Taking A Peek Inside The Turtle's Shell

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Abstract

This paper considers two issues. Firstly it examines the efficacy of a mechanical trading model freely available from the 'Turtletrader' web page on the Internet. The results are tested against the Efficient Market Hypothesis (EMH) Weak-Form as proposed by Fama (1970). The findings show that EMH Weak-Form fails to describe the profits generated by the model when examining CBOT Corn and T-Bond futures contracts. The second issue examined is the impact of optimal fixed fraction (or optimal *f*) trading to determine minimum account capitalisation and reinvestment issues on the futures trading portfolio per the method in Vince (1990). When portfolio capitalisation and reinvestment issues are considered, insufficient funds rapidly produces a trading account with a zero balance.

INTRODUCTION

Financial market folklore has resounded with talk of traders known as the 'Turtles'. This group of traders was central to a bet between Richard Dennis and William Eckhardt as to whether traders were born, rather than made. The central tenet of the bet was that any individual armed with discipline and a viable mechanical trading system should be able to produce profits in the seemingly random futures markets.

This paper examines two issues. Firstly, it assesses the validity of a trading model offered free on the 'Turtles' web page against Fama's (1970) Efficient Markets Hypothesis. The 'Turtles' model is assessed using the trading system they have made freely available by mechanically applying the rules on two Chicago Board of Trade (CBOT) futures contracts. These are the US T-Bond and Corn contracts between 1978 and 1997. Secondly, the model's performance is also examined when variable size 'bets' are placed according to the trading account equity under the gambling theory style 'Optimal f' strategy proposed by Vince (1990).

RELEVANT LITERATURE

The modelling of financial price data for various properties has been actively conducted through the twentieth century. The earliest academic work extends back to Bachelier's (1900) doctoral thesis on Bond price modelling on the Paris Bourse. The studies moved into the randomness debate and the development of the 'Random Walk Hypothesis' with significant numbers of subsequently published papers. Some of the authors in this category include Working (1934), Kendall (1953), Mandelbrot (1963, 1966) and Fama (1965).

Although the randomness research was of a high quality, numerous efforts have been made to identify mechanical trading models which will extract the elusive 'consistent excess returns' referred to in Fama's (1970) seminal work on Efficient Capital Markets. Authors have met with limited success in generating significant trading model returns in equity markets, particularly once transaction costs were included. Some of the studies of equity markets include Alexander (1961), Fama & Blume (1966), Praetz (1969) and Szakmary, Davidson and Schwarz (1999). But has poor profitability been reported in futures markets?

The highly leveraged nature of futures markets make them particularly appealing to trading model developers. A number of researchers have been able to generate profits greater than the zero-sum-game, or zero profit expectations, model accepted by authors including Peterson & Leuthold (1982) and Anderson (1997).

Numerous authors have reported trading model profits across different futures markets. These include Stephenson & Bear (1970) in agriculturals, Sweeney (1986), Taylor (1992, 1993), Dooley & Shafer (1976, 1982), Boothe & Longworth (1986) in foreign exchange, Anderson (1997) in interest rates, and Lukac (1985, 1989) across twelve different markets. This list of authors is by no means exhaustive, but indicative of some researchers reporting EMH anomalies in refereed academic journals.

The image of trading model research is relentlessly plagued by the poor (and occasionally fraudulent) 'research' promoted in the commercial arena. Given that much of the research reported to date relies on simple moving averages, channel rules, filter rules and the like, this study aims to assess the robustness of the more complex 'Turtle' model provided on the 'Turtletrader' website.

As research is increasingly considering the impact of gaming theory on portfolio management techniques (Vince, 1990 and Shelton 1997), the impact of reinvestment of futures profits is also considered. The study relies on the 'Optimal f' concept of optimal fixed fraction betting for maximum portfolio growth in Vince (1990).

MODEL SPECIFICATIONS

The data set used for this study has been drawn from the free data section of 'Turtletrader' web page (http://www.turtletrader.com). The author of the 'Turtle' web page does inform users that this is not the 'Turtle' system, but is similar to those sold by other trading model firms for thousands of dollars.

