USING MECHANICAL TRADING SYSTEMS TO EVALUATE THE WEAK FORM EFFICIENCY OF FUTURES MARKETS

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An efficient market has been described by Fama (1970) as one in which prices always fully reflect all available information. Of the three tests of efficiency discussed, the weak form test is concerned with the randomness of price movements and measures the ability to predict future price changes from past and present changes. There are two general ways to evaluate weak form efficiency: statistical tests and mechanical trading rules. Statistical methods, including serial correlation, spectral analysis and nonparametric runs tests, permit hypothesis testing, but Fama and Blume (p. 227) point out that they may be of limited value with complex or irregular price structures.

Mechanical trading systems, such as filter rules and moving averages, provide a more sensitive test for nonrandomness, because they do not depend on the pattern or cause of the price changes (Bear and Stevenson, p. 980). However, Cargill and Rausser (1975, pp. 1045–1046) noted that while results from filter rule tests generally parallel those from serial correlation tests, the lack of agreement on the level of "expected" profits and the inability to make probabilistic statements severely limit their use. Consequently, there have been only a few weak form studies (Houthakker; Leuthold, 1972; Smidt; Stevenson and Bear) that employ trading rules.

This paper develops a general framework for using mechanical trading systems as a test of weak form efficiency in futures markets, and creates a procedure for statistical analysis of the results produced by these methods. An example is given using filter rules to test the weak form efficiency of the hog futures market from 1973 to 1977.

THEORETICAL BACKGROUND

It has been shown by Samuelson and Mandelbrot (1966) that speculative prices follow a martingale process

$$E(\pi_{t+1}|\phi_t) = 0$$

where π_{t+1} is the profit in the next period, and ϕ_t is the information available in the current period. Samuelson (p. 44) explained it this way: "Let us observe numerous sequences of futures prices generated by (a martingale) up until their terminal date. They will turn out, *on the average,* to have no upward or downward drift anywhere!" emphasis his). Given this, ". . . there is no way of making an expected profit by extrapolating past changes in the futures price, by chart or any esoteric devices of magic or mathematics. The market quotation already contains in itself all that can be known about the future, and in that sense it has discounted future contingencies as much as is humanly possible." Fama (1970, p. 385) added that assumptions of weak form efficiency "rule out the possibility of trading systems based only on information in ϕ_t that have expected returns in excess of equilibrium expected profits or returns." We would then expect a weak form efficient market to yield zero profits to any mechanical trading scheme, thus the null hypothesis for any statistical test would be zero profits, with any "excess" or nonzero returns indicating some degree of weak form inefficiency.

The choice of a benchmark of zero for the "equilibrium expected profits or returns" requires elaboration. Praetz (1976, 1979) proposed that the returns to a buy and hold strategy be used as a benchmark in futures market analysis, as it is in studies of the securities markets. Two futures market studies (Houthakker; Stevenson and Bear) have in fact used the buy and hold benchmark. However, we seriously question the validity of the buy and hold strategy in connection with futures market research.

The efficient market hypothesis was originally used to evaluate securities markets, where stockholders buy shares and expect to benefit from share price increases in addition to dividends. Regular dividends represent the "equilibrium expected profits or returns," and share price increases becomes the "excess" returns discussed by Fama (1970).[1] Since futures contracts have no guaranteed return, there is nothing

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[1] Much the same process also applies to bondholders who receive regular interest payments ("equilibrium expected profits or returns") and may also gain from bond price increases ("excess" returns).

analogous to a dividend payment, and the "equilibrium expected profits or returns" is, therefore, zero.

