product-moment coefficient of .479 which explained only 23 percent of the data.

USDA GRADES

The most commonly used descriptors were those found in the USDA's feeder-cattle grading system. These are the grade names Prime, Choice, Good, and Standard. The most important single criteria used in the determination of these grades is conformation, which is determined by appraising the development of the cattle's muscular system in relation to its skeletal system. Unfortunately, cattle are purchased in lots and not by single animals. This contributes to classificatory difficulties by the addition of combinational problems. For example, single grade lots might only contain 80 to 90 percent of the specified grade. Mixed categories such as Choice and Good might contain approximately equal numbers of each. To get an idea of the frequency of grade mixing as well as the use of USDA grades, look at Table 7. This table contains a rank ordering of the occurring combinations of government grades. Some combinations, especially those containing the grade Prime, did not occur. Approximately 65 percent (88 of 134) of the descriptive phrases mentioned the grade names but over 54 percent (45 of 88) of the reported lots having USDA grades contained more than one quality grade of cattle.

Table 7 leaves out one important aspect in the problem of grade mixture as it does not specify the degree or extent of mixture. On the other hand, Table 8 contains a collapsed list of the combinational descriptors found in our samples. Note that Table 8 also presents the probable percentage of the grade mixtures. Almost 55 percent of the phrases indicated mixture, while only 36 percent were sufficiently homogeneous so that mixtures did not need to be mentioned by the market reporter. This clearly demonstrates the problems of purchasing a lot of feeder cattle whose composition is made up of a single grade. This also indicates the difficulty of basis calculation and delivery in fulfillment of a hedged futures contract.

As far as the feeder-cattle information system is concerned, only three

TABLE 6
RANK ORDERING OF FEEDER-CATTLE DESCRIPTORS AND CALVES ON FARMS BY SELECTED STATES

State of Report Origin	Number of Descriptors	Calves on Farm 1975 (Millions)	Rank Ordering by Number of Calves
Missouri	55	2.84	2
Texas	18	6.00	1
Washington	14	.53	17
Kansas	14	1.88	7
Colorado	11	1.02	12
South Dakota	10	2.10	6
Wyoming	10	.76	14

TABLE 7

RANK ORDERING OF THE USDA GRADE COMBINATIONS FOUND AMONG THE LIST OF FEEDER-CATTLE QUALITY DESCRIPTORS

Grades	Frequency of Use	Percentage of Total
Choice	25	18.5
Prime and choice	19	14.1
Choice and good	19	14.1
Good	12	9.0
Good and standard	9	6.7
Standard	3	2.2
Choice and good and standard	1	.7
Totals	88	65.3
Mean	12.57	9.47
Standard Deviation	8.90	6.68

categories are necessary for the description of combinational problems. These three replace the more than 10 that are presently used. The first term would be the simple grade description such as Choice or Good. These terms would describe the condition when more than 80 percent of the cattle in the lot are of a single grade. The second term, Mostly, would indicate that a lot is made up of 60 to 80 percent of a single grade with the balance being of either a higher or lower quality. As the minority grade would also have to be mentioned, the combinational category of Some, Few, and so on, as found in Table 8 would be placed in this second category. An example of this would be the descriptive phrase, Mostly Choice, Some Good. The third and final combinational descriptors, Mixed or And, would indicate the condition when the grade mixture is roughly

TABLE 8

COMBINATIONAL DESCRIPTORS FROM SELECTED MARKETS

Combinational Descriptor	Possible Mixture (Percentage)	Number of Descriptors	Percentage of Total
Single grade (No mixture mentioned)	80	49	36.3
Mostly, largely	60–80	17	12.6
Mixed, and, to, or	50	43	31.9
Some, new, with end, part, including	20–30	14	10.4
Not applicable		12	8.9

equal. The respective relative percentages of combinational descriptors for these three categories are 29.8, 25.2, and 35.0. Since the division between the three combinational descriptors is approximately equal, an efficient partition of the set is indicated.

Regional Traditions and Graphical Connections

Regional history and tradition can also have a small effect upon the terms used in describing feeder cattle. Since historical data are not available on the development and use of descriptors, we will assume here that spatial proximity of similar descriptors indicates a historical connection. In simple terms, if two adjoining states use similar terms, they will be considered as being historically related. To evaluate this hypothesis, we set up two tests comparing the number of descriptors found in common within multistate cattle-feeding regions as well as those found between markets of each state.

Six multistate cattle-feeding regions were set up in Table 9 on the basis of geographical and market proximity. On the average, only about 38 percent of the descriptors were found in common within the regions as a whole. But the range was from 0 percent, or none in common, to 100 percent where descriptors were found within a region. The southeastern region, having the highest percentage, is also the region which has undergone the fastest development in the past few years. Another region, the High Plains, had almost 48 percent in common.

In Table 10 we examine the within-state variation of feeder-cattle descriptors. Only five states were found to have more than one city of report origin. We found that the mean number of descriptors found in common between cities of report origin was a low 37 percent.

TABLE 9
QUALITY DESCRIPTORS UTILIZED WITHIN MULTISTATE REGIONS

Regions	Mean Number of Descriptors Per State	Number of Descriptors in All States of the Region	Percentage
Pacific Northwest	5.5	1	18.0
Mountain states	5.2	0	0.0
High Plains	6.3	3	47.6
Northern Plains	5.7	1	17.5
Southeast	3.0	3	100.0
Arizona, California	4.5	2	44.4
Mean	5.04	1.67	37.96

TABLE 10
QUALITY DESCRIPTORS UTILIZED WITHIN STATES HAVING MORE THAN ONE CITY OF REPORT ORIGIN

States	Mean Number per City of Origin	Number of Descriptors Found in All Cities of Origin with the State	Percentage
California	2.2	1	44
Kansas	6.0	4	67
Missouri	9.3	0	0
Texas	5.5	2	36
Mean	5.76	1.75	36.75

STYLE

Reporting style can be measured in a number of different ways. Here we shall be measuring it as the variation within the market-reporting cities of the quality descriptor use. For example, Redding, California, is the city of report origin for two markets at Red Bluff and Shasta, but if we look at the way descriptions are made in these two markets, we find that they both use the same three descriptors. Hence, the style of the reporting is similar between the two markets. Although there might possibly be less variance in the kind of cattle found between two closely connected markets, still the mean percentage in common is about 58 percent or over 1.5 times as high as that found within region or state boundaries (Table 11). This points to the market reporters and their nonstandard descriptions as a source of the confusing information in the feeder-cattle teletype system.

This section is an analytical and objective discussion of the feeder-cattle information system in which the communicatory noise can make the purchasing decisions of cattle feedlot operators unnecessarily complex. In the next section we will look at the final link in the communicatory chain, the feedlot operator. In the final analysis, his opinions and use should carry the most weight in the evaluation of the information system.

ARIZONA CATTLE FEEDERS

Southwestern cattle feeders purchase their animals from an L-shaped region which includes western and southern states from the Pacific Northwest to Georgia and Florida. The flow of feeder cattle is from the calf and stocker production states to the cattle-feeding areas and finally to the major consumption centers. The interstate highway system and large capacity trucks now account for more than 97 percent of the shipments

TABLE 11
VARIATION OF QUALITY DESCRIPTORS WITHIN REPORTING CITIES HAVING MORE THAN ONE MARKET LOCATION

Cities	Mean Number of Descriptors Used per Market	Number Found in Common between Markets	Percentage
Redding, California	3.0	3	100.0
San Francisco, California	1.0	1	100.0
Stockton, California	1.7	1	59.9
Greeley, Colorado	5.1	3	58.3
Fort Worth, Texas	3.5	1	28.6
San Antonio, Texas	4.5	1	22.2
North Salt Lake City, Utah	2.5	1	40.0
Moses Lake, Washington	4.3	1	23.1
Torrington, Wyoming	7.0	0	0.0
Sioux City, Iowa	4.0	3	75.0
Dodge City, Kansas	7.0	5	71.4
Clovis, New Mexico	4.0	4	100.0
Billings, Montana	4.0	3	75.0
Mean	3.97	2.08	57.96

(Gustafson and Van Arsdall, 1970). Governmental control and regulation have stabilized the costs. Furthermore, these costs can affect the shipments from region to region (Kibler, 1976). Even though these costs play a crucial role, the uncertainty of price variability associated with them is low.