The model is essentially a trend-following amalgam of two different techniques. It employs a basic simple moving average rule combined with a moving average plus/minus two standard deviations similar to the use the Bollinger Band approach, ie moving averages +/- a standard deviation variable, offered on some charting software such as Omega Tradestation.

The model rules provided are specified as follows.

> *"A. Enter Long Position:*
> *Assuming one is neither long or short a position, if the commodity price closes above the top barrier, enter via a market order to buy (go long) the next day.*
> *B. Exit Long Position:*
> *Assuming one is long a position, if the commodity price closes below price moving average, exit is made via a market order to sell the next day.*
> *C. Enter Short Position:*
> *Assuming one is neither long or short a position, if the commodity price closes under the bottom barrier, enter via a market order to sell (go short) the next day.*
> *D. Exit Short Position:*
> *Assuming one is short a position, if the commodity price closes above price moving average, exit is made via a market order to buy the next day.*
> *Definitions:*
> *1. Commodity Price:*
> *actual closing price of commodity*
> *2. Price moving average:*
> *moving average of commodity closes for last 70 days*

3. Two (2) sigma price standard deviation
(2X)(price standard deviation)
4. Top barrier:
70 day price moving average + 2X price standard deviation
5. Bottom barrier:
70 day price moving average - 2X price standard deviation"
(Source: http://www.turtletrader.com/ltts.html)

The model, as with some models promoted/published, fails to include certain information in the testing procedures which affects the ability of the study to be readily replicated by other researchers. The omitted information is left to be included in a fairly arbitrary manner. The decisions taken when modelling this technique include,

(i) Only one contract is traded for each buy/sell signal,
(ii) In testing, the model has not been allowed to have multiple positions taken in a similar direction, eg a buy signal at time t_0 is not permitted to be followed by another subsequent buy signal at t_n, therefore long (or short) positions greater than one contract are not accumulated. Only one position per signal of the same direction (eg subsequent buy signals) is taken,
(iii) Stop-loss orders are not used as they were not specified in the original testing methodology even though they were shown to have beneficial effects in Barnes (1970),
(iv) Transaction costs are incurred at the rate of $100 per round-turn trade (ie $50 when the position is opened and $50 when the position is closed). Transaction costs are modelled to allow for various costs including brokerage, exchange fees and poor order execution in accordance with Lukac (1985), Taylor (1992, 1993) and Anderson (1997).

The model detailed above has been programmed and tested on the 'System Tester' module of the software package Omega SuperCharts v2.00.

Having detailed the trading model, the specifications for the optimal fixed fraction trading, or 'Optimal f', calculations are adapted below per the method provided in Vince (1990). The basic approach proposed by Vince is an adaptation of an engineering solution to data transmission modelling by Kelly (1956, in Vince, 1990). Vince's (1990) research attempts to identify how many contracts should be traded for a portfolio dollar value, including the allowance for reinvestment of profits.

The analysis relies on the determination of the optimal number of futures contracts to be taken per buy/sell signal relative to the size of the portfolio. Therefore, as the model earns trading profits the number of futures contracts increases to reflect the increased capital base. The method relies on assessing which portfolio size and reinvestment rate will provide the highest return relative to the initial investment, or Total Wealth Relative (TWR).

This method looks to the size of the largest observed loss on any single trade to determine how many futures contracts should be traded for a given portfolio size. Testing for optimal *f* is then conducted according to the method shown in equation 1.1 below. The values for *f* are tested between 0.04 and 1.0 at increments of 0.04.

1.1 $$\text{Optimum Portfolio Size} = \frac{\text{Largest Observed Loss}}{f}$$

The optimum portfolio size is then used to determine the rate at which successive long (short) position sizes in futures contracts are increased/decreased. For example, assume that the trader ascertains an optimal portfolio size of $5,000. The portfolio will take only one contract per trade when the trading account balance is between $5,000 and $10,000. When the account is between $10,000 and $15,000 the position taken per trade will be two contracts and so on. This approach aims to make the portfolio grow as quickly as possible after successive profitable trades and, equally important, reduce the number of contracts held after a succession of unprofitable trades. The optimal number of contracts traded relative to the size of the portfolio is shown in equation 1.2 below.

