The Crack Spread:
Day Trading the Oil Futures Complex

Various studies of futures spread trades are available, with trading horizons ranging from intra-day to long term holding periods, using strategies varying from purely technical rules to those derived from arbitrage conditions, involving both intra and inter-commodity positions. An important production spread trade is the crack spread, involving the prices for crude oil, heating oil and gasoline.[1] Such spreads have underlying economic fundamentals driving the relationship between the prices of the commodities involved in the spread. Other examples of production spread trades include the soy crush and the spark spread. For various reasons, the combination of prices involved in a production spread can deviate from the underlying fundamentals and the resulting reversion to the fundamental value creates a trading opportunity. From this point, trading strategy design depends on the trading horizon selected. Some production spread trades, e.g., Simon (1999) and Girma and Paulson (1999), are designed to speculate on long run deviations and have long holding periods. Other trades, e.g., Rechner and Poitras (1993), are designed to be day trade speculations. This study uses the daily New York Mercantile Exchange (NYMEX) opening and closing prices for crude oil, heating oil and gasoline futures, to examine the profitability of ***day trading*** strategies derived from the crack spread relationship.[2] It is demonstrated that the crack spread trade is a substantively different type of production spread trade than the soy crush spread, i.e., there is a unique timing of contract opening times for the crack spread components that separates this trade from other production spread trades.

I. Background and Review

Unlike spread trades derived from arbitrage conditions (Poitras 1997), the profit function for the production spread depends on economic fundamentals. In some cases, such as the soy crush spread (Simon 1999), the production relationship is well defined; a bushel of soybeans is crushed into predictable amounts of soybean meal and soybean oil. In other cases, such as the feeder cattle/live cattle spread (Shafer, Griffin and Johnston 1978) or the hog production spread (Kenyon and Clay 1987), the relationship is less clear cut. As producers can choose and mix from a variety of feed grains, such as soybean meal, corn and feed grade wheat, the feed prices to use in the spread, together with the relative weightings makes the precise production relationship difficult to specify. Ultimately, the true weightings depend on the practices of the marginal feedlot producer. In some ways, the crack spread is similar to the soy crush; a barrel of crude oil is distilled (cracked) into predictable amounts of heating oil and gasoline. Unlike the soy crush, the production relationship can vary, depending on the specific refinery setup and distillation process used (Oil and Gas Journal 1996; Olan and Molnar 1995; Tippe 1997). Market practice supports the use of a 3:2:1, crude oil, gasoline, heating oil, production relationship as representative of the marginal refinery production process, e.g., NYMEX (1989), even though an 8:5:3 ratio is arguably closer to the crack configuration for a typical refinery..

There are a number of possible methods for designing a speculative spread trading strategy. For example, Johnson et al. (1991), Girma and Paulson (1998) and Abken (1989) use buy-and-hold strategies with long holding periods to exploit inter-temporal deviations from long run production relationships. In contrast, Rechner and Poitras (1993) showed that a filter based day trading strategy based on the gross processing margin (GPM) can profitably be used to day trade the soybean complex spread. More precisely, Rechner and Poitras found that participants in the soybean complex pits can potentially pursue profitable day trading strategies based on the GPM, the production relationship underlying the prices for soybeans, soybean meal and soybean oil. The spread trades involve combining a short (long) position in soybeans, the input or feedstock, with long (short) positions in meal and oil, the outputs or by-products. The number of contracts used is determined by duplicating the physical processing relationship for the soybean complex. The trading rule used indicates that if the GPM at the open is above (below) the previous day's close, a normal crush/long position (reverse crush/short position) spread is placed. Outstanding positions are liquidated at the close of trading on the same day. Such a strategy avoids the costs associated with margin requirements.