Arizona cattle feeders are no exception to this standard pattern. First, after considering all the possibilities in the form of cattle from Los Angeles and southern California shipped to the beef-deficient market, they have calculated that the cattle feeder can save more by purchasing feeder cattle in Texas, feeding them in Arizona, and then shipping the finished product to California (Kibler, 1976). This is remarkable considering the fact that Arizona is deficient not only in the production of feeder cattle but also in the production of the grain necessary for feeding. Nearly all of the basic resources necessary for the feedlot's operation in Arizona come from outside the state. This shows the importance of transportation costs and the reasons why the Arizona Cattle Feeders' Association was engaged in lobbying and administrative hearings which led them to the successful reduction of grain shipping rates from the Panhandle regions of Texas and Oklahoma.

But the transportation costs are fixed and known for any single period of time which minimizes the risk and uncertainty associated with them.

On the other hand, although the current costs of the feeder-cattle input are also known via the information system, the quality of the feeder cattle for which the price quotes are given is unknown. The descriptions found in the system obfuscate the predictive performance in the feedyard. This complicates not only the efficient price valuation of the animals, but the calculation of the basis with which the feeder cattle may be hedged on the futures exchange as well. In short, the feeder cattle are purchased sight-unseen on the basis of descriptions from the information system. If a unified description system of feeder cattle can be developed which predicts feedyard performance, then much of the uncertainty and risk can be eliminated from the interstate purchase of animals destined for finishing in the feedlot.

Cattle Shipments in Arizona

Arizona again possesses a typical shipment pattern where feeder cattle are shipped both in and out of the state. The reason for this peculiar pattern rests in the fact that feeder cattle produced in the state are not of the type desired by the in-state feedlot operations. The shipment of calves and feeder steers from Arizona is similar to the shipments from the Plains States to the Corn Belt. In the Plains States, feeder cattle from the British breeds are produced and shipped to the Corn Belt feedlots (Gustafson and Van Arsdall, 1970) where there is a preference for these breeds. On the other hand, shipments of different quality grades, normally Okie[1] or other mixed breeds from the southeastern states, replace the feeder cattle that are destined elsewhere. The reason behind this seemingly illogical movement lies in the preferences of the Northern cattle feeders for the British breeds and in the excellent performance in southwestern feedlots of the mixed breeds. Furthermore, the major markets in the Southwest, including southern California, have a preference for these animals which grade typically at Low Choice. Thus the inshipments and outshipments have been profitable.

The magnitude of this movement in Arizona can be seen in the state cattle and calf inventory of 1975 (ERS, 1976). Arizona had a calf crop that year, after adjustments for deaths, of 291,000 head. Of these, 27 percent were shipped out of state. Past destinations indicate that these calves went to the states of Utah, Wyoming, Colorado, and New Mexico (Menzie and Gum, 1971). The inshipments, on the other hand, were

[1] "Okies are beef cattle of mixed breeding, including some dairy but no noticeable Brahma or Charolais blood. Their mottled coloring reflects their mixed ancestry. They vary in quality from Choice to plainer feeders and are mainly Southern in origin." (Gustafson and Van Arsdall, 1970)

880,000 head and probably came mainly from Texas and the southeastern states. Instead of going to the smaller feedyards where most of the cattle go in the Corn Belt states, 87 percent of the inshipments went to Arizona feedlots with capacities in excess of 16,000 head per year. In 1974, there were only about 20 feedlots in Arizona which had that large of a capacity (Archer, 1976). Even without considering the attrition rates which reduced the number of feedlots by one-third last year alone (Newell, 1977), 75 percent of these large-capacity operations (15) were intimately involved in the feeder-cattle information through the placement of a teletype on their premises. These firms are listed in Table 1.

The above characterization of the feedlots in Arizona shows that the state is an ideal location for the study of the impact of the feeder-cattle information system. First, a large amount of cattle are shipped into the state for finishing. Second, these cattle are purchased sight-unseen on the basis of verbal descriptions of their characteristics. Third, the feedlots which purchase the majority of the animals are directly linked to the teletype information system. Finally, the efficiency of a small sample of purchasers is relatively great as 20 purchasing agents would account for the vast majority of the cattle placed on feed in Arizona.

With the objective being a survey of the opinions of Arizona feedlot operators concerning their use of the information system, a sample of 23 firms was drawn from the roster of the Arizona Cattle Feeders' Association. Assuming a turnover rate of two per year, the sample accounted for 78 percent of the cattle placed on feed in Arizona during 1976 (ERS, 1977). The results of the survey are found in the following sections.

Ownership of Cattle Placed on Feed in Arizona

There are three basic kinds of feedlot cattle ownership in Arizona. In the first, cattle are owned by the same firm that owns the feedlot facilities. In our sample, this category accounted for 36.2 percent of the total (see Table 12). The second category is the rancher who either raised the calves from their own breeding herds or who purchased the calves and brought them through the yearling stage with range and forage feeding. In short, they retain ownership from birth to slaughter. They accounted for 6.4 percent of the market. Although the cow-calf operator currently occupies an insignificant portion of the cattle placed on feed in Arizona, the cost reduction associated with vertical integration of cattle ownership (Farris and Williams, 1973) and the risk reduction through hedging are such that there should be an increased percentage of ownership in this category. The third category of ownership is the client investor. Although the investor owns the cattle on feed, he does not share ownership of the

TABLE 12

OWNERSHIP OF CATTLE PLACED ON FEED IN ARIZONA FEEDLOTS IN 1976

	Mean	Standard Deviation	Range	Maximum	Minimum	Total	Percentage of Total
Number placed on feed per feedlot in 1976	24,395.65	34,029.03	119,600	120,000	400	561,100	
Number owned by the feedlot firm per feedlot	8,830.44	9,727.57	33,000	33,000	0	203,100	36.2
Number owned per feedlot by rancher or cow/calf operator	1,558.70	4,641.82	21,850	21,850	0	35,850	6.4
Number owned per feedlot by investor	14,006.52	23,639.96	90,000	90,000	0	322,150	57.4

feedlot facilities. These client investors account for the majority of the cattle (more than 57 percent) placed on feed in Arizona.

Look at the range, as well as the maximum and minimum of ownership categories, in Table 12. In each of the three categories the minimums are zero, while the smallest end of the range, 21,850, is almost equal to the average number placed on feed per feedlot. This indicates the wide disparity between feedlots, each specializing in the service of their client's needs to the exclusion of other potential investors.

Arizona feedlot firms have developed two financial strategies that parallel the growth of large-capacity feedyards and the decline in the number of smaller-capacity lots (Archer, 1976). These strategies involve the ownership of the cattle which are placed on feed. The basic objective of the smaller lots with placements of less than 15,000 in 1976 is to make their profits through the conversion of feedstuffs into meat. They must pay close and constant attention to the costs of gain and of the feeder cattle. Their profits are contingent entirely upon the sale of the finished animals. The evidence of this strategy is seen in Table 13, where the smaller lots themselves own about 72 percent of the cattle placed on feed in their own lots, while client investors own only about 27 percent. On the other hand, the larger feedlots with placements equal to or greater than 15,000 head in 1976 are more directly concerned with the sale of the feedstuffs than with the sale of the finished cattle. In these larger feedyards, the ownership

TABLE 13
ARIZONA FEEDLOT SIZE AND OWNERSHIP OF CATTLE PLACED ON FEED IN 1976

Category	Mean	Standard Deviation	Total	Percentage
Smaller Feedlots[a] (n = 13)				
Number placed on feed	5,623	3,683.3	73,100	13.03[b]
Number owned by feedlot	4,046	3,231.0	52,600	71.96[c]
Number owned by rancher or cow/calf operators	77	277.4	1,000	1.37[c]
Number owned by investors	1,500	2,872.3	19,500	26.68[c]
Larger Feedlots (n = 10)				
Number placed on feed	48,800	40,518.3	488,000	86.97[b]
Number owned by feedlot	15,050	11,888.8	150,500	30.84[c]
Number owned by rancher or cow/calf operators	3,485	6,724.5	34,850	7.14[c]
Number owned by investors	30,265	28,903.9	302,650	62.02[c]

[a] Smaller feedlots had placements of less than 15,000 head in 1976.
[b] Percentage of all cattle placed on feed in Arizona feedlots.
[c] Percentage of total found respectively in small or large feedlots.

situation is exactly reversed from that in the smaller feedyards. Investors control 62 percent of the cattle, while the larger firms own only 31 percent.