1.2 $$\text{Number of Contracts} = \frac{\text{Account Balance}}{\text{Optimal Portfolio Size}}$$

One problem with using this method is that the optimal *f* can only be reported *a posteriori* so telling how many contracts *should* have been traded. The difficulty for the practitioner is knowing *a priori* what size *f* should be. To solve this problem, a simple bi-annual optimisation has been carried out.

Whichever *f* provides the greatest return relative to the initial investment over a two year period will then be applied out-of-sample in the following two years. Therefore, the first two year's results will only trade one contract per signal. Years 2 to 4 will trade on the optimal *f* strategy reporting the highest geometric growth over the previous two years. Years 4 to 6 trade on the optimal *f* strategy reporting the highest relative return over the previous 4 years and so on.

Finally, any test of trading models requires some measure by which the results are accepted or rejected. Fama (1970) provided researchers with zero-expected return benchmark under the Weak-Form of the Efficient Markets Hypothesis (EMH).

It has often been stated that futures is a zero-sum-game where wealth is not created, but simply redistributed. Under this zero-sum-game proposition, Peterson & Leuthold (1982) argued that futures profits should be measured against a zero expected profit and profits should be measured as a *z-score* to determine the statistical significance, if any, of reported profits. To this end, the following hypotheses are tested.

Hypothesis #1

Null Hypothesis H_0 : Average Profit Per Trade - US Bonds = 0

Alternative Hypothesis H_a : Average Profit Per Trade - US Bonds > 0

Hypothesis #2

Null Hypothesis H_0 : Average Profit Per Trade - Corn = 0

Alternative Hypothesis H_a : Average Profit Per Trade - Corn > 0

The two hypothesis tests are then used as the criteria by which to evaluate the zero profit expectations of EMH Weak-Form. If the trading model can produce a positive average profit after transaction costs relying only on historical data, then the EMH model will not be an adequately describe the markets under examination.

TRADING MODEL RESULTS

The trading models and their results are presented below. This section also outlines the results of the hypothesis tests detailed above. The data tested consists of daily open, high, low close, volume and open interest information for the CBOT US T-Bond and Corn contracts. The period considered is between 3 January 1978 and 12 December 1997 for T-Bonds and 3 January 1978 and 19 December 1997 for corn.

Table 1 presents trading details for CBOT T-Bonds during the test period for the 'Turtle' trading model.

Table 1: Trading Summary - T-Bonds 1978 to 1997

Total net profit	$14,206.25	Open position P/L	$3,562.50
Gross profit	$107,168.75	Gross loss	-$92,962.50
Total # of trades	57	Percent profitable	40%
Number winning trades	23	Number losing trades	34
Largest winning trade	$19,212.50	Largest losing trade	-$20,475.00
Average winning trade	$4,659.51	Average losing trade	-$2,734.19
Ratio avg win/avg loss	1.7	Avg trade(win & loss)	$249.23
Max consec. winners	4	Max consec. losers	6
Avg # bars in winners	85	Avg # bars in losers	28
Max intraday drawdown	-$37,731.25		
Profit factor	1.15	Max # contracts held	1
Account size required	$37,731.25	Return on account	38%

The ‘Turtle’ model was able to generate overall profitability in the US T-Bond contract during the test period. The model produced a total Net Profit (ie after transaction costs of $100 per round-turn trade) of $14,206.25 during the test period. This profit result translated into an average profit per trade of $249 per trade.

During the test period the model suffered from significant intraday and interday drawdowns, as high as $37,731 at one point. Given the amount of money required to fund sustained losses in this model, it is arguable that significant benefits could have been provided by the use of some form of stop-loss mechanism in accordance with Barnes (1970).