The Rechner and Poitras day trading strategy is based on the assumption that the GPM will demonstrate "open-to-close reversals". Rechner and Poitras confirmed that open-to-close reversals do occur through the trading day. Implementation of the GPM trading signal involves imposing filters to limit the number of trades initiated in order to achieve higher mean profit per trade and a higher percentage of profitable trades. Rechner and Poitras concluded that the evidence of significant profit opportunities reflects the potential profitability of floor trading operations for participants in the soybean complex pits. Whether such trading strategies could profitably be exploited by off-exchange traders is difficult to verify, due to the inherent features of the trading simulations. The strategies require trades to be established at market opening prices, something which is difficult for off-exchange traders to accomplish. In addition, the extent of potential profits cannot be precisely determined as it is difficult to assess how much trading activity is required to have an offsetting effect on the associated prices.

For institutional reasons, day trading the crack spread is fundamentally different than trading the soy crush. More precisely, while the soybean complex contracts traded on the CME have the same opening times, the NYMEX crude oil futures contract opens at 8:45, a full 5 minutes prior to the opening for the heating oil and gasoline contracts. The reason for this delay is to provide time for the oil complex byproduct traders to adjust to the opening level for the crude oil futures. The soy crush aims to exploit the mis-pricing that occurs at the simultaneous opening of three different commodity futures contracts. The opening prices for each individual contract reflect the demand and supply present at the market open for that commodity. It takes the inter-market relationships, such as the soy crush, some time to emerge in market prices. In this time interval, there are profitable trading opportunities available to coordinated floor trading operations. In contrast, at the open of the crude oil contract, the crack spread trader knows only the closing prices for heating oil and gasoline. The guidance of the crack spread relationship is available to heating oil and gasoline traders, at the open of those contracts. For this reason, identification of mis-pricing opportunities using the crack spread relationship is unlikely to produce profitable trading opportunities if the trade involves executing all three commodity positions at the by-product opening time.

Unlike the soy crush which is predicated on distortions in prices with simultaneous opening times, the crack spread trader must undertake a riskier speculation predicated on over-shooting of the crude oil price at the open. Over-shooting or mean reversion has been the basis for a number of studies of futures spread trading strategies, e.g., Park and Switzer (1996). Over-shooting at the crude oil opening is a distinct possibility as the crude oil opening does not have information about openings in heating oil and gasoline. Supply and demand in the oil market will determine the opening crude oil price, e.g., a large supply coming onto the crude oil market at the open may lower the price below the crack spread consistent value that clears all three markets. In this crack spread, the trader is obligated to hold an uncovered position in crude oil for the five minute period leading up to the opening in the gasoline and heating oil contracts. Trades are then executed at the opening prices for those contracts. The risk that the uncovered crude oil futures price will move adversely in the time leading up to the open of the other contracts is compounded by the risk that the gasoline and heating oil prices will not open favorably. As such, the crack spread is a speculation based on an economic theory about how prices evolve stochastically over time, as opposed to the crush spread which relies on mis-pricing at one point in time.

Empirically, the profitability of the crack spread depends crucially on the properties of the tails of the distribution for crude oil price changes. As in the crush spread, appropriate filtering procedures can be used to censor trades. Because the only information available to signal the trade is the close-to-open change in the crude oil price, the resulting set of trades is derived exclusively from the properties of the observations in the tail of that distribution.

II. Designing the Trading Strategy

There are three components in a crack spread contract: crude oil (*CL*), gasoline (*HU*), and heating oil (*HO*). The crack spread is quoted in dollars per barrel. However, the by-products, gasoline and heating oil, are both quoted in dollars per gallon. To handle this, all prices are converted to a per barrel basis. In order to calculate the crack spread value, *SV(t,T)*, the following equation is used:

$$SV(t,T) = \frac{\frac{42\ gallons}{barrel}\left(M * HU(t,T) + N * HO(t,T)\right) - \left((M+N) * CL(t,T)\right)}{(M+N)}$$