The expansion of the facilities by Arizona feeders in recent years has required substantial capital. These larger firms have turned to the custom feeding of investor-owned cattle as a means of obtaining operating capital and of spreading risk. Thus, the capital obtained from the custom clients reduces the large cash and credit reserves needed to finance feeding operations. This has permitted the feedlots to expand in size and gain economies of scale. The custom feedlot also performs certain marketing-service functions such as: purchasing feeder cattle, marketing finished cattle, and arranging for or providing a client's financing (Archer, 1976).

Use of the Market-News System

The purchase of the cattle placed on feed in Arizona is concentrated in the hands of only a few individuals. This can be seen in Table 14, where the mean number of individuals per firm that keep up on the market trends and that actually make the purchasing decisions is respectively 2.39 and 1.65. This translates into 38 individuals who made the decisions leading to the purchase of over 560,000 head of feeder cattle last year. Even the investor clientele of the larger feedlots rely heavily upon the market opinions of these persons. Such a vast concentration of purchasing power offers the opportunity of market-penetration studies that can influence the attitudes and actions on the purchase and futures market hedge of feeder cattle. Although the receptivity of Arizona's cattle industry is rather poor towards the futures market, close one-to-one discussions of the usefulness and benefits derived from hedging probably could influence their opinions and actions.

TABLE 14
USE OF FEEDER-CATTLE MARKET NEWS BY ARIZONA FEEDLOTS IN 1976

	Mean	Standard Deviation	Range	Maximum	Minimum
Number of members per firm reading market news	2.39	2.37	12	12	0
Number of members per firm deciding feeder-cattle purchases	1.65	.98	4	5	1
Frequency of market-news use per week	4.26	1.42	5	5	0

In order to keep up on the current market situation, these persons in charge of purchasing read the market-news reports on feeder cattle almost daily with a mean of 4.26 days per week. However, the major source of market information in 47.8 percent of the cases is informal telephone conversations with the order buyers associated with the different regional auction markets (Table 15). This heavily indicates that the feeder-cattle market-news system is doing a mediocre job in the dissemination of information. In fact, standing second in importance as a source of news is the combination of informal telephone reports and the market news. Thus, the crucial supply-and-demand information necessary for the purchase of any given lot seems to be obtained informally over the phone, while the background information concerning the ebb and flow of the regional markets comes over the market-news service's teletype wire. Recalling the large amount of noise from the inconsistent use of the quality and grade descriptors in the feeder-cattle information system, the reports received over the telephone from the order buyers are a means of bypassing the uncertainty inherent in the system.

Further evidence documenting the system's noise and the cattle-feeder's reliance upon the order buyer as a significant source of information can be seen in the answer to a question about whether prior to purchase they calculate the best buy among several alternative markets. Although the majority indicated that they actually did do this, a significant proportion, more than 40 percent, stated that they did not. A probable reason for this apparent lack of economic rationality may be found again in the noise present in the system. The amount of noise, the discrepancy between the feeder cattle's description, and their actual physical traits, may be reduced by limiting the number of order buyers and markets the firm deals with. Thus, by repeated contacts with an order buyer and by consistently purchasing from a limited number of markets, knowledge is built up about the kind and description of cattle that are typically for sale at that market.

TABLE 15
MAJOR SOURCES OF MARKET INFORMATION

	Frequency	Percentage	Cumulative Percentage
Combination of informal phone reports and market news	10	43.5	43.5
Informal phone reports from order buyers	11	47.8	91.3
Other commercial services including Cattle Fax market summaries (market arm of ANCA)	2	8.7	100.0

The risk and uncertainty of an inefficient descriptive system is averted through personal knowledge, but this risk aversion comes at the cost of not always getting the best buy.

Industry's Evaluation of the Feeder-Cattle News System

Further evidence of the risk and uncertainty associated with the market-news system was found when questions were asked regarding the cattle feeders' attitudes toward the system. In Table 16, we can see that almost all (78.3 percent) feel that the objective of the market-news system should be the facilitation of the comparison of cattle between markets. Unfortunately they feel that, by the same percentage, this objective is not reached and that the reports do not help in making intermarket comparisons. Similarly, the Arizona cattle feeders feel that the market-news system does not play an important role in their own or their investor clients' purchases. Since, as seen above, not all feedlots engaged in custom feeding for investors, a proportion of the respondents were listed as not applicable. A high percentage (73.9) also felt that a standardization of the terms describing feeder cattle was needed between markets.

While the standardization of the descriptors was desired, the direction the industry would like the news system to develop was unclear. They have mixed opinions about the usefulness of the current USDA feeder-cattle

TABLE 16
EVALUATION OF FEEDER-CATTLE MARKET NEWS BY ARIZONA'S CATTLE-FEEDING INDUSTRY

	Agree	Neutral	Disagree	Missing or N/A
Current news reports should facilitate comparisons between markets	78.3[a]	13.0	8.7	
Current news reports do facilitate comparisons	13.0	8.7	78.3	
We depend heavily upon market reporting for our purchases	8.7	4.3	87.0	
Clients depend heavily upon market reporting	8.7	0.0	52.2	39.1
Current USDA grade categories are sufficient for evaluation	56.5	8.7	34.8	
Standardization of feeder-cattle descriptors between markets is needed	73.9	17.4	8.7	
Highly detailed descriptions of feeder-cattle sales are desirable	13.0	8.7	78.3	

[a] Relative frequency in percent.

grades with over one-third of the respondents stating that these grades were not sufficient. While they did not desire highly detailed descriptions of the feeder cattle, in open conversation most felt that an adequate system would be one which would describe the animals with traits that could predict future feedlot performance. In order to develop this thesis, the next two sections will discuss the possibility of obtaining these predictive traits.

TYPES OF FEEDER CATTLE

In the first section of this report, the reader was confronted with a disorganized, inefficient information system that could not express exactly the salient points necessary to describe feeder cattle offered for sale on the basis of traits which predict future feedlot performance. For those readers who have not been intimately involved in the livestock sector of American agriculture, even though some of the descriptors may have sounded vaguely familiar, the underlying reasons for their use might not have been thoroughly understood. Therefore, the objective of this section is to clarify the physiological and economic characteristics of the information communicated in the feeder-cattle information system. This section will also lay the foundation for improving the present feeder-cattle information system.

Sex Class

There are five sex classes of cattle placed on feed: steers, heifers, cows, stags, and bulls. The bulk of the feeder cattle are composed of steers and heifers.

STEERS

Between 1970 and 1975, steers have made up slightly over 52 percent of the total fed cattle that were slaughtered under federal inspection (ERS, 1976). There are four major reasons for their favored position: their availability, disposition, growth rate, and price premiums. Since many heifers are kept for breeding replacements in the cow herd, there are simply more steers available for purchase and feeding. Steers are also quieter in the feedlot since they do not come into heat as heifers do and are not as likely to engage in fights as bulls are.

Several studies have shown that steers outgain heifers (see Table 17). By averaging four typical feeding experiments, we see that steers gain approximately 12 percent more per day than heifers. Steers also are fed to heavier weights and contain less fat than heifers. This translates into an extra 30 pounds of trimmed retail cuts — 568 pounds (50.3 percent) for steers, and 515 pounds (49.7 percent) for heifers (Thrift et al., 1970).

TABLE 17
COMPARISON OF STEERS AND HEIFERS ON POSTWEANING AVERAGE DAILY GAIN (ADG)

Sex	Experiments 1	2	3	4
Steers ADG	1.85[a]	2.22	2.18	1.80
Heifers ADG	1.63	1.89	2.02	1.63
Difference	0.22	0.33	0.16	0.17
Mean percentage difference = 12.3				

[a] Numbers refer to pounds per day.
SOURCES: Williams et al., 1965; Bradley et al., 1966; Wilson et al., 1967; and Thrift et al., 1970.

HEIFERS

After a sufficient number of heifers are retained by producers as replacements and additions to the breeding herd, the surplus heifers are available for feeding and slaughter. An average of 25.7 percent of the cattle slaughtered between 1970 and 1975 were heifers (ERS, 1976).

Because of the biological differences between heifers and the other sex classes, certain production problems arise. The first set of problems revolve around heifer growth rates. Heifers are lighter than steers at all stages of growth including weaning and maturity. They gain weight at a slower rate than steers and require more feed per unit of gain — 961 pounds versus 865 pounds (Williams et al., 1965). They also mature earlier than steers. This indicates that heifers should be slaughtered at younger ages and lighter weights than steers before the growth rate slows as maturity is reached.

