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INEFFICIENCIES IN THE S&P 500 STOCK INDEX FUTURES MARKET ?

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ABSTRACT

This study attempts to determine if inefficiencies exist in the S&P 500 stock index futures market. Using time series analysis, futures and cash prices are found to be cointegrated. A trading model based on the cointegrated is developed to determine if positive net returns from trading can be generated. A trading model was developed and used to demonstrate that these inefficiencies can be employed to generate positive net returns from trading. These results indicate that the S&P 500 stock index futures market appears to be inefficient in a semistrong form sense. As a result, this trading model and the trading rules developed for use in this study may serve as a useful tool in investment decision-making.

Market efficiency is vital in insuring the optimal allocation of resources. In an efficient market, prices fully and instantaneously reflect all available relevant information. More specifically, prices in an efficient market are such that the marginal benefits do not exceed the marginal costs of utilizing additional information. The efficient market hypothesis (EMH) deals with the degree of capital market efficiency. Under the EMH, there are three forms of market efficiency: weak, semistrong, and strong. The weak form of the EMH asserts that price changes are random and do not reflect any distinguishable pattern. Prices reflecting all publicly available information is indicative of the semistrong form of the EMH, which focuses on the speed with which prices adjust to information available to the public. A suggestion of the strong form of the EMH is that all available information (public and private) is fully reflected in prices. The factor of interest is whether any inside information that could affect prices is available to any market participants (Cheney and Moses; Fama). Inefficiencies identified and addressed in this paper would fall under the semistrong form category.

Several studies have addressed the efficiency of futures markets. Garcia, Hudson, and Waller report, for example, that pricing inefficiencies in agricultural futures markets can lead to a misallocation of resources which could cause a decrease in economic surplus. Working provides evidence of the existence of "trends" and "cycles" in futures prices, which are supposed to follow the random walk hypothesis. Despite these nonrandom qualities, futures prices can be described as nonrandom (markets as inefficient) only if these nonrandom qualities provide for possible abnormal economic returns (Kamara). Another study conducted by Stoll and Whaley used intraday data to test for inefficiencies in the S&P 500 futures market. They found that returns on the futures tend to lead those of the stock index. Further, evidence was presented indicating that the futures market disperses new information ahead of the stock market. Arbitrage activities quickly bring prices back into alignment. Brock, Lakonishok, and LeBaron, using the Dow Jones index, found that technical analysis aids in the prediction of stock price changes, providing additional evidence of existing market inefficiencies.

The objectives of this study are two-

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fold. First, potential statistical inefficiencies in the S&P 500 Stock Index futures market are examined using time series analysis. The second objective is concerned with the question, are these statistical inefficiencies large enough to translate into economic inefficiencies? A trading model that incorporates these inefficiencies is developed to determine if positive net returns from trading can be generated.

S&P 500 STOCK INDEX FUTURES TRADING

Stock indexes exist to provide a method to track the performance of the stock market. The S&P 500 stock index is based on 500 different companies that fall under four broad categories weighted in the following manner: 78 percent industrials, 12 percent utilities, 2 percent transportation companies, and 8 percent financial institutions. These percentages are subject to change to allow for flexibility in choosing new stocks when openings occur. Adjustments are also made to avoid distortions caused by stock splits, mergers, or spin-offs (Cheney and Moses). The market value of these 500 stocks is equal to approximately 80 percent of the value of all stocks listed on the New York Stock Exchange. The index is capitalization-weighted, meaning that the index represents the market value of all outstanding shares of the listed firms. Calculation of the actual index includes the sum of each component stock's price multiplied by the number of common shares outstanding for that company which is then compared to the base period (1941-1943). Consequently, a change in the price of one stock affects the index by the amount proportionate to the market value of that firm's outstanding shares.

In 1982, the Chicago Mercantile Exchange introduced the S&P 500 stock index futures contract which currently accounts for two-thirds of all stock index trading. A futures contract is a legal agreement to buy or sell the cash value of the index at a specified future date. The dollar value of an S&P 500 futures contract is the contract's price multiplied by 500. Further, the contract is cash settled with no exchange of the underlying stocks. S&P 500 futures contracts move in .05-index-point intervals, called ticks. One tick is the minimum price change and is valued at $25 (500*$0.05) (Chicago Mercantile Exchange).

Positions held in the S&P 500 futures market are "marked-to-market" (re-valued) twice daily. Should an investor let a contract expire, his or her margin account will be debited or credited by the Special Opening Quotation on the following morning after the last trading day (the third Friday of the delivery month). Four contract months, March, June, September, and December, exist for the S&P 500 futures (Chicago Mercantile Exchange).