where: *SV(t,T)* is the per barrel crack spread value observed at time *t* using NYMEX futures contracts with maturity at time *T* $(T>t)$; *HU(t,T)* is the associated price of gasoline per gallon; *HO(t,T)* is the associated price of heating oil per gallon; *CL(t,T)* is the associated price of light sweet crude oil per barrel; *M* is the number of gasoline contracts bought (sold); *N* is the number of heating oil contracts bought (sold); *M+N* is the number of crude oil contracts sold (bought). In this form, $SV > 0$ implicitly assumes a long position in the by-products and a short position in the feedstock. If a short position in the spread at the open is indicated, long the feedstock and short the by-products, a reverse crack spread is established and $SV < 0$, as the inputs *CL, HU* and *HO* now have the opposite signs . This form is general, allowing for different production mixes in the crack process. For the conventional 3:2:1 exchange spread, a balanced position of 3 crude oil, 2 gasoline and 1 heating oil is established. For an 8:5:3 production spread, a balanced position of ($M+N$ = 8) crude oil, (M = 5) gasoline and (N = 3) heating oil is taken. Similarly, the 'gasoline crack' can be specified as 1:1:0 and the 'heating oil crack' as 1:0:1.

The trading strategy requires the calculation of three values for $SV(t,T)$, using different combinations of closing and opening prices. Using O or C to denote opening and closing values, the crack spread values of interest are: the value at the close, either $SVC(t-1,T)$ or $SVC(t,T)$; the value at the opening of the crude oil contract, $SVS(t,T)$, calculated using $CLO(t,T)$ and the previous closing by-product prices, $HUC(t-1,T)$ and $HOC(t-1,T)$; and $SVO(t,T)$ the crack spread value calculated using the opening values for the complex prices, $CLO(t,T)$, $HUO(t,T)$ and $HOO(t,T)$. Gross profits on the trade can be calculated as, $\pi(t,T) = SVC(t,T) - SVO(t,T)$. In the trading simulations, profits net of transactions costs, $NSP(t,T)$, is the variable of interest. This is calculated as: $NSP(t,T) = \pi(t,T) - TC(t)$.

Example of Calculating SV(t,T)

8/7/1995 (June 1996 contract)	Opening Price	Closing Price
HU (dollars/gallon)	\$0.5420	\$0.5383
HO(dollars/gallon)	\$0.4740	\$0.4780
CL(dollars/barrel)	\$17.34	\$17.34

For the value of the 3:2:1 crack spread using opening prices, $SVO(t,T)$:

$$SVO(t,T) = \frac{42 * (2 * 0.5420 + 1 * 0.474) - ((2 + 1) * 17.34)}{3} = 4.472 \ \$/barrel$$

For the closing 3:2:1 spread value, $SVC(t,T)$:

$$SVC(t,T) = \frac{42 * (2 * 0.5383 + 1 * 0.478) - ((2 + 1) * 17.34)}{3} = 4.424 \ \$/barrel$$

It follows that, if a long 3:2:1 crack spread was established at the open: $\pi(t,T)$ = -0.048

\$/barrel. Using the minimum number of contracts, the resulting dollar profit would be (3000)(-.048) = -\$126.

In Rechner and Poitras (1993), the daily spread values are calculated from both opening prices and closing prices to determine $\Delta SV = SVO(t,T) - SVC(t\text{-}1,T)$. This value is compared to the censoring parameter to assess whether the trade will be placed or not. The close-to-open change in the spread, ΔSV, is calculated by subtracting the previous trading day's closing value, $SVC(t\text{-}1,T)$, from the opening spread value, $SVO(t,T)$. Because the by-product prices are not available at the open of the crude oil contact, this triggering variable is not available. Rather, for a 3:2:1 spread the triggering variable is: $\Delta SV = SVS(t,T) - SVC(t\text{-}1,T) = -3\ \Delta CL$. With this adjustment, the mechanics of the day trading procedure at time t follows: at the CL open, observe the known crack spread value, $SVC(t\text{-}1,T)$ and calculate the spread value, $SVS(t,T)$; a short crack spread position is placed if $\Delta SV > X$, where X is a filter size of either 0, 3, 6, 10, 15, or 20 cents, defined in terms of $\{-\Delta CL\}$; if $\Delta SV < -(X)$, a long crack spread position is placed; if neither condition applies, there is not trade for that date. All positions are closed out at $SVC(t,T)$.[3] By design, when increasingly larger filters (X) are imposed on the spread values (ΔSV), this will decrease the number of days during which trades are initiated. Consistent with results from numerous studies of naive trading rules, the ***expected*** relationship between filter size and trade performance is as follows: as the filter size increases, the mean net profit per trade and the percentage of profitable trades will increase while the total number of trades will decrease.