Furthermore, shares of stock represent assets that exist and therefore must be owned by someone. For example, an investor must own shares to receive the benefits discussed above. Short sales of stock in no way affect the number of shares outstanding and relate more to short-term investor strategy than to stock market performance. In contrast, futures contracts are simply —contracts—and are created whenever a buyer and a seller agree to make a trade. Similarly, these contracts are terminated (cease to exist) whenever the buyer and the seller liquidate their positions. Futures trading, unlike securities trading, is a two-party, zero sum game, with any price change resulting in a gain for one party and a loss for the other. Under these conditions, a buy and hold strategy is no more valid than a sell and hold strategy (Leuthold, 1976). Since this is a zero sum game, zero is the logical benchmark for futures market studies.

Finally, since Samuelson (p. 44) emphasized that "on the average, . . . there is no way of making an expected profit," we should concern ourselves with zero *mean* profits and not simply zero profits for any single trade.

STATISTICAL ANALYSIS

From the foregoing discussion, the appropriate null hypothesis for any statistical test should be mean gross profits (MGP)—gross profits (total gains minus total losses) divided by the total number of trades—equal to zero (MGP = 0). The choice of gross, rather than net, returns is justified by the lack of a standard transaction cost, since commissions vary considerably across time, types of traders, and trading firms. Results will be expressed in terms of MGP, and the reader can deduct an appropriate commission charge to obtain some value for mean net profits. This adjustment will not affect the variance of profits.

The use of a two-tailed (MGP $\neq$ 0) rather than a one-tailed (MGP > 0) test is justified, because any trading system that consistently generates losses could also be used to generate consistent profits simply by buying when the system gives sell signals and vice-versa. Similarly, using the two-tailed test eliminates confusion caused by losses resulting from "pathological" trading systems—selling in a rising market, for instance —because use of the opposite approach would have produced gross profits of the same magnitude.

Having selected a null hypothesis, a statistical test is needed that takes into account the variance of gross profits from each trade and the total number of trades, to allow comparison of results from different trading systems, time periods and markets, and to provide some way to evaluate the weak form efficiency of the price series under study. A common measure that considers all of these factors is the Z statistic

$$Z = \frac{X - X_0}{\sqrt{\frac{s^2}{n}}} \qquad (n > 30)$$

where X is the actual MGP from a given strategy, X_0 is the expected MGP (zero in this case), s^2 is the variance of gross profits per trade, and n is the number of round-trip trades. This provides a simple yet adequate test from which one can infer whether or not the market in question is weak form efficient during the time period under study.[2]

While there is no way to use statistical analysis to determine in absolute terms how efficient or inefficient a market is during a given period, one can still make inferences about the relative efficiency of a market based on the significance level, α. Rejecting the null hypothesis for small values of α implies less market efficiency (greater inefficiency) than for large values of α. The user should be careful not to make Type II errors (concluding that a market is efficient when it is not) by relying on the results of a single mechanical trading scheme. However, *any* strategy that generates statistically significant profits indicates that the market fails the weak form test.

FILTER RULES

Mechanical trading systems are rigid, systematic methods that base buy and sell decisions on specific price changes or price relationships. One such method is the filter rule, which is essentially a trend-following device. It receives its name from the way it "filters out" fluctuations smaller than some predetermined amount and initiates trades only on the larger price changes. Filter rules were first used by Alexander (1961, 1964) to analyze stock market prices, and his methods provide the basis for those used here in analyzing futures market prices.

For each filter, having determined the general trend in prices prior to the beginning of the series of closing prices under study, an initial position is taken at the closing price for the first day of the series so as to take advantage of that trend. For

[2] Use of the Z-statistic assumes that prices have a normal and independent distribution. However, Mandelbrot (1963, 1966) and others suggest that speculative price distributions are members of the stable Paretian class, of which the normal is a special case. The stable Paretian class is characterized by symmetric distributions, but, typically, the tails are higher than for the normal. Fama (1970, pp. 399, 400) also cautions against the assumption of a normal and independent distribution, even though it is common in studies such as ours to assume that these conditions are met. In later writings, Fama (1976, p. 20) concedes that since statistical tools do not exist for the true distributions, and in almost all cases those distributions are not known and may change over time, using standard statistics based on normal and independent distributions is both acceptable and necessary.

example, if the trend is up, one takes a long position. When prices fall from a subsequent peak by some predetermined amount X, where X may be either an absolute dollar amount or some fixed percentage of an extreme price, the original long position is liquidated, and the opposite, or short, position is taken at that day's closing price.[3,4] This short position is held until prices rise by X from a subsequent trough when that position is liquidated, and a long position is taken. This process is repeated until the end of the series, when the position held at this time, either long or short, is liquidated at the closing price on the last day of trading for that contract. Note that the net position at any time is one contract, long or short.