Given that the ‘Turtle’ model generated average net profits after transaction costs of > 0, the null hypothesis in hypothesis #1 must be rejected in this test. When the results were analysed for their statistical significance using the z-test in accordance with Peterson & Leuthold (1982), the z-score equalled 0.349. The z-score made the result significant at the 20% level. As the z-score reflects a relatively weak level of statistical significance, EMH Weak-Form cannot be statistically rejected for CBOT T-Bonds during the test period – although it may be argued that the profit is economically significant.

Table 2 details the performance of the ‘Turtle’ model during the test period.

Table 2: Trading Summary - Corn 1978 to 1996

Total net profit	$22,150.00	Open position P/L	$4,450.00
Gross profit	$41,662.50	Gross loss	-$19,512.50
Total # of trades	50	Percent profitable	48%
Number winning trades	24	Number losing trades	26
Largest winning trade	$10,200.00	Largest losing trade	-$2,700.00
Average winning trade	$1,735.94	Average losing trade	-$750.48
Ratio avg win/avg loss	2.31	Avg trade(win & loss)	$443.00
Max consec. winners	4	Max consec. losers	5
Avg # bars in winners	97	Avg # bars in losers	27
Max intraday drawdown	-$4,925.00		
Profit factor	2.14	Max # contracts held	1
Account size required	$4,925.00	Return on account	450%

Table 2 shows that during the test period 1978 to 1996, the ‘Turtle’ model was able to produce net profits of $22,150. As the ‘Turtle’ model is essentially a trend-following system it was able to profit significantly from the large bull market in corn during 1995-1996. The corn market was far friendlier to the model that the T-Bond contracts where the model was able to produce a far smaller net profit result. To determine the significance of the results, the test established in hypothesis #2.

The 'Turtle' model applied in the CBOT corn market produced total profits of $22,150, or an average profit per trade of $443. When the average profit is treated as a z-score, the result of 1.570 produced a significance just under the 5% level. Consequently, the null hypothesis must be rejected and therefore the EMH Weak-Form is rejected for the corn market during the test period.

The third aspect examined in this paper is the use of gaming mathematics in the money management aspects of futures trading. Tables 3 and 4 provide some indication of how the portfolio would have performed using different optimal *f* values based on the largest observed losing trade during the test period.

Table 3 illustrates how using changing levels of optimal *f* changes the dollar value of the portfolio required to trade the model. The higher the optimal *f*, the more aggressively profits are being pursued. As higher losses were experienced during the test period the amount of money required to trade the position increases markedly.

Table 3: CBOT T-Bonds - Portfolio Size $ Required At Each Optimal f

Year	***78-79***	***78-81***	***78-83***	***78-85***	***78-87***	***78-89***	***78-91***	***78-93***	***78-95***	***78-97***
Max Loss To Date	-$ 2,413	-$ 3,975	-$ 3,975	-$ 3,975	-$ 5,475	-$ 5,475	-$ 5,475	-$ 5,475	-$ 5,475	-$ 5,475
f Value					**Portfolio Size Required**					
0.04	60313	99375	99375	99375	136875	136875	136875	136875	136875	136875
0.08	30156	49688	49688	49688	68438	68438	68438	68438	68438	68438
0.12	20104	33125	33125	33125	45625	45625	45625	45625	45625	45625
0.16	15078	24844	24844	24844	34219	34219	34219	34219	34219	34219
0.20	12063	19875	19875	19875	27375	27375	27375	27375	27375	27375
0.24	10052	16563	16563	16563	22813	22813	22813	22813	22813	22813
0.28	8616	14196	14196	14196	19554	19554	19554	19554	19554	19554
0.32	7539	12422	12422	12422	17109	17109	17109	17109	17109	17109
0.36	6701	11042	11042	11042	15208	15208	15208	15208	15208	15208
0.40	6031	9938	9938	9938	13688	13688	13688	13688	13688	13688
0.44	5483	9034	9034	9034	12443	12443	12443	12443	12443	12443
0.48	5026	8281	8281	8281	11406	11406	11406	11406	11406	11406
0.52	4639	7644	7644	7644	10529	10529	10529	10529	10529	10529
0.56	4308	7098	7098	7098	9777	9777	9777	9777	9777	9777
0.60	4021	6625	6625	6625	9125	9125	9125	9125	9125	9125
0.64	3770	6211	6211	6211	8555	8555	8555	8555	8555	8555
0.68	3548	5846	5846	5846	8051	8051	8051	8051	8051	8051
0.72	3351	5521	5521	5521	7604	7604	7604	7604	7604	7604
0.76	3174	5230	5230	5230	7204	7204	7204	7204	7204	7204
0.80	3016	4969	4969	4969	6844	6844	6844	6844	6844	6844
0.84	2872	4732	4732	4732	6518	6518	6518	6518	6518	6518
0.88	2741	4517	4517	4517	6222	6222	6222	6222	6222	6222
0.92	2622	4321	4321	4321	5951	5951	5951	5951	5951	5951
0.96	2513	4141	4141	4141	5703	5703	5703	5703	5703	5703
1.00	2413	3975	3975	3975	5475	5475	5475	5475	5475	5475