DATA

Values for the S&P 500 stock index and S&P 500 index futures from August 8, 1990 to November 11, 1992 are used to address the first objective. Index values and futures values from December 2, 1992 through April 6, 1993 are used in an out-of-sample trading period. The data used represents a period following the implementation of regulations in response to the crashes of 1987 and 1989. Waller, Mjelde, and Bessler suggest such regulations may have altered the underlying market structure.

The data to be tested and utilized consists of daily closing values of the 1) cash index and 2) the daily closing values of the nearby index futures. Because of the forced convergence of the S&P 500 futures to the actual stock index at expiration, the last 14 trading days of each contract are omitted to eliminate possible end-of-contract price fluctuations. The index futures series then continues with the next nearby contract. Procedures similar to this have been used in other studies dealing with futures prices that cover several contract lengths (Goldenberg).

Values of the futures levels (August 1990 to November 1992) are graphed in Figure 1. Values of the cash level for this time period are similar to the futures but are not presented because of space limitations. These levels exhibit a general upward trend, rarely crossing their mean values.

METHODOLOGY

To properly conduct time series analysis, the data used must be stationary. Stationarity refers to the tendency of the data to return to its mean value after a shock. If the data is not stationary, then the variance of the series is infinite, causing statistical tests to be inaccurate. A common test for stationarity is the Dickey-Fuller test. This test is performed by regressing the first differences of the levels on the lagged values of the levels,

$$\Delta X_t = \alpha + \beta X_{t-1} + \varepsilon_t \qquad (1)$$

where ΔX_t is the first difference of the series, α and β are coefficients to be estimated, and ϵ is an error term. Stationarity is indicated if the following two conditions are met: 1) the estimated coefficient (β) is negative, and 2) the absolute value of the t-ratio is greater than a prespecified critical value based on the number of observations. For this study, a critical value of 2.8 is used (Fuller). If the series are not stationary, then second differences are taken and the Dickey-Fuller test is run on the second differences to determine whether the first differences are stationary. This process is repeated until stationarity is achieved.

Once the data is stationary, tests for market inefficiencies can be conducted. These tests involve the estimation of several model types to determine if a statistical relationship between the futures series and the cash series exists. Such a relationship would suggest statistical inefficiencies classified as a semistrong form of the EMH. Models estimated include univariate, and cointegrated or error correction models for both series. The univariate model, which assumes no relationship between the different series is present, is a test for weak form efficiency. The univariate model is

$$\Delta X_t = \alpha + \sum_{i=1}^{M} \beta \Delta X_{t-1} + \varepsilon_t \qquad (2)$$

where ΔX is the stationary series of interest (futures or cash levels or differences), M is an optimal number of lags, and ϵ_t is an error term. This univariate model assumes that today's futures (cash) price can be predicted by simply using previous futures (cash) prices.

The final model estimated is based on the cointegrated model. Cointegration implies that two series are related in the long run. Further, the past performance of one series can be used to forecast the other. In an efficient market, this relationship would not exist (Waller, Mjelde, and Bessler). The test for cointegration begins with a regression of one series on the other to create an error term (Z_t),

$$X_t = \alpha + \beta W_t + Z_t . \qquad (3)$$

The Dickey-Fuller test is then run on $\hat{Z}_t$ to determine if it is stationary. The series are said to be cointegrated if $\hat{Z}_t$ is stationary.

An error correction model can be used to represent cointegrated data (Engle and Granger). For the purposes of this study, the error correction model is:

$$\Delta X_t = \alpha + \sum_{i=1}^{M} \beta_i \Delta X_{t-i} + \sum_{j=1}^{M+1} \gamma_j \hat{Z}_{t-j} + \varepsilon_t . \qquad (4)$$

According to Campbell and Shiller, cointegrated models are normally estimated in the error correction form for forecasting purposes because it allows for the elimination of one series when forecasting the other.

Once the models have been estimated, they are subject to evaluation to determine which most accurately fit the two series. To determine the number of lags in each of the models, a search procedure using the Schwarz loss function is followed. This information criteria uses the sum of squared errors and includes a penalty for the number of parameters. The Schwarz function is

$$T(\log(\hat{e}'\hat{e})) + K(\log(T)) \tag{5}$$

where T is the number of observations, K is the number of variables in the model, and $\hat{e}'\hat{e}$ is the sum of squared errors. The lower the value of the Schwarz loss function, the "better" the model fits the data. The Schwarz information criteria serves two purposes in this study. First, it is used to determine the optimal number of lags within each model type. Second, it suggests which model type performs the best.