In practice, empirical studies of speculative trading rules are fundamentally dependent on the specification of transactions costs. Girma and Paulson (1998) demonstrated that long term buy-and-hold trading strategies can be profitable for trading the crack spread. Profits were due primarily to significant unpriced long term periodicity in crack spread values. In this study, Girma and Paulson estimated transaction costs for a round trip trade of a crack spread contract (3:2:1) at $100.[4] This charge is consistent with the average transaction costs for a round trip crack spread trade for a non-exchange member. To be comparable to *TC(t)*, which is used to calculate *NSP(t)*, this dollar value transaction cost has to be converted to a dollars/barrel basis. Based purely on price ticks for crude, gasoline and heating oil futures, a $0.01/barrel change in spread value represents $30 for a 3:2:1 crack spread, because the spread has to be put on using 3000 barrels to balance the positions. Thus, for a 3:2:1 crack, a $0.033/barrel provision for transaction costs is close to the Girma and Paulson transaction cost value. This assumption for transactions costs is high for a day trading study, if only because the trades are likely to be executed by floor traders who are exchange members rather than the off-exchange traders used in Girma and Paulson.

Precise handling of transactions costs depends on the type of trade being executed. For example, in studies of covered interest arbitrage it is essential to take accurate accounting of the bid/offer spread. This is because arbitrage trades have to be executed immediately, i.e., by selling at bids and buying at offers. Arguably, studies of long term trading strategies also have to account for the bid/offer spread when calculating transactions cost. This type of transactions cost is less applicable to studies of speculative strategies which trade at the open and close. Due to the difficulty in obtaining the precise transactions costs for clearinghouse members, the lowest possible level of transactions costs for traders capable of executing the strategy, an estimate of transaction costs for a round trip trade is immediately not available. Yet, clearinghouse members' execution costs are substantially lower than the long term trader in Girma and Paulson. Based on the observed price ticks, $.03/barrel appears to be a conservative assumption for the transactions costs most applicable to actual execution of the day trading strategy. This 3¢/barrel assumption is made even though the a day trader using the strategy is likely to execute transactions at, or near, clearinghouse commission rates and may be able to avoid bid/offer costs by trading efficiently. For both exchange and non-exchange traders, margin costs are minimal as all outstanding positions are not carried overnight and all gains or losses are realized and settled in cash at the end of the trading day. Because of the wide possible variation of transaction costs across various types of traders, trading profitability results are also reported for 4¢ and 5¢/barrel transactions cost levels. All this leaves considerable room for any cost savings arising from cheaper execution costs to offset unrecognized costs such as those arising from noisy opening and closing prices preventing execution of trades at prices applicable to the first or last trade of the day.

III. Empirical Results

Empirical results are based on the opening and closing (settlement) prices of the NYMEX crude oil, gasoline and heating oil futures contracts obtained from Market Research Inc. (www.barchart.com). Though trading can be as long as fifteen consecutive months for gasoline and heating oil and eighteen consecutive months for crude oil, there is usually not much trading volume until about 10 months before the expiration date. As a consequence, all contracts are followed for a 10 month period before the expiration date. The trading volume for heating oil and gasoline is also subject to seasonality. In order to control for seasonality and to contain the number of results being reported, June and December contracts are chosen for this study. A continuous time series is constructed using ten-month trading periods for each of the June, December contracts for 1996, 1997 and 1998. (M = June contract, Z= December contract). For June contracts, the trading period starts from mid-July of the prior year and continues until the third week of May of the delivery year. The trading period used for December contracts starts from mid-January and continues until the third week of November in the delivery year. To this end, the empirical analysis is categorized into six sub-periods: M1996, 1997, M1998, Z1996, Z1997, Z1998. In the few cases where data observations for a specific date were not available, all prices for that date are omitted.