From Table 3 the account size required under each level of *f* is shown. Therefore, during the test period 1978-1979 the largest observed loss was $2,413. To trade using an optimal *f* of 0.04 would require an account balance equal to $2,413 / 0.04 = $60,325 (shown in Table 3 as $60,313 allowing for rounding errors). Similarly, during the entire test period

1978 – 1997, the largest observed loss was $5,475 and the account size required to trade at an optimal *f* value of 0.04 was $136,875.

To examine only the account size required does not complete the analysis as the manager needs to know how well the returns are being generated relative to the initial investment for each different value of *f*. Table 4 shows what the simple return (ie, Optimum Account/Final Return) was for each level of *f*.

Table 4: CBOT T-Bonds – Total Wealth Relative (TWR) At Each Optimal f

Year	***78-79***	***78-81***	***78-83***	***78-85***	***78-87***	***78-89***	***78-91***	***78-93***	***78-95***	***78-97***
Opt f	0.12	0.04	0.04	0.2	0.16	0.08	0.12	0.04	0.04	0.04
Opt TWR	1.135	0.957	0.959	1.778	1.229	1.061	1.254	0.921	1.030	1.062
Opt A/c	***$ 20,104***	***$ 99,375***	***$ 99,375***	***$ 19,875***	***$ 34,219***	***$ 68,438***	***$ 45,625***	***$136,875***	***$136,875***	***$136,875***
0.04	1.088	0.957	0.959	1.255	1.111	1.052	1.126	0.921	1.030	1.062
0.08	1.130	0.893	0.889	1.475	1.187	1.061	1.212	0.784	0.975	1.034
0.12	1.135	0.814	0.801	1.642	1.226	1.032	1.254	0.611	0.840	0.914
0.16	1.112	0.728	0.702	1.744	1.229	0.971	1.251	0.425	0.641	0.714
0.20	1.066	0.640	0.601	1.778	1.198	0.886	1.207	0.246	0.405	0.461
0.24	1.003	0.552	0.502	1.746	1.139	0.786	1.129	0.089	0.160	0.185
0.28	0.929	0.469	0.410	1.657	1.056	0.678	1.025	0.000	0.000	0.000
0.32	0.847	0.391	0.328	1.520	0.958	0.570	0.904	0.000	0.000	0.000
0.36	0.762	0.321	0.256	1.352	0.849	0.467	0.776	0.000	0.000	0.000
0.40	0.676	0.259	0.196	1.164	0.736	0.373	0.648	0.000	0.000	0.000
0.44	0.591	0.205	0.146	0.972	0.624	0.291	0.526	0.000	0.000	0.000
0.48	0.509	0.159	0.106	0.786	0.518	0.221	0.416	0.000	0.000	0.000
0.52	0.432	0.121	0.075	0.614	0.419	0.163	0.319	0.000	0.000	0.000
0.56	0.361	0.090	0.052	0.464	0.332	0.117	0.238	0.000	0.000	0.000
0.60	0.296	0.065	0.035	0.338	0.256	0.082	0.172	0.000	0.000	0.000
0.64	0.239	0.046	0.022	0.236	0.192	0.055	0.120	0.000	0.000	0.000
0.68	0.188	0.032	0.014	0.158	0.140	0.036	0.081	0.000	0.000	0.000
0.72	0.144	0.021	0.008	0.100	0.098	0.023	0.052	0.000	0.000	0.000
0.76	0.107	0.013	0.005	0.060	0.066	0.014	0.032	0.000	0.000	0.000
0.80	0.076	0.008	0.002	0.034	0.043	0.008	0.019	0.000	0.000	0.000
0.84	0.052	0.004	0.001	0.017	0.026	0.004	0.010	0.000	0.000	0.000
0.88	0.032	0.002	0.000	0.008	0.014	0.002	0.005	0.000	0.000	0.000
0.92	0.018	0.001	0.000	0.000	0.007	0.001	0.002	0.000	0.000	0.000
0.96	0.007	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4 shows the level of returns generated for each optimal *f*. As can be seen, the capital management aspects of trading are shown to be of greater importance than just trading model profits alone. The more aggressive the trader is, ie using a higher *f* value, the risk of losing all trading capital becomes apparent. During the period 1978 – 1997, if the trader had used an optimal *f* value of 0.04, the account size required would have been $136,875, but the TWR (Total Wealth Relative) in relation to the final account balance would have been only $136,875 (1.062) = $145,361.