The second set of problems encountered when heifers are placed on feed is centered around reductions in their already slow rates of gain by pregnancy and estrus. The correction of these problems adds further increases in veterinary handling and yardage costs (O'Mary, 1977).

BULLS AND STAGS

Cow-calf producers have not permitted bull calves to enter the feeder-cattle market primarily because of the higher price at similar weights that steers receive. Bulls and stags together comprise only 2 percent of the slaughter cattle over the period from 1970 to 1975, but bulls have an advantage over steers in the rate and efficiency of gain. They possess a more desirable carcass from the standpoint of percent carcass to muscle composition or cutability (Field, 1971). Although some researchers have argued in favor of bull feeding because of these production advantages which include 40 percent higher average daily gain and 16 percent better feed per pound of gain conversion ratio (Champagne, 1969), bullock meat has a low consumer acceptance. The combination of price premiums for steers, low consumer demand, and increased likelihood of injury from fighting have severely limited the numbers of bullocks placed on feed.

Stags are male cattle that have been castrated after reaching an advanced state of sexual maturity. Stags are not usually produced because of the labor cost of the operation, the setback in gain performance, and the possible loss of animals from the operation. Sometimes an animal with one or both testicles remaining in the body cavity is found in a group of steers. All animals with a staggy appearance are discounted upon sale.

COWS

Cows are the final sex class of cattle placed on feed. They are not usually thought of as feeder cattle even though they have comprised just under 20 percent of the cattle slaughtered from 1970 to 1975 (ERS, 1976). Old cows are typically culled from the breeding herd when the calves are weaned. Replacement heifers are saved at this time to bring the herd to a desired level. Those cows that are just off grass that have not weaned a calf are probably in good condition and can be slaughtered as is, without further feeding. If the animal is thin from nursing, some feeding is justified. The gains made by cows must be put on cheaply. Since a large portion of their ration goes for maintenance alone, and since most of the gain is in fat rather than muscle, feed-to-gain conversion ratios are low as are profits (O'Mary, 1977).

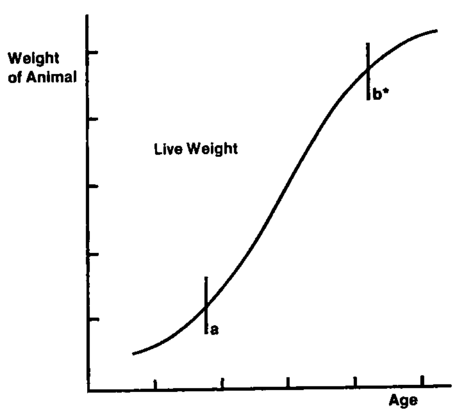
Age Groups

Feeder cattle have been classified by rather broad ranges into diffuse age groups: calves, yearlings, and other cattle. Most market reports rarely mention age as a descriptor, although it is potentially one of the crucial predictors of feedlot performance. Age is a central measure in the U.S. Department of Agriculture's proposed revision of the feeder-cattle classification but very little is actually known about it. However, as information on the growth curves of various breeds and cross-breeds becomes known through performance testing, the optimal feeding program can be instituted when the age of the animal is known. The value of knowing the age of an animal has been clearly demonstrated by experimentation (O'Mary et al., 1956). The experiment showed that, when feeder cattle were divided on the basis of previous gains, the higher group continued to gain faster than the slower-gaining group. Since the weight of an animal can be easily obtained, and if the age is known, the feedlot operator can immediately know whether the animal is a slow or fast gainer.

Although the understanding of the growth process is not complete for beef cattle, there are two general relationships that the cattle feeder must keep in mind when evaluating different age groups. First, the entire growth curve, weight as a function of time, has a characteristic sigmoid or S shape (Nelson and Purcell, 1973) but for the period during which the animals are in the feedlot, the growth curve can be closely approximated by a quadratic equation (Smith et al., 1976). The growth curve has this shape because of the rapid and efficient gains at the younger ages and conversely the slower, costly gains as maturity approaches. Second, the production of bone, muscle, and fat reaches mature levels in succeeding order; that is, bone is early-maturing, muscle is intermediate, and fat is late-maturing (see Figure 3).

CALVES

If calves are to be fed to the typical slaughter weights of 1,050 to 1,100 pounds, several things follow directly from the two growth processes mentioned above: 1) since the animal is fed over a long period of time, more feed is required per animal and capital is tied up longer; 2) since the rate of gain is the fastest when the calf is initially placed on feed, the cost of gain is lower than if it is placed on feed at a later age; 3) several ration changes are necessary to take the calf through the growing (bones and muscles) and the finishing (fat and marbling) stages; and 4) even though calves have cost more per pound than older animals over the past 20 years, the initial costs on a per-head basis are less.



*The proportion of the growth curve explained by Smith et al.'s quadratic equation is included between the lines marked a and b.

FIGURE 3. GROWTH CURVE FOR CATTLE (ADAPTED FROM NELSON AND PURCELL, 1973)

YEARLINGS

Yearling cattle have already experienced the rapid growth of the skeletal system and have a large enough frame to utilize large quantities of feed, yet they are still young enough to make rapid and efficient gains in protein (or musculature). Yearlings that perform well typically were weaned at about 6 to 7 months, and then placed on cheap, high roughage feed until they weigh about 700 pounds and are about 13 months old. Such cattle will reach market weights at about 17 to 18 months of age.

OLDER CATTLE

Older cattle are at the point in the growth curves when deceleration in the rate of gain begins. The rate of protein or muscle growth is slowing, while bone growth has stopped. Fat is added at an increasing rate but will also soon plateau. Furthermore, the amount of feed required for maintenance alone has increased faster than the amount required for gain. Although older animals have a much poorer feed efficiency, they turn capital over quickly. Cattle that have already reached sexual maturity are not fed in any great numbers. The only exception to this is the short-term fattening of culled cows mentioned above.

Weight Groups

Weight groups and age groups tend to overlap. This can easily be seen in Figures 3 and 4 where older cattle are heavier than younger cattle. Of course, management regimens can alter this pattern. A chronic lack of feed can stop an animal from reaching its potential weight. Similarly, overfeeding high concentrate rations to a calf can make it half-fat, insuring slower future gains. Since in the simplest sense, weight groups do

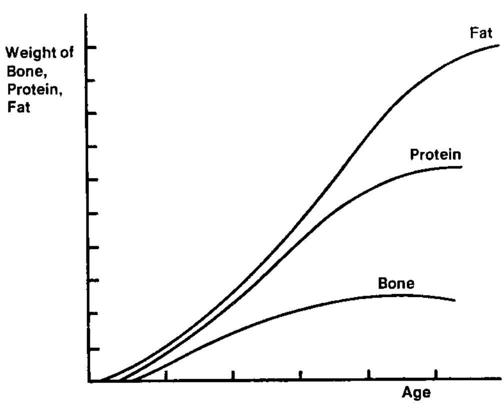


FIGURE 4. RELATIVE GROWTH OF PROTEIN, FAT AND BONE IN CATTLE

correspond closely to age groups on well-managed cattle, weight will be discussed in the context of the other categories.

Frame Size

Frame size is rapidly becoming one of the most important criteria in the evaluation of differences in feedlot performance among feeder-cattle types. The Wisconsin type study made by V. H. Brungardt (as reported in O'Mary, 1977) divided feeder cattle into seven body types categorized on the basis of the animal's height and length.

Several important production relationships exist between body type and feedlot performance. As the frame size increases, average daily weight-per-day of age, carcass weight, total feed bill, feed efficiency, and weight attaining Choice grade increase. For example, one experiment as reported in O'Mary (op. cit.) had mean percentage increases between body types 1 and 5 (where 1 is the smallest frame size) of 26 percent for average daily gain, 22 percent for weight-per-day of age, 4 percent in feed efficiency, and 27 percent in carcass weight. In general, the energetic efficiency of the feed ration required to produce units of edible beef increases as frame size increases. Fox and Black (1975) have constructed a graph comparable to the average cost curves in economics that clearly shows this energy efficiency relationship and is therefore reprinted here as Figure 5. We shall be discussing frame size as a predictor of feedlot performance in more detail as one of the three most fundamental units of information that must be communicated in the feeder-cattle information system.