APPLICATION

This study used two types of filters, percentage filters (X = A%) and dollar filters (X = $B), to test the weak form efficiency of the hog futures market with the methods just developed. It examines the final 10 months of trading in each of the 7 hog futures contracts (February, April, June, July, August, October, December) traded at the Chicago Mercantile Exchange that were deliverable in each of the 5 years, 1973–1977, for a total of 7,076 observations (*Chicago Mercantile Exchange Yearbook*). This period was chosen because of the dramatic changes taking place in the agricultural sector and the general economy. Record grain exports, rising inflation, the presence and subsequent removal of wage and price controls, and a consumer boycott of beef were only a few of the major events that would be expected to have an impact on hog prices during this time. Because of these activities, this is an attractive period in which to evaluate the market's ability to react quickly and accurately to new information.

Long term (4–6 year) cycles in hog prices have been recognized with some of the earliest empirical findings published in the 1930s by Coase and Fowler (1935, 1937). However, shorter term (less than one year) hog price behavior has received little attention. Leuthold and Hartmann, and Elam found that hog futures prices failed the semi-strong form test of market efficiency. To the authors' knowledge, no weak form tests have been performed on the hog futures market, in contrast to the numerous weak form studies for other livestock and livestock-oriented futures markets: live cattle (Cargill and Rausser, 1972, 1975; Leuthold, 1972; Mann and Heifner), pork bellies (Cargill and Rausser, 1972, 1975; Mann and Heifner) and shell eggs (Mann and Heifner).

Ten different percentage filters—1% to 10% in one percentage point increments—and 10 different dollar filters—50¢ to $5 in fifty-cent increments—were used to evaluate each contract individually. These filters were chosen on the assumption that a 10% or $5 price change was the maximum that could reasonably be expected to occur with any degree of regularity for any given contract. The major concern was to have a sufficiently large number of transactions for the larger filters. Given the choices for the largest percentage and dollar filters, 10 equally spaced intervals were specified to permit a comprehensive evaluation of weak form efficiency over a wide range of values. The profits from each individual trade across all 35 contracts were compiled for each filter and then used to calculate the values shown in Table 1.

For all 20 filters, MGP exceeded zero. Tests of these values against the null hypothesis of zero MGP were performed, and the results appear in Table 1, along with the calculated Z statistics and levels of significance for each filter. All 20 filters generated MGP values significantly different from zero, at least at the 5% level. Many MGP values were significant at the .05% level and lower. In general, MGP increased with larger filter sizes, as did variance of profits. However, total gross profits were fairly uniform across all 20 filters, thus the increase in MGP and variance of profits experienced by the larger filters is apparently the result of the smaller number of transactions. These profit levels would, in most all cases, exceed any reasonable commission charges.

Based on these results, one would reject the null hypothesis at the 5% level for all filter tests evaluated and conclude that the hog futures market during this period failed the weak form test of market efficiency.[5]

SUMMARY AND CONCLUSIONS

Mechanical trading methods have been shown here to be a feasible and appropriate method for evaluating the weak form efficiency of a market. Linking the theories of Samuelson and Mandelbrot (1966) to Fama's (1970) efficient market hypothesis results in a framework that provides a statistical basis for analyzing the results that

[3] Mandelbrot (1963) showed that for non-normal stable Paretian distributions, assuming that transactions occur at exactly X introduces substantial positive bias into filter rule profits, because with such distributions, price series may show discontinuities. Therefore, all transactions in this study occurred at the first closing price exceeding X.