STATISTICAL RESULTS

This section contains the results of the time series analysis. In examining Figure 1, it can be concluded that the levels are not stationary. First differences of the levels appear, however, to be stationary (Figure 2). The first differences of the cash series behave similarly, although not presented here because of space limitations. A summary of the results of the Dickey-Fuller stationarity test performed on the levels and their first differences are given in Table 1. For both the futures and cash levels, the absolute value of the t-ratio is less than the prespecified critical value of 2.8, indicating that the levels are nonstationary. First differences however, meet both requirements of the test; therefore they are considered stationary and are used in the model estimations.

Next, both series are tested for cointegration. As previously stated, cointegration suggests that there is some relationship between the two series, and ultimately that market inefficiencies may exist. Estimated error terms, $\hat{Z}_C$ and $\hat{Z}_F$, were created by regressing futures levels on cash levels and cash levels on futures levels, respectively. Both of these error term levels are found to be stationary (Table 1). This indicates that the series are cointegrated.

The level of significance indicated by the high t-ratio values for the tests on Z_C and Z_F shown in Table 1 should be noted. These results strongly imply that statistical inefficiencies do exist. The next step in determining if statistical inefficiencies exist is determination of which model best fits the data. As noted earlier, two different model types are estimated: univariate and cointegrated or error-correction models. Listed in Table 2 are the values of the Schwarz loss function for these formulations. The best overall model (smallest Schwarz value) for the cash series is the univariate form with the cash variable lagged once. The error correction form with the least number of lags is the best form for forecasting the futures series. These results indicated that statistical inefficiencies appear in the futures, but not in the cash. Because inefficiencies have been found, the second objective is addressed.

TRADING RESULTS

The second objective of this study is concerned with the ability of the identified statistical inefficiencies to generate positive net returns from trading. Because the cointegrated model best forecasts changes in futures prices, it is used as the basis for the trading model. The model is based on the forecasted change in the futures price (ΔF_{t+1}) from time period t. An expected change in the futures price is generated using the cointegrated model. This expected change in futures is then used to determine an action as follows:

$$\Delta F_{t+1} > a \quad \text{BUY,} \tag{6}$$
$$\Delta F_{t+1} < -a \quad \text{SELL, and}$$
$$-a \leq \Delta F_{t+1} \leq a \quad \text{HOLD}$$

where "a"representsthe bounds on the trading band. Trading trading band. Trading commences once a buy/sell signal is generated. During the out-of-sample trading period, the nearby contract month switches to a new nearby month. Instead of rolling the position over to the next contract, the expiring contract is terminated at the opening price for the expiring contract. A position corresponding to the new nearby contract is executed once a buy/sell signal is generated.

The following assumptions are incorporated into the trading model: 1) a reversal strategy is used so that once an initial position is established, the model maintains a position until forced termination at the end of a contract or the end of the trading period, 2) 14 days before the end of each contract, the existing position is liquidated and a new position for the new nearby contract is established once a buy/sell signal is received, 3) all signals are estimated using closing prices, 4) all transactions are executed at the next day's opening price.

It is important to distinguish between a trade (round turn) and a transaction (one position taken in the market). Commission costs for both a full service broker ($135) and a discount broker ($20) are included and are based on a round turn trade. Because published opening prices are single prices taken from a range of opening prices, a slippage cost of $100 per trade is added. Because the S&P 500 futures trades at a bid-ask spread, the slippage cost compensates for trades not being executed precisely at the reported opening price.

An optimal within-sample trading band is derived using a complete search technique. Values for "a" ranging from zero to two are used to determine net profits. Using both a full service and a discount broker's commission charge, the "a" value that produced the highest net returns is .56. This suggests that within the sample, the difference in commission charges is not large enough to influence the estimation of the trading signal. As seen in Figure 3, within a range of approximately .4 to .8 for trading band values, the largest net returns are generated.

OUT-OF-SAMPLE TRADING RESULTS

Next, the optimal "a" value derived from within-sample (.56) is used in trading the out-of-sample data. Summarized in Table 3 are the results of the 82-day out-of-sample trading period. A total of five trades are executed utilizing this trading band, with four of those trades turning a profit. The fifth trade which generated a loss was a forced execution at the of the out-of-sample trading period. The average length of time that a single position is held is 10.25 days. Using a discount broker, a maximum profit of $6820 is gained on one trade, while a maximum loss of $6720 from one trade is incurred. If a full service broker is used, the largest profit is $6648 on one trade, and the largest and only loss is $6835. The total net return over the trading period is $9560 using a discount broker and $9042 using a full service broker. These results suggest that the statistical inefficiencies previously identified are significant enough to allow for positive net returns from trading.

When accessing the return on equity over the trading period, the model generated a 17% annualized rate-of-return if the initial equity invested is the full value of the initial S&P 500 contract. This is a very conservative estimate. A more realistic estimate of the rate-of-return would be generated under the assumption that an investor is willing to invest approximately four times the required initial margin ($12000/contract). With a total initial equity investment of approximately $50,000, an annualized return of 73.5% is realized.