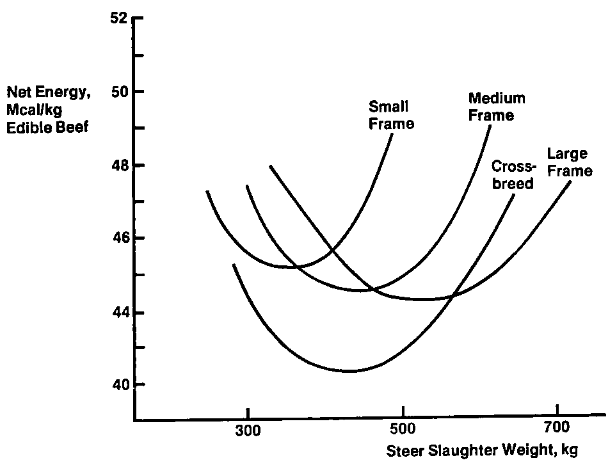


FIGURE 5. IMPACT OF STEER SLAUGHTER WEIGHT ON ENERGETIC EFFICIENCY (ADAPTED FROM FOX AND BLACK, 1975)

U.S. DEPARTMENT OF AGRICULTURE'S PROPOSED REVISION OF THE FEEDER-CATTLE GRADES

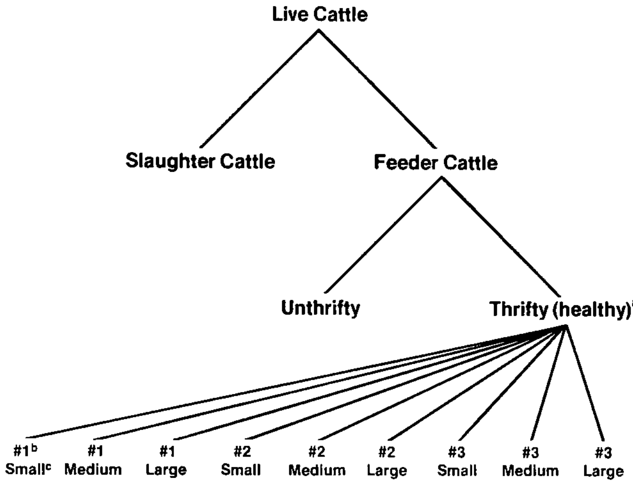
The official United States standards for grades of feeder cattle are currently undergoing change from their 1964 revision. So instead of focusing on grades that will soon be history, we shall concentrate on the proposed revision as it has considerable merits in reducing the noise in the feeder-cattle information system.

The objective of their proposed revision is to have feeder grades reflect or predict feedlot performance so that the merit of the feeder cattle can be properly described and efficiently valued in the market place. The two most important factors affecting merit or value are frame size and the degree of muscling. The U.S. Department of Agriculture therefore proposes that a dual system of grading, based upon frame size and degree of muscling, is superior to single-term classificatory systems in use today.

A tree diagram (Figure 6) of the proposed revision is included and can act as a short visual summary. Note that for live, healthy feeder cattle, the classification utilizes three major components or descriptors: sex class, frame size, and muscling (fleshiness). Recalling from the previous discussion on feeder types that each of these components has different broad general effects on the production efficiencies and meat yields, we can see the power of this classification system. The relationship of the first component, frame size, to the feed energetic efficiency and average cost curve has already been amply demonstrated. The second component, degree of muscling, correlates with the red-meat yield of the final carcass. The third component, sex class, relates to production efficiencies, final yields, and consumer acceptance. Examples of classificatory phrases used in the proposed revision include: #1 large-frame steers, #2 medium-frame bulls, and #3 small-frame heifers. Let us now discuss these components and some of the problems of implementation as well as its economic benefits.

Frame Size

The value of frame size as a predictor of feedlot performance exists in the correlation of feed-to-grain conversion ratios and the slaughter weight at which a Choice grade carcass is achieved. Large animals are generally better convertors and require less feed to put on a pound of gain than do smaller animals. Frame size is also directly correlated with the slaughter weight at which an animal grades Choice. Thus, larger cattle are better feed-to-gain convertors than smaller-framed animals but they must be fed to higher slaughter weights to reach Choice grade. Conversely, smaller-framed animals grade higher at lower slaughter weights than do larger ones. Therefore, under the proposed revision, feeder cattle are to be



[a] Sex of the animal is categorized by steers, stags, bulls, cows, and heifers.
[b] Degree of muscling.
[c] Frame size.

FIGURE 6. PROPOSED REVISION OF U.S. DEPARTMENT OF AGRICULTURE FEEDER-CATTLE CLASSES

graded relative to the live weight necessary to produce Choice carcasses. There are three classes of frame size: large, medium, and small.

We feel that frame size is a very important component in the evaluation of the performance of feeder cattle and should be included in any revision of the U.S. Department of Agriculture classificatory system. There are some important spin-offs of this system. More homogeneous groups of cattle with similar conversion ratios and similar nutritional needs can be placed in pens on the feedlot to allow better, more efficient feedbunk management with a reduction in the costs of gain. Also, categorizing feeder cattle by frame size allows the development and storage of statistical information on feedlot performance. This information can be used to more accurately predict the growth rates and feed conversion of animals placed on feed. Thus, classification by frame size can lead to more efficient management of cattle feedlots.

There is one major overriding criticism of the use of frame size in the proposed revision. Frame size is dependent upon an animal's age and breed. As an animal matures, its frame continues to get larger until physiological maturity is reached. Therefore, federal inspectors must be able to accurately judge age independent of the animal's current frame size. Frame size can vary markedly even within a breed. How would an inspector judge two animals of the same breed that are equal in size but of different ages? Unless age can be accurately guessed or certified, an improper classification of frame size will be made. With the average yearly cattle slaughter since 1970 running in excess of 32 million head, certification of age would be a monumental task. Therefore, more research is necessary to expand our common knowledge about the growth rates and frame size for all the different breeds and crossbreeds. Special indicator traits are needed for the development of quick and cheap tests. Furthermore, any federal inspectors must be thoroughly trained to judge an animal's age.

If we look closely at the industry's use of feeder-cattle quality descriptors as derived from the previously mentioned samples of daily market reports (see Table 5), we find that frame size does not occupy a share as large as it should. In fact, only 15 of 134 phrases specifically mentioned frame size. There are some possible reasons for this unexpected deficiency. Apparently, only exceptionally large or small animals were given frame-size descriptors. Possibly to decrease repetition, medium-frame feeder cattle were not reported as such. In conclusion, although the industry and scientists realize the value of frame size as a predictor of feedlot performance, the industry does not consistently use it as a descriptor.

Degree of Muscling

The second major component of the dual grading system proposed by the U.S. Department of Agriculture is the degree of muscling found in the feeder cattle. The degree of muscling in feeder cattle often correlates with the yield grade of the final carcass. Carcass yield grade is important as it indicates the relative amounts of red meat obtained from the carcass. The categories of muscling within the proposed system (#1, #2, #3), with their rough equivalence to the current U.S. Department of Agriculture feeder classes of Prime, Choice, and Good, should be able to predict for the cattle feeder the approximate yield grade his animals will attain.

The first criticism of the degree of muscling as a component of the feeder classes is an inefficient allocation of the classificatory types. Currently, the market share of Prime feeder cattle is never greater than 8 percent, yet #1 feeders occupy one-third of the possible feeder types found within the U.S. Department of Agriculture's proposed classification. A similar argument can be made at the other end of the scale. The U.S. Department of Agriculture's proposed system categorizes feeder cattle as #3 if they are neither #1 or #2. This equates the current classes of High Good with Standard-grade feeders. As an alternative, we suggest that they equate Prime and High Choice with #1, Low Choice and High Good with

#2, and Low Good and Standard with #3. This makes sense, especially here in Arizona, where we often buy Good-grade feeders and try to upgrade their quality by heavy grain feeding to Low Choice slaughter cattle (see Table 18).

Another way of evaluating the degree of muscling as a component for judging feeder cattle is to see how the industry uses the terms. Again we use Arizona State University's survey of the industry's descriptive phrases referred to in preceding paragraphs. The distribution of groups of feeder cattle by grade are: Prime (1.2 percent); Prime and Choice (21.7 percent); Choice (27.7 percent); Choice and Good (22.9 percent); Good (13.3 percent); Standard and Good (9.6 percent); and Standard (3.6 percent). If we collapse these into three categories, then the distribution is more equally divided. The new categories and their relative frequencies are: Prime and/or High Choice (26.5 percent); Choice and/or High Good (47 percent); and Good and/or Standard (26.5 percent). If this second distribution is roughly equated with the new grades of muscling, rather than the U.S. Department of Agriculture's proposed distribution, a more efficient classification results.