Table 4 also reveals that the trader using an *f* value of greater than 0.28 would have lost all capital (ie TWR = 0), and so been excluded from trading with this model without further capital injections. Therefore it may be suggested that the trader using the 'Turtle' model relying on a starting capital of less than 4 times the largest observed loss would have probably been unable to sustain trading activities in the T-Bond contract during the test period.

When the same tables are produced for corn, it can be seen that the corn market requires far less trading capital to produce profitable trading results. Table 6 shows the dollar size of the portfolio required at each *f* level.

Table 5: CBOT Corn - Portfolio Size $ Required At Each Optimal f

Year	***78-79***	***78-81***	***78-83***	***78-85***	***78-87***	***78-89***	***78-91***	***78-93***	***78-95***
Max Loss To Date	-1525	-1525	-1525	-1525	-1525	-1525	-1525	-1525	-2700
f Value	**Portfolio Size Required**								
0.04	38125	38125	38125	38125	38125	38125	38125	38125	67500
0.08	19063	19063	19063	19063	19063	19063	19063	19063	33750
0.12	12708	12708	12708	12708	12708	12708	12708	12708	22500
0.16	9531	9531	9531	9531	9531	9531	9531	9531	16875
0.20	7625	7625	7625	7625	7625	7625	7625	7625	13500
0.24	6354	6354	6354	6354	6354	6354	6354	6354	11250
0.28	5446	5446	5446	5446	5446	5446	5446	5446	9643
0.32	4766	4766	4766	4766	4766	4766	4766	4766	8438
0.36	4236	4236	4236	4236	4236	4236	4236	4236	7500
0.40	3813	3813	3813	3813	3813	3813	3813	3813	6750
0.44	3466	3466	3466	3466	3466	3466	3466	3466	6136
0.48	3177	3177	3177	3177	3177	3177	3177	3177	5625
0.52	2933	2933	2933	2933	2933	2933	2933	2933	5192
0.56	2723	2723	2723	2723	2723	2723	2723	2723	4821
0.60	2542	2542	2542	2542	2542	2542	2542	2542	4500
0.64	2383	2383	2383	2383	2383	2383	2383	2383	4219
0.68	2243	2243	2243	2243	2243	2243	2243	2243	3971
0.72	2118	2118	2118	2118	2118	2118	2118	2118	3750
0.76	2007	2007	2007	2007	2007	2007	2007	2007	3553
0.80	1906	1906	1906	1906	1906	1906	1906	1906	3375
0.84	1815	1815	1815	1815	1815	1815	1815	1815	3214
0.88	1733	1733	1733	1733	1733	1733	1733	1733	3068
0.92	1658	1658	1658	1658	1658	1658	1658	1658	2935
0.96	1589	1589	1589	1589	1589	1589	1589	1589	2813
1.00	1525	1525	1525	1525	1525	1525	1525	1525	2700