The mean spread value and some statistics of the closing and opening values for the 3:2:1 ratio crack spread are shown in Table I. For comparison purposes, statistics for the 8:5:3, 1:0:1 and 1:1:0 spread ratios are also given. For all the spread ratios, mean values for both closing and opening spread prices of all the June contracts (M1996, M1997, M1998) are consistently 10% higher than for December contracts (Z1996, Z1997, Z1998). Mean values of December contracts show a downward trend over the three years while the trend is more neutral for June contracts. In addition, the mean opening spread values for December contracts (not reported) are all greater than the mean closing spread values. This observation indicates potentially profitable trading positions from shorting the crack spread (buying crude oil futures and selling gasoline and heating oil futures). In Table II, summary statistics for opening and closing prices for gasoline, heating oil and crude oil are shown. For gasoline, the mean price of June contracts (1996-98) is consistently higher than December contracts. However, the mean price of December heating oil contracts is consistently higher than the mean price of June contracts. These results support the seasonality effect hypothesis observed in previous studies, e.g.,Girma and Paulson (1998), Cho and McDougall (1990), Gay and Tae-Hyuk (1987).

Table III provides a summary of the profit simulations for the 3:2:1 crack spread using all six different contract samples grouped by size of filter and by long/short trade position. All the aggregate profit values are quoted on a per barrel basis. The mean value is the average *NSP(t)* for crack spread trades which were initiated at the relevant filter level. Aggregate profit is the sum of the *NSP(t)* for all the trades at that filter level. For example, the mean *NSP(t)* for a 3:2:1 short crack spread with a 20 filter size is $0.0493/barrel. Thus, the aggregate profit is calculated as: Aggregate Profit = (Average *NSP*)(total trades) = (0.0493)(81) = 3.99¢/barrel. Dollar profit on the sum of all trades can be calculated as: (3 contracts) (1000 barrels) ($0.0399/barrel contract) = $11,979, which is net of transactions costs of 3¢/barrel per trade. As discussed earlier, the "overnight" price changes, ΔSV = -$3\Delta CL$, are used as the trade indicator. If the crude oil price price opens up by more than a specific filter size (e.g., +15 cents), a long position for the intraday trade (long by-products, short feedstock) is triggered. The trigger values reported in Table III are expressed in terms of ΔCL. Given that the crack ratio is 3:2:1, this means that a filter of ΔCL = 10¢ translates into a ΔSV = -30¢. If the hypothesis of over-shooting is correct, it will be profitable to buy the by-products and sell the feedstock.

Given this, the trade profit results are generally consistent with expectations for a profitable, filter based trading rule (Poitras 1987): as the size of the filter increases, mean profit per trade increases and the number of profitable trades decreases. The optimal filter size is determined by examining aggregate trading rule profits. For both short and long crack spread trades, among the 4 different filter sizes used, the 15-cent filter size delivers the highest aggregate profits, though the 20-cent filter does have a higher average profit per trade. Aggregate profit is positive for filter sizes of 6¢ and higher. The relationship between filter size and aggregate profit is not monotonic from 15 to 20 cents because the reduction in aggregate profits resulting from the diminishing number of transactions is not effectively offset by the increase in the mean profit per trade. The percentage of profitable trades is above 60% for filter sizes 15 cents and higher. This percentage is substantially lower than the percentages associated with the higher filters for soy crush days trades reported in Rechner and Poitras where the percentage of profitable trades at high filter levels is greater than 80%. This speaks to the fundamental differences in the types of trades involved, i.e., the soy crush trade executes all contracts simultaneously while there is a 5 minute lag in the crack spread trade. In addition, the crack spread is based on over-shooting at the open. Conceptually, this means that there has to be considerable movement in the crude oil price before over-shooting will occur. As a consequence, the number of profitable events is likely to be smaller in number than in trades such as the soy crush where the mis-pricing originates from inter-market clearing at the open.