The industry already recognizes muscling as a valid description of feeder cattle. Of the 120 descriptive phrases found in the Arizona State Univer-

TABLE 18
FEEDER-CATTLE INDUSTRY'S USE OF TERMS DESCRIBING PENS OF FEEDER CATTLE SOLD IN MAJOR U.S. MARKETS

Proposed Categories[a]	U.S. Department of Agriculture Categories		Own Indigenous Categories	
		(Percentages)		(Percentages)
#1	Prime and/or High Choice	26.5	Fleshy	29.5
			Moderately fleshed and fleshy	4.6
#2	Choice and/or High Good	47	Moderately fleshed	22.7
			Thin and moderately fleshed	20.5
#3	Good and/or Standard	26.5	Thin fleshed	22.7
		100		100

[a] Proposed categories represents the author's attempt at a more meaningful classification to the cattle feeder than that of the U.S. Department of Agriculture's revision. By slightly lowering the U.S. Department of Agriculture's proposed revision to include High Choice within #1 and High Good within #2, the new categories reflect the feedlot's strategy of upgrading feeder cattle to a higher slaughter grade.

sity's feeder-cattle survey, 44 or 36.7 percent of the phrases contained a reference to muscling, although they used the terms fleshy, moderately fleshed, and thin fleshed instead. One suggestion would be for the U.S. Department of Agriculture to adopt the industry's terms rather than vice versa. The distribution of the terms describing groups of feeder cattle are as follows: fleshy (29.5 percent); moderately fleshed (22.7 percent); thin or thin fleshed (22.7 percent); moderately fleshed and fleshy (4.5 percent); and thin and moderately fleshed (20.5 percent). The proposed revision closely corresponds to the industry's current concepts and standards of feeder cattle and should include reference to muscling.

There is another potential problem that could arise with the use of muscling as a quality descriptor under the U.S. Department of Agriculture's proposed revision. If premium prices are associated with fleshy and overly fattened animals, firms which specialize in the backgrounding and preconditioning of calves may be tempted to overfeed and force the extra grade-boosting gain.

Calves that are overly fattened at the lighter weights and younger ages are not efficient feed-to-gain converters at the heavier weights. Thus, the potential problem exists that premium prices and higher-quality grades may sometimes be associated with animals that are poor performers in the feed yard.

The Enigma of Dairy Cattle

Throughout the entire U.S. Department of Agriculture's preliminary report, there is absolutely no reference to dairy cattle. This seems strange since there are always a few pens of Holsteins being fed in every feedlot. The market share taken by dairy cattle often equals or surpasses that of prime animals, yet their place in the proposed revision is unclear. Ten percent of the feeder-cattle descriptions found by the Arizona State University survey specifically mentioned dairy cattle. Furthermore, as they have one of the best feed-to-gain conversion ratios, and as our meat preferences continue to turn towards hamburger, dairy cattle will play a larger role in the feeding industry.

The major problem in classifying Holsteins or other large-frame dairy cattle under the newly proposed dual system is that they will probably never grade Choice at any slaughter weight. Certainly, they are large-framed animals and should be placed in that category but how do you differentiate them from other large-grade feeder cattle? For example, we in Arizona often buy Okie feeders that would grade under the revised system as #2 or #3 large-frame feeder cattle. The strategy for the purchase of these Okies is to upgrade them to Low Choice. Now as the proposed system does not specifically have a place for dairy cattle, they would be graded similarly to the Okies. Since the dairy cattle would probably never grade Choice (Radloff et al., 1973; Wellington et al., 1974), their inclusion with other large-frame animals would be a serious fault in the new system. Consequently, one possible solution to this dilemma would be to add the term "dairy" to the list of the different sexual types of feeder cattle. Thus, the new list of feeder types should be: bulls, stags, heifers, cows, and dairy.

Descriptor Summary

The U.S. Department of Agriculture's proposed revision of their feeder classification, summarized in Figure 5, is basically a valid one. Frame size and degree of muscling are two traits which can predict feedlot performance. The only two direct reservations with this system are the treatment, or lack thereof, of dairy cattle and the underrating by divisions of the degree of muscling of the upgrading strategies typically followed by southwestern feedlots. As far as the teletype information system is concerned, the weight ranges reported for the animals are probably most efficient if reported on the basis of 100-pound intervals. Furthermore, since lots of feeder cattle are not always homogeneously composed, mixtures can be described using the conjunctives in Table 8.

THE EFFICACY OF FEEDER-CATTLE INFORMATION

The preceding sections have included detailed discussions about the feeder-cattle information system. The idea of noise and its complicating effects upon the risks of purchasing cattle as well as a classification of feeder-cattle types has been presented. All this encompasses what might be called the form of the information system and represents a first step in our understanding of the system. The following section is something more than just form and structure; it represents an attempt to get at the function of the feeder-cattle information system. The function, here defined and previously alluded to, is the signaling of information about the feeder cattle that indicates and predicts the animal's feedlot performance. This should allow for efficient price evaluation in the market through a series of price premiums and discounts contingent upon the value to the feedlot operator.

Cattle at different grades, weights, ages, and frame size all convert feedstuffs into beef at different rates. These facts and the fact that prices have varied drastically over the past 20 years raise the question: Would any difference be found if the information system is partitioned in the manner suggested in this paper? The objective of this final section is to test the efficiency of the proposed feeder-cattle descriptors by a price simulation.

One way of testing the validity of the proposed descriptors would be to run a price simulation over a period of years. The prices should include the costs of the feeder cattle, the costs of obtaining the weight gains, and the prices received for the finished animals. Each price or cost should be associated with the feedlot performance and the likely price attained. For example, recall that a large-frame feeder steer converts grain into meat at a higher rate than that of a small-frame animal. This suggests that gains at any one weight are attained at less cost with the latter. On the other hand, the former animal will achieve the finished market grade of Choice at a lighter weight. Thus, the smaller animal is worth more per pound if it is slaughtered at the lighter weight than the larger animal. Table 19 contains the frame sizes and weights of the feeder and slaughter cattle utilized in this study. Note that the cumulative metabolizable energy requirements for the gain, as well as the average weight attaining Choice grade, are also listed by frame size and weight. In the price simulation in this study, if the finished cattle are not of sufficient weight to grade Choice, then they are sold at the good cattle price. These data in Table 19 are derived from a series of studies performed to analyze the performance of the different genetic breeds in all aspects of the cattle industry (Smith et al., 1976).

The USDA grade attained is very important to the determination of the final slaughter price received for cattle. Therefore, in this price simulation certain conventions are used to reflect the fact that as an animal's weight increases, the amount of fat, especially the longissimus fat, and the marbling score increases. Hence the USDA grade increases (Smith et al., 1976; Nelson and Purcell, 1973). The finished price decisions criteria, by frame size and weight, is as follows:

1. Small-frame steers are graded Choice at all weights.
2. Medium-frame steers are graded half Choice and half Good at 1,000 pounds and all Choice at succeeding weights.
3. Large-frame steers are graded all Good at 1,000 pounds, equally mixed Good and Choice at 1,100 pounds, and all Choice at 1,200 pounds.

The average ration used in this study is a standard one found in many of the Southwestern and Southern Plains States (ERS, 1977). This is termed an "average" ration because over the time span during which an animal is on feed, the ration is changed many times, typically beginning with a very high percentage of roughages and low percentage of concentrates and gradually changing until the two positions are reversed (Gill, 1972). The amount of the ration needed to obtain the gains found in

TABLE 19
FRAME SIZE, TIME ON FEED, AND CUMULATIVE METABOLIZABLE ENERGY[a]

Initial Weight	Finish Weight	Days on Feed	Average Daily Gain	Metabolizable Energy
Small frame:		(Choice grade at 1,000 lbs.)		
500	1,000	210	2.38	4,712
500	1,100	269	2.23	6,302
500	1,200	344	2.03	8,490
625	1,000	166	2.26	3,847
625	1,100	225	2.11	5,437
625	1,200	300	1.92	7,624
750	1,000	117	2.14	2,807
750	1,100	176	1.99	4,397
750	1,200	251	1.79	6,585
Medium frame:		(Choice grade at 1,050–1,100 lbs.)		
500	1,000	204	2.45	4,812
500	1,100	256	2.34	6,270
500	1,200	316	2.22	8,071
625	1,000	160	2.34	3,897
625	1,100	212	2.24	5,355
625	1,200	272	2.114	7,001
750	1,000	111	2.25	2,798
750	1,100	163	2.15	4,257
750	1,200	223	2.02	6,057
Large frame:		(Choice grade at 1,150–1,200 lbs.)		
500	1,000	171	2.92	4,105
500	1,100	216	2.78	5,375
500	1,200	268	2.61	6,945
625	1,000	140	2.68	3,447
625	1,100	180	2.64	4,717
625	1,200	237	2.43	6,287
750	1,000	98	2.55	2,495
750	1,100	143	2.45	3,765
750	1,200	195	2.31	5,335

[a] Data are derived from Smith et al., 1976.