[4] To give a hypothetical example using a percentage filter, assume that a long position was taken at a closing price of $43.50 per hundredweight, and prices continued to rise over a period of time to a closing price of $51.75, after which they began to decline. Using a 10% filter, the long position would be maintained until prices first closed under $46.575 ($51.75 − 10% ($51.75)). Suppose that the first closing price below $46.575 was $46.50; then two contracts would be sold at $46.50—one to liquidate the long position taken at $43.50 and one to give a net short position. For the first transaction, the gross profits would be $3.00 per cwt. ($46.50 − $43.50) or $900 for a contract of 30,000 pounds.

[5] A similar study using various two-track moving averages and the statistical methods developed in this paper produced similar findings as those presented here, and the details are available from the authors. We wish only to remind the reader that the analytical framework is a general one and may be used with any mechanical trading system, not only filter rules.

TABLE 1. Summary of Simulated Trading Results for 20 Filters Over the Final 10 Months of Trading, All 35 Hog Futures Contracts Deliverable Between 1973 and 1977

Filter	Total Gross Profits	Number of Trades	Mean Gross Profits (MGP)	Variance of Profits	Calculated Z-Statistic	Significanc Level (α)
1%	$ 85,836	2,144	$ 40.04	195,016	4.20	.00005
2%	107,550	1,304	82.48	392,598	4.75	.000005
3%	94,740	913	103.77	571,664	4.15	.00005
4%	92,760	621	149.37	954,555	3.81	.0005
5%	93,375	477	195.75	1,284,830	3.77	.0005
6%	102,955	362	284.41	1,755,220	4.08	.00005
7%	94,725	299	316.81	2,157,250	3.73	.0005
8%	93,870	247	380.04	2,535,940	3.75	.0005
9%	86,820	208	417.40	3,069,310	3.44	.001
10%	76,725	189	405.95	3,631,970	2.93	.005
$0.50	81,976	1,950	42.04	218,232	3.97	.0001
1.00	101,940	1,129	90.29	455,907	4.49	.00001
1.50	100,380	747	134.38	782,979	4.15	.00005
2.00	101,190	484	209.07	1,294,270	4.04	.0001
2.50	111,488	365	305.45	1,907,840	4.23	.00005
3.00	108,960	278	391.94	2,304,300	4.31	.00005
3.50	100,920	233	433.13	2,548,690	4.14	.00005
4.00	75,675	211	358.65	3,115,110	2.95	.005
4.50	61,575	187	329.28	3,644,020	2.36	.05
5.00	77,100	152	507.24	3,728,250	3.24	.005

these systems generate. This study is an application of an alternative analytical approach.[6]

Mechanical trading methods have several desirable properties. Since they do not depend on repetitive patterns of price changes, they have the capacity to detect nonrandomness that other methods may overlook. The simulation techniques are simple, intuitively appealing, and consistent with the theory of efficient markets. This paper has presented a method by which their results may be analyzed with standard statistical techniques. Using a null hypothesis of zero mean gross profits, any trading strategy that generates significant mean gross profits, either positive or negative, implies the existence of nonrandom price movements and, consequently, failure of the weak form test of market efficiency.

In an application to the hog futures market between 1973 and 1977, it was found that the market failed the weak form test of market efficiency for each of the 20 trading strategies used.

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[6] One *Journal* reviewer argued that we failed to analyze the why, how, and implications of inefficient markets and the policy alternatives to reverse the inefficiency. Such analysis is far beyond the scope of this paper, which is technique oriented. Nevertheless, we concur with the reviewer that this gap in the literature is important. Many notable authors of empirical market efficiency studies have failed to address properly the economic relevance of inefficient markets and the potential cures. We urge researchers in the future, while doing marketing studies, to orient their efforts more toward understanding the causes and consequences of inefficient markets.

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