The higher moments of the profit distribution, skewness and kurtosis, can contain valuable information about validity of the trading rule under consideration. For example, the theory underlying a filter-based trading strategy could predict that filtering will reduce the number of losing trades relative to winning trades. This roughly leads to a prediction that skewness will become more positive as the filter size increases. Yet, it is difficult to develop precise testable hypotheses about the behavior of the higher moments of the profit distribution, e.g., Rechner and Poitras (1993). It is conventional to proceed heuristically, relating the observed values of skewness and kurtosis to those for the normal distribution. Given this, the higher moments of the profit distribution gives somewhat ambiguous information. Kurtosis roughly increases with filter size for the long trades, but this is not repeated for the short trades. All kurtosis values indicate wide divergence from normality. The reported kurtosis values also appear to indicate that one or two extreme outliers do not seriously impact the profit distributions. Rather the distribution is quite fat-tailed with a number of observations in the tails. The results for skewness are more ambiguous. With the exception of the long crack 15¢ and 20¢ filters, the profit distribution is symmetric. Recognizing the impact of extreme values on the higher moments, it is possible that the large minimum value of -0.905 weighs on the skewness statistics for those two filter sizes. More importantly, there is a general indication of symmetry in the profit distribution, largely unaffected by changes in filter sizes. This differs from behavior of profit distribution skewness in Rechner and Poitras where increasingly positive skewness values accompany increases in filter size. It is likely that differences in both the motivation and execution of the trading rule have significant implications for the behavior of the higher moments of the profit distribution.

On average, the 3:2:1 *short* crack position gives higher returns than the 3:2:1 *long* crack position. The difference is not statistically significant. At the 5% level in a *one tailed test,* the t-values for the short and long 15 and 20¢ filter sizes all reject the null hypothesis that the mean (*NSP*) profit equals zero in favor of the alternative hypothesis that the mean profit is greater than zero. Table IV provides results for three other crack spread ratios, 8:5:3, 1:1:0 and 1:0:1. The 8:5:3 ratio is examined because it could be a closer fit to the 'true' production spread ratio for a typical US refinery. Given this, the 8:5:3 results are only marginally different than using a 3:2:1 ratio, the 8:5:3 t values are slightly higher for the short trades and slightly lower for the long trades. iterating the spread ratio to different refinery production ratios does not appear to have much impact. The same cannot be said for the gasoline crack, 1:1:0, and the heating oil crack, 1:1:0. Ranked in terms of aggregate profit, the rankings for long, short and total combined positions is:

Long Crack Spread:	1:1:0 > 3:2:1 > 8:5:3 > 1:0:1
Short Crack Spread:	1:0:1 > 8:5:3 > 3:2:1 > 1:1:0
Total Profit:	1:1:0 > 3:2:1 > 8:5:3 > 1:0:1

The performance of the gasoline and heating oil crack spreads is significant because these ratios are not derived from underlying production relationships. These trades are based only on the equivalence of the quantities underlying the contracts. The relative performance of the different crack spread ratios suggests that factors such as seasonality and asymmetric price changes (e.g., Balke et al. 1998) play an important role in market dynamics.

The final point to consider concerns transactions costs. Though the value of 3¢/barrel used in Tables III and IV is conservative, it is difficult to shake the suspicion that the results are driven by inadequate specification of *TC(t)*. Table V contains results for the effect that higher transaction cost levels have on trading rule profitability for a 3:2:1 crack spread ratio. In Table V, considers two additional values for transaction costs (4¢ and 5¢/barrel). Much of the information in Table V is predictable. The impact of the increase in transactions costs is reflected in the correspond 1¢ falls in the mean values. Both the standard deviation and the number of trades are not affected by the change in transaction costs. This produces a predictable change in the t-value. Using 5¢ for transactions costs, even at the 10% level none of the mean values is significantly different from zero. Using 4¢ for transactions costs, three of mean profits for the are significantly different from zero at the 10% level (one-tailed test). This leaves the number and percentage of profitable trades to examine. Despite the sizable reduction in the mean values associated with increases in transactions costs, there is little reduction in the number of profitable trades. For the case of 4¢ transactions costs with a 20¢ filter size, over 60% of the trades are still profitable for both short and long trades. Moving to 5¢ transactions costs the number of profitable trades fall from {33,49} to {31,44}. This speaks to the properties of the observations in the tail of the distribution of crude oil price changes: over-shooting is likely to occur with larger changes in crude oil prices.