Table 5 highlights that fact that the trader could have remained operational at varying levels of *f* during the period. It is noteworthy that the trader requires far less capital in corn than is required to trade the T-Bonds using the 'Turtle' model. Table 6 shows the TWR generated at varying *f* levels.

Table 6: CBOT Corn - Simple Return At Each Optimal f

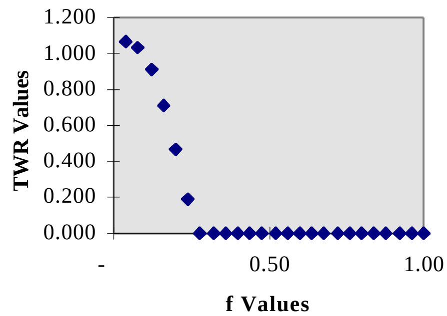
Year	***78-79***	***78-81***	***78-83***	***78-85***	***78-87***	***78-89***	***78-91***	***78-93***	***78-96***
Opt f	0.04	0.40	0.60	0.60	0.52	0.40	0.36	0.32	0.52
Opt TWR	0.985	1.766	6.955	8.340	5.777	4.252	3.667	3.166	6.085
Opt A/c	***$ 38,125***	***$ 3,813***	***$ 2,542***	***$ 2,542***	***$ 2,933***	***$ 3,466***	***$ 4,236***	***$ 4,236***	***$ 5,192***
0.04	0.985	1.125	1.335	1.369	1.347	1.353	1.364	1.361	1.359
0.08	0.966	1.244	1.725	1.811	1.748	1.750	1.768	1.753	1.778
0.12	0.943	1.357	2.167	2.325	2.196	2.177	2.193	2.149	2.251
0.16	0.916	1.459	2.657	2.907	2.679	2.615	2.610	2.517	2.765
0.20	0.885	1.550	3.188	3.550	3.185	3.041	2.991	2.826	3.306
0.24	0.851	1.627	3.749	4.241	3.695	3.433	3.308	3.049	3.855
0.28	0.814	1.689	4.329	4.966	4.191	3.768	3.537	3.165	4.391
0.32	0.775	1.733	4.913	5.706	4.653	4.025	3.659	3.166	4.890
0.36	0.733	1.759	5.486	6.439	5.060	4.190	3.667	3.053	5.330
0.40	0.689	1.766	6.030	7.140	5.394	4.252	3.561	2.841	5.688
0.44	0.643	1.753	6.526	7.783	5.638	4.207	3.350	2.548	5.944
0.48	0.596	1.721	6.955	8.340	5.777	4.058	3.052	2.204	6.085
0.52	0.547	1.669	7.298	8.783	5.802	3.815	2.690	1.835	6.099
0.56	0.498	1.597	7.535	9.086	5.709	3.493	2.291	1.469	5.982
0.60	0.449	1.508	7.649	9.224	5.497	3.109	1.883	1.129	5.736
0.64	0.399	1.401	7.623	9.178	5.171	2.687	1.488	0.830	5.370
0.68	0.350	1.279	7.444	8.931	4.743	2.248	1.128	0.582	4.897
0.72	0.301	1.143	7.099	8.473	4.227	1.814	0.815	0.386	4.337
0.76	0.253	0.995	6.583	7.800	3.643	1.403	0.558	0.242	3.712
0.80	0.206	0.838	5.890	6.916	3.013	1.033	0.359	0.141	3.047
0.84	0.161	0.674	5.023	5.831	2.361	0.713	0.213	0.075	2.369
0.88	0.117	0.505	3.987	4.567	1.710	0.450	0.113	0.036	1.704
0.92	0.076	0.335	2.793	3.149	1.086	0.246	0.051	0.014	1.075
0.96	0.037	0.165	1.457	1.613	0.510	0.098	0.016	0.004	0.501
1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