Table 20 can be calculated by dividing the megacalories needed by the megacalories provided by the ration. Ration costs for the gain can easily be calculated thereafter by obtaining the current monthly ration costs.

Variable and fixed costs are slightly harder to calculate as they are dependent upon such factors as the size of the feedlot, death rates, weather conditions, energy prices, and current financial interest rates (Uvacek, 1977), Dietrich (1969), and Dietrich and Schake (1974) have published

TABLE 20
AVERAGE RATION FORMULATION[a]

Ingredient	Percentage	Net Energy for Maintenance	Net Energy for Gain	Contribution per Ton of Ration
Corn, No. 2[b]	35	.92	.60	1,064
Milo, No. 2 yellow	35	.87	.58	1,016
Alfalfa hay, 28-percent	20	.46	.41	248
Cottonseed meal, 41-percent solvent	10	.64	.41	210
Total in ration (90-percent dry matter)[c]				2,538

[a] The ration has been averaged over the starting, growing, and finishing phases.
[b] Net energy values are taken from Gill (1972), and Morrison (1976), and are measured in megacalories.
[c] Ration costs are inflated by 20 percent to cover all other fixed and variable costs.

data concerning costs in Texas and Oklahoma as a function of feedlot size, but the data are from one year only. Menzie and Archer (1973) and ERS (1977) have also made estimates about fixed and variable feedlot costs. The range of these studies for a feedlot with a single time capacity of about 12,000 head is from 18 to 27 percent of the ration costs. For this price simulation, a simplifying assumption will be made that fixed and variable costs are set 20 percent higher than the quoted ration costs for each lot of cattle regardless of current occupancy in the feedyard. This may have the effect of undervaluing the true costs at times, but simplifying assumptions must sometimes be made in order that analysis may proceed.

Cattle Price Predictions

Prices can vary tremendously in the cattle market. The large price variations over the time span from 1957 to 1975 for Choice-grade feeder and slaughter steers are now well-documented. Data used here were taken from the Kansas City market (ERS, 1957-1976) because of the consistent availability and complete set of price quotes for each of the grades and weights over the time span of the study. Furthermore, price data from this area were also available for the determination of ration costs. This allows for a more homogeneous study where transportation of cost differentials are minimized.

Price-related risk is one of the most important factors confronting the cattle industry. This risk has been defined as to the variation, over a series of years, around the price trend and seasonal variation found (Purcell and Elrod, 1974). There have been many attempts at prediction of cattle prices that try to take into account the variation, as well as the fundamental factors underlying the price trends. These studies range from the prediction of yearly average prices for the fundamental supply-and-demand factors such as the beef production per capita and the income per capita (Knox, n.d.), to highly complex studies that interrelate the beef sector with vast amounts of data and large numbers of variables (Folwell and Shapouri, n.d.).

Price predictions and feedlot strategy studies can take several forms that range from random number experiments to simply using past price history. Furthermore, the period of time during which the price information is gathered can be important. Even with random numbers, when the mean and its variance used to generate the random prices are taken from a period when prices are stable or rising, the data and conclusions gathered from the experiment are limited. For example, in a rather complex experiment performed by Bullock and Logan (1972), prices were taken from a rather stable period in the 1960's. Consequently, their price-predicting equations were extremely accurate. Immediately after their study was published though, the price of grain, feeder cattle, and slaughter cattle doubled in a period of less than a year. Similarly, the prices collapsed soon after that.

Since the objective of this study is to evaluate the proposed descriptions of feeder cattle, only available prices were used to represent the actual situation facing the cattle feeder over the last 19 years. Furthermore, as the average length of the cattle cycles is about 10 years and includes some interrelated price movements that could not be simulated by random numbers alone (Knox, n.d.), this data would be sufficiently realistic to include all sorts of variation. The price prediction equations developed herein could also be used to some advantage in the real world predicting future price changes.

The standard variables such as number of beef marketings, cow herd size, or consumer disposable income adjusted for inflation were not included as these add undue complications to the study and are not the data used by the average cattle feeder in his decision to place animals on feed. He would typically look at the current costs of the feeder cattle, the current ration costs, and the current and projected finished fat-cattle prices. Since prices are, in fact, derived from the total supply-and-demand situation that is currently acting upon the market, use of the prices themselves in the prediction of future prices seems both logical and incredibly simple. For example, if the price of slaughter cattle is at a certain level in the winter months, we know from experience that the relative position of summer prices would be higher. This simple example can be seen in

Table 21 where the relative monthly price changes have been analyzed for the time span of this study. A further example of the link between current and future prices can be seen in the psychological connection between current high slaughter prices and feeder-cattle prices. In the hope that slaughter prices will remain high, the cattle feeder must be prepared to bid higher on feeder cattle.

The price prediction equations utilized in this study can be found in Table 22. The variables in the multiple-regression model include the current feeder price, current ration costs, a monthly time index or trend line, and the current slaughter-cattle prices adjusted for seasonality. These equations which predict prices for slaughter cattle from 1 to 12 months away are remarkably accurate in that they all explain about between 72 and 95 percent of the variation. The standard errors of the samples are also quite low and indicate that the equations can predict the majority of future prices within a range of 10 percent. The F-ratios are also significant and indicate that the probability of the relationship could have occurred by chance alone is less than .001.

This study does not deflate prices or profits for inflation. At first this might seem unreasonable, but consider also that the costs of production as well as the benefits have increased by similar amounts. Since this is a highly circumscribed market, Gittinger (1972) suggests in his book on the economic analysis of agricultural projects that inflation is accounted for, although not directly calculated, in the analysis. One of the major measures used to evaluate the feeder-cattle descriptors is the internal rate of return which represents a discounted measure of the income stream. This measure has the added benefit that comparisons between the feeder-cattle types can be made, not on the basis of the absolute cash value which is subject to inflation, but rather upon the relative worth through time of each feeding strategy.

Results of the Price Simulation

The simulation provided both expected and unexpected results (see Table 23) that probably reflect some of the forces shaping the beef-cattle industry today. For example, the large-frame feeder cattle provided the highest internal rate of return. In the 1950s, short, dumpy British-breed cattle were the ideal toward which the breeding industry was directed. The exotic, continental-breed feeder cattle and their associated large frame size were consistently given price discounts even up until 1969. That situation is now reversing itself (Menkhaus and Kearl, 1976), and the trend will probably continue until they receive price premiums for large frame size.