VI. Conclusion

This study explored the profitability of a day trading strategy for the crack spread, involving crude oil, gasoline and heating oil futures contracts traded on the NYMEX. The empirical results support the notion that floor traders can profitably employ a filter based day trading strategy to speculate on the crack spread relationship. What is to be concluded from this result? It would be possible to say that this is yet another study added to the sizable list which demonstrates that production spread relationships can be used to design profitable trading rules. Girma and Paulson (1998, p.594) provide the conventional conclusion drawn in these studies: "If the markets for petroleum futures are efficient, then average profits on the crack spread trades should be zero. A statistically significant trading profit implies that the markets for these commodities may not be efficient." This conclusion is understandable. The study of trading rules has a history stretching back to the introduction of the efficient markets hypothesis (EMH). A number of studies have used trading rules to evaluate the EMH, e.g., under the weak form of EMH, expected profits from simple trading rules based on trending in prices have a zero expected value. It is, somehow, still surprising to find that profitable trading rules can be identified. The essential connection between the profit and the activities of market participants is not developed. If the empirical results of trading rule profitability are correct, then prices are likely capturing the gains associated with certain market activities. In the vein, studies of open-to-close day trading rules speak to the profitability of exchange floor trading activities.[5]

Arguably, the EMH leads to incorrect intuition about the expected results from trading rule studies. Under the EMH, purely speculative trading activities have zero expected value. It is sufficient to identify a profitable trading rule, as this is evidence against EMH. Yet, there are participants in the exchange process that provide essential services, such as liquidity or price coordination. These services require adequate compensation. This compensation is earned through trading activities. If a trading rule captures the trading activity of, say, a coordinated trading operation of a clearing member firm, it is not surprising that the trading rule is profitable. The profits can be interpreted as the returns to such exchange floor activities. For example, Rechner and Poitras (1993) examined a trading rule which was likely to be profitable because clearing member firms are known to maintain floor trading operations to coordinate trading activities in different soybean complex pits. Rechner and Poitras did identify the connection between the profitability of exchange floor trading operations and the performance of the trading rule. However, this point was not developed. This study examines the profitability of a different type of floor trading activity: the provision of speculative liquidity. The results support the hypothesis of over-shooting. In a trading context this suggests that large movements in the crude oil price create order imbalances at the opening in the crude oil pit. This attracts floor traders willing to take the other side of the trade, given a favorable enough expected crack spread relationship. The five minute delay to the by-product opening gives individual floor traders more than sufficient time to relocate to or coordinate with the by-product pits in time to execute the offsetting trades at the opening of those contracts.

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Table II. Statistics of the Closing Prices of Energy Futures*

Crude Oil ***Closing Price Unit: dollars/barrel***

	M1996	M1997	M1998	M1999	Z1996	Z1997	Z1998	Z1999
Mean	18.325	20.884	18.142	14.925	20.018	20.264	15.871	18.967
Standard Deviation	1.681	1.461	2.064	1.849	2.559	0.636	1.484	3.595
Kurtosis	0.161	-0.931	-1.262	-0.912	-0.887	0.467	-0.846	-1.065
Skewness	1.222	-0.097	-0.309	0.095	0.721	0.801	-0.259	0.002
Max	22.8	23.91	21.27	18.98	25.53	22.55	18.68	26.6
Min	16.54	17.93	12.96	11.78	16.74	19.16	12.14	12.58
T. # of obs.	202	215	196	202	204	211	204	200