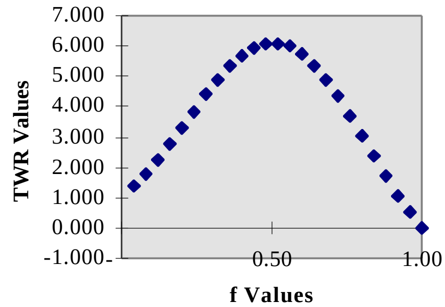
Table 6 reveals the TWR at different *f* values for Corn futures during the test period. Had the trader used an *f* value of 0.04, the TWR would have been 1.359, ie a final account balance of $5,192(1.359) = $7,056. However, had the trader used the optimal *f* value of 0.52, the TWR would have produced a final account balance of $5,192(6.099) = $31,666.

Table 6 further illustrates how the level of trading aggression is far less sensitive than the T-Bond contract. The model was able to remain profitable even with *f* values as high as 0.96 during the test period. It should be noted however that the more aggressive reinvestment trading strategy, eg *f* > 0.60, was at no time the optimal solution to maximising portfolio growth.

As the tables above have clearly illustrated, the dangers of being undercapitalised when trading using a mechanical trading model can lead to the trader rapidly being unable to stay in the market without further funds. Figures 1 and 2 below illustrate how the TWR (terminal wealth relative to starting capital) is affected at varying *f* levels.

Figure 1 - T-Bonds TWR ***Figure 2 – Corn TWR***





Both graphs very clearly indicate the dangers of insufficient capital (or trading with an *f* value too high). At any point to the right of the optimal *f* the trader is far more exposed to a fatal drawdown, resulting in cessation of trading or the need for further capital injections.

The CBOT T-Bond contract also clearly depicts the danger of trading any model without first assessing the sort of capital required to maintain positions. The corn produced superior to the T-Bonds in a trading capital sense, but also demonstrates that an optimal funding requirement can be determined, albeit *a posteriori*. Whether the issue of undercapitalisation contributes to the poor performance of many unsophisticated speculators, the results suggest that trader undercapitalisation may be a significant cause of failure.

CONCLUSION

This paper aimed to test two main areas. The first being whether the freely available 'Turtle' trading system provided on the 'Turtletrader' web page was able to generate profits. The trading model was tested on two arbitrarily selected CBOT futures contracts, namely US T-Bonds and Corn between the periods 1978 to 1997 and 1978 to 1996 respectively. The trading model was tested against the zero expected profits predicted under Fama's (1970) EMH Weak Form. The second objective was to test the impact of optimal fixed fraction trading (or optimal *f*) according to an adaptation of the model provided by Vince (1990).

Results have been presented indicating that the 'Turtle' model was able to generate profits after transaction costs of $14,206 in the T-Bond futures market and $22,150 in the corn futures market. The trading model was able to generate profits after transaction costs in both markets. EMH Weak-Form failed to be rejected in the T-Bond market, though was rejected for the Corn futures market. This does not necessarily mean that the Corn market was inefficient, but the profit outcome was significantly different from the profit result predicted by EMH using the mechanical 'Turtle' trading model.

Results have also been presented for the two futures contracts showing the effects of fixed fraction trading to determine minimum account capitalisation and the effects of increasing the number of contracts per position as profits increased trading capital. The results indicated that the T-Bond futures market required greater capitalisation using the 'Turtle' model than the corn futures examined.

Although no attempt was made to determine *a priori* what the optimal account capitalisation should be, the model presented above highlighted the need to be conscious of minimum account capitalisation issues.

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