TABLE 21
KANSAS CITY, 900-1,100 POUND CHOICE SLAUGHTER, MONTHLY PRICE INDEXES

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1957	.8764	.8584	.9297	.9722	.9962	1.0134	1.0533	1.0761	1.0542	1.0366	1.0473	1.0864
1958	.9618	.9840	1.0600	1.0834	1.0586	1.0231	.9833	.9395	.9720	.9647	.9811	.9884
1959	1.0204	.9991	1.0442	1.0727	1.0456	1.0081	1.0070	.9958	.9900	.9669	.9301	.9200
1960	.9965	1.0127	1.0436	1.0694	1.0413	1.0093	.9838	.9634	.9464	.9456	.9734	1.0147
1961	1.0706	1.0471	1.0313	1.0131	.9531	.9244	.9301	.9779	.9856	.9989	1.0244	1.0435
1962	.9516	.9541	.9615	.9859	.9516	.9357	.9586	1.0170	1.0769	1.0658	1.0880	1.0533
1963	1.1215	1.0318	.9572	.9761	.9513	.9576	1.0427	1.0322	1.0197	1.0092	.9748	.9258
1964	.9807	.9497	.9559	.9328	.8929	.9466	1.0327	1.0757	1.0952	1.0686	1.0415	1.0278
1965	.9133	.8947	.9189	.9764	1.0390	1.0771	1.0565	1.0438	1.0430	1.0228	1.0073	1.0073
1966	1.0014	1.0402	1.0953	1.0510	1.0091	.9816	.9734	1.0029	.9975	.9707	.9396	.9373
1967	.9740	.9566	.9388	.9392	.9847	1.0171	1.0460	1.0468	1.0555	1.0318	1.0069	1.0025
1968	.9502	.9652	.9932	.9902	.9977	1.0026	1.0201	1.0231	1.0201	1.0033	1.0052	1.0291
1969	.9412	.9301	.9680	1.0174	1.1108	1.1514	1.0620	1.0218	.9737	.9426	.9263	.9548
1970	.9687	.9967	1.0476	1.0524	1.0148	1.0291	1.0544	1.0182	.9994	.9772	.9341	.9075
1971	.8851	.9942	.9842	1.0063	1.0197	1.0026	.9895	1.0284	1.0016	.9914	1.0256	1.0716
1972	.9845	1.0048	.9848	.9693	1.0014	1.0513	1.0591	.9963	.9834	.9859	.9557	1.0236
1973	.9049	.9631	1.0262	1.0203	1.0178	1.0464	1.0631	1.2030	1.0379	.9286	.9013	.8874
1974	1.1230	1.1306	1.0201	.9965	.9783	.9144	1.0325	1.1082	.9921	.9373	.8989	.8681
1975	.82120	.7970	.8088	.9634	1.1091	1.1635	1.1363	1.0362	1.0817	1.0728	1.0067	1.0033
Average	.9709	.9742	.9878	1.0046	1.0091	1.0134	1.0255	1.0319	1.0172	.9958	.9825	.9870
Standard Deviation	.0755	.0711	.0635	.0433	.0520	.0653	.0465	.0560	.0405	.0437	.0509	.0621

TABLE 22

COEFFICIENTS OF EQUATIONS FOR PREDICTING 900-1,100 POUND KANSAS CITY CHOICE STEERS[a]

Number of Months from Current Month	Current Monthly Adjusted Choice Steer, ($ per cwt.[b])	Current 650 Pound Choice Feeder Steers, ($ per cwt.)	Current Ration Cost, ($ per ton[c])	Monthly Time Index from Jan. 1957	Constant	R Squared[d]	Standard Error
1	.91606	.02447	.00003	.00446	1.25340	.94893	1.55994
2	.78200	.06056	.00960	.00972	2.96767	.88056	2.38070
3	.70891	.07531	.00793	.01450	4.26118	.83157	2.82494
4	.65213	.08315	.00953	.01785	5.24831	.79545	3.11284
5	.58652	.10922	.02468	.01748	5.54713	.78283	3.20827
6	.52159	.12888	.04084	.01735	5.93321	.77025	3.30144
7	.49009	.12294	.04376	.01962	6.63369	.74914	3.45317
8	.45716	.12792	.04640	.02124	7.12994	.73545	3.55045
9	.45540	.12851	.04026	.02268	7.39058	.73307	3.60307
10	.47005	.12740	.02946	.02400	7.51514	.72514	3.62523
11	.42481	.16200	.03139	.02447	7.64534	.72413	3.63504
12	.34767	.20897	.03542	.02607	8.07031	.71677	3.68807

[a] Data are based on ERS-published prices of Choice cattle in Kansas City from January, 1957 to December, 1975.
[b] For monthly adjustment indexes see Table 21.
[c] Ration is 35 percent No. 2 Chicago corn per cwt, 35 percent No. 2 Yellow Kansas City Milo, 20 percent Kansas City Alfalfa hay, 10 percent Memphis Cottonseed meal.
[d] All equations have F-ratios significant at least to the .001 level.

TABLE 23

RESULTS BY WEIGHT AND FRAME SIZE OF PRICE SIMULATION

	Buy-and-Sell Weight Groups (in Pounds)								
	500-1,000	500-1,100	500-1,200	625-1,000	625-1,100	625-1,200	750-1,000	750-1,100	750-1,200
Small Frame[a]									
Internal rate of return (percent)	8	1	none[b]	6	negative	none	17	5	none
Head fed per year	5,684	3,158	0	5,053	1,895	0	10,421	2,526	0
Cost per pound	.2436	.2491	0	.2447	.2492	0	.2406	.2462	0
Profit per pound	.0194	.0028	0	.0122	−.0021	0	.0175	.0104	0
Medium Frame									
Internal rate of return (percent)	7	negative	none	6	1	none	16	7	none
Head fed per year	5,684	3,789	0	5,053	1,895	0	10,737	3,784	0
Cost per pound	.2464	.2580	0	.2460	.2473	0	.2408	.2439	0
Profit per pound	.0161	−.0042	0	.0104	.0020	0	.0170	.0012	0
Large Frame									
Internal rate of return (percent)	28	17	4	18	13	negative	38	15	11
Head fed per year	11,053	8,211	5,053	9,263	5,684	3,789	17,895	10,421	3,158
Cost per pound	.2462	.2404	.2507	.2387	.2385	.2568	.2378	.2398	.2450
Profit per pound	.0329	.0192	.0088	.0200	.0275	−.0031	.0215	.0202	.0156

[a] Number of head fed per year, costs, and profits per pound of slaughter weight are averages taken over the 19-year time span of the study.
[b] If the predicted price of the finished cattle in the price simulation is greater than the 87.5 calculated break-even price, then animals were placed on feed. In this case, the predicted price was always less than that level. Therefore, none were placed on feed.

Another interesting result associated with frame size is that even though the large-frame steers graded only Good at the 1,000 pound weight, they attained the study's highest rates of return. Apparently, the production efficiency and turnover rate was so great that the grade discounted prices were easily overcome. This result mirrors the study of Nelson and Purcell (1973).

One unexpected result was the near equivalence of the medium- and small-frame animals. Apparently the smaller animals' ability to attain a Choice grade at a lower live weight, and thereby receive a higher market price, overcame the productive efficiency of a faster rate of growth in the medium frames.

If we look at the classification by weight groups, we can see that the heavier-weight feeder cattle obtained higher profits than did lighter weights. The ability to purchase weight already put on by cheap forage and range feeding in the stocker phase of the market chain is the key here to profitability. Also unexpected was the relative position of the smaller-weight over the mediumweight feeders. Apparently a calf's fast growth spurt, ability to utilize high roughage rations in this growth phase, and overall lower (i.e., better) feed-to-live weight conversion rates place it at an advantage over the mediumweight ranges.

If we look at the cost per pound of gain, we find the average for all groups to be between 23 and 25 cents. There is a moderately significant relationship between cost and internal rate of return. In fact, a least-square linear analysis showed that as the cost declines, the profit increases. This cost analysis explained 51 percent of the relationship.

The other half of the profit equation concerns the average number of animals fed per year. The more animals that are fed, the more profit that is made. Again a least-square analysis was performed between the internal rate of return and the mean number fed (in thousands of head per year) with 64 percent of the rate of return explained. Hence, turnover rate is slightly more important than the cost of gain since the objective should be to utilize the feedlots' facilities to the maximum.

Of course, the results found in this study do not exactly mirror the experience of feedlots over the past 20 years. The managerial ability assumed in the study could have been better or worse than that found in the industry. Also, only one kind of feeder cattle was chosen for each price simulation, while in reality several types may be placed in a single year depending upon the prices available to local feeders. Furthermore, there were periods when the decision criteria for placing cattle on feed were not met, which indicated a potential loss. In these circumstances, cattle were not placed on feed in the simulation for those months.

Implications and Conclusions

Information presented in this paper leads to the conclusion that the feeder-cattle information system is in need of revision and is not operating as efficiently as possible. The descriptors used in the teletype communication of information are deceptively complex and cloud the perspective purchaser's price evaluation of the animals. Obtaining lots repeatable in performance traits is difficult and further complicates the feedlot operator's calculation of the basis for use in hedging on the futures market. The conclusion was reached by sampling the teletype reports themselves to discover descriptor variation and by surveying the attitudes of and the use made by Arizona's feedlot industry. This difficult situation can be alleviated by the adoption of the feeder-cattle classification system suggested in this paper. This system is based upon traits such as sex, frame size, degree of muscling, and weight, which can predict the future performance in the feedlot and in the slaughter house.

The implication of these conclusions is that risk and uncertainty associated with the inputs of production can be lessened through the proposed revision. The increased price efficiencies of this revision can signal to the cow-calf producers the kind of animals desired by the feedlots and slaughter houses. This will help the entire beef industry become more efficient, overcome its current crisis, and return profitability. Hopefully, the increased production efficiencies and cost reductions will be passed on to the final consumers of beef products so that the entire society can benefit.

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