An important issue with trading futures is risk. Plotted in Figure 4 are the daily "paper" equity movements (not including commission costs and slippage). Once the model signals the investor to enter the market (day 9), equity positions tend to steadily increase. However, around day 50 to 52, the market falls which is reflected in a large decrease in the equity positions surrounding those days. These observations suggest that risk is a factor to be taken into consideration.

Sensitivity analysis is conducted on the out-of-sample data to determine the affects of different trading band values. "A" values ranging for zero to .75 are entered into the model. An "a" value of zero results in the maximum number of trades possible, while an "a" value of .75 results in two trades (Table 4). Because the difference in brokerage costs do not create substantial differences in the results, sensitivity analysis conducted using only the discount brokerage charges is reported. If an "a" value of zero is used, results would be favorable, but many trades are required. An "a" value of .75 provides negative net returns. These results indicate that the trading model is sensitive to the "a" value.

CONCLUSIONS AND EXTENSIONS

In addressing the first objective of this study, statistical inefficiencies appear to exist in the S&P 500 futures market. Further, the cash series appears to be only a function of itself. A plausible explanation for these conclusions is that the cash index is not traded as is the futures. Another conclusion that can be made from the estimation results is that both markets adjust to price information quickly; because the optimal number of lags for each series is one period.

A trading model was developed and used to demonstrate that these inefficiencies can be employed to generate positive net returns from trading. These results indicate that the S&P 500 stock index futures market appears to be inefficient in a semistrong form sense. As a result, this trading model and the trading rules developed for use in this study may serve as a useful tool in investment decision-making.

Several issues concerning trading which are beyond the scope of this initial study have not been addressed, although important. Nevertheless, these issues and considerations are vitally important in the efforts to generate profits from trading S&P 500 futures. An immediate concern to investors is the risk involved in an investment. Risk analysis is an area to which more complete testing and research should be devoted. Implementation of the model is another area of concern. The model could be designed to be updated by re-estimating a signal incorporating past days within the trading period. The model currently forecasts only daily price changes. Longer term forecasting that incorporates trends in the market should also be incorporated into the model. Finally, an extended trading period is necessary to more extensively test the model.

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Table 1. Results of Dickey-Fuller Test for Stationarity[1].

Series	Constant	Estimated Coefficient	t-Ratio
		Levels	
F_t	1.7187	-.0040	-1.0449
C_t	-1.3742	.0032	.8848
		First Differences	
ΔF_t	.1574	-1.0243	-24.6159
ΔC_t	-.1507	-.9964	-23.2337
		Z-Error Term	
Z_F	.0006	-.4468	-12.9033
Z_C	-.0003	-.4462	-12.8901

[1] Dickey-Fuller Test for Stationarity is based on following criteria.
a. Estimated coefficient is negative.
b. Absolute value of t-ratio is greater than some critical value based on the number of observations.

Table 2. Schwarz Loss Function Values for the Various Model Specifications Estimated.

Series			
Futures	Cash	Number of Lags	Lags of Z
	Univariate[1]		
5026.25	4957.62	1	
5032.05	4963.96	2	
5038.30	4969.31	3	
5043.48	4975.02	4	
5049.27	4981.24	5	
	Error correction[2]		
5021.68	4967.14	1	2
5030.95	4979.63	2	3
5042.83	4990.35	3	4
5052.33	5001.99	4	5
5063.00	5013.00	5	6

[1] In the univariate model, only the series of interest is lagged, see equation (2).
[2] For the error correction model, only the series of interest and the Z_t term are lagged, as in equation (4).

Table 3. Out-of-Sample Trading Results, with Slippage of $100/trade, and Trading Bounds at .56.

	Full service broker's charge ($135/round turn)	Discount broker's charge ($20/round turn)
Number of wins	4.00	3.00
Number of losses	1.00	1.00
Number of trades	5.00	4.00
Average net return/trade ($)	2261.00	2390.00
Total net return($)	9042.00	9560.00
Maximum profit/trade ($)	6648.00	6820.00
Minimum profit/trade ($)	-6835.00	-6720.00
Average # days position held	10.25	10.25

Table 4. Results of "a" Value Sensitivity Analysis on Out-of-Sample Data.

	a				
	0	.25	.5	.62	.75
Number of wins	16	6	3	2	1
Number of losses	10	5	1	1	1
Number of trades	26	11	4	3	2
Average return/trade	337	43	2390	1526	-1500
Total net returns	8770	470	9560	4580	3000
Maximum profit/trade	5180	4220	6820	6820	3720
Minimum profit/trade	-5494	-3745	-6720	-6720	-6720