Gasoline ***Closing Price Unit: dollars/gal.***

	M1996	M1997	M1998	M1999	Z1996	Z1997	Z1998	Z1999
Mean	0.574	0.633	0.567	0.474	0.563	0.570	0.472	0.545
Standard Deviation	0.057	0.036	0.041	0.046	0.057	0.019	0.038	0.088
Kurtosis	0.077	-0.612	-1.087	-1.163	-0.895	-0.611	-0.933	-1.036
Skewness	1.183	-0.122	-0.197	-0.277	0.587	0.363	-0.366	0.042
Max	0.723	0.709	0.643	0.559	0.689	0.626	0.539	0.734
Min	0.508	0.549	0.472	0.384	0.485	0.532	0.375	0.39
T.# of obs.	202	215	196	202	204	211	204	200

Heating Oil ***Closing Price*** ***Unit: dollars/gallon***

	M1996	M1997	M1998	M1999	Z1996	Z1997	Z1998	Z1999
Mean	0.493	0.557	0.496	0.403	0.590	0.578	0.452	0.517
Standard Deviation	0.031	0.032	0.047	0.042	0.073	0.018	0.048	0.082
Kurtosis	0.088	-0.918	-1.346	-1.117	-0.793	-0.638	-1.138	-1.089
Skewness	1.143	-0.064	-0.258	-0.489	0.768	0.340	-0.088	0.001
Max	0.590	0.622	0.573	0.464	0.757	0.628	0.547	0.687
Min	0.457	0.490	0.402	0.314	0.497	0.545	0.348	0.368
T. # of obs.	202	215	196	202	204	211	204	200

* See Notes to Table 1.

Table I. Statistics of the Closing Crack Spread Values

Crack Spread Ratio: 3:2:1

Closing Crack Spread Values Unit: dollars/barrel

	M1996	M1997	M1998	M1999	Z1996	Z1997	Z1998	Z1999
Mean	4.638	4.642	4.672	3.979	4.004	3.772	3.687	3.515
Standard Deviation	0.432	0.198	0.387	0.525	0.277	0.231	0.338	0.308
Kurtosis	2.352	-0.099	4.122	0.964	1.919	0.954	-1.168	-0.622
Skewness	1.148	0.089	1.544	-1.262	0.622	0.608	-0.252	-0.271
Max	6.061	5.233	6.760	4.660	5.164	4.646	4.313	4.147
Min	3.104	4.110	4.051	2.251	3.257	3.224	3.018	2.815
T. # of obs.	202	215	196	202	204	211	204	200

Crack Spread Ratio: 8:5:3

Closing Crack Spread Values Unit: dollars/barrel

Mean	4.496	4.508	4.549	3.855	4.053	3.786	3.652	3.466
Standard Deviation	0.393	0.191	0.372	0.540	0.268	0.221	0.348	0.312
Kurtosis	2.937	-0.054	4.477	0.955	2.523	0.981	-1.218	-0.664
Skewness	1.013	0.136	1.598	-1.266	0.911	0.609	-0.240	-0.240
Max	5.796	5.087	6.599	4.547	5.242	4.617	4.288	4.067
Min	2.914	3.999	3.954	2.096	3.380	3.260	2.985	2.769
T. # of obs.	202	215	196	202	204	211	204	200

Crack Spread Ratio: 1:1:0

Closing Crack Spread Values Unit: dollars/barrel

Mean	5.768	5.711	5.654	4.971	3.615	3.659	3.971	3.906
Standard Deviation	0.777	0.280	0.508	0.433	0.454	0.352	0.315	0.297
Kurtosis	1.129	-0.247	2.297	0.920	1.232	0.330	-0.933	-0.068
Skewness	1.353	-0.051	1.238	-1.037	-1.072	0.675	-0.207	-0.247
Max	8.186	6.410	8.053	5.900	4.583	4.872	4.612	4.867
Min	4.629	5.001	4.820	3.487	2.241	2.943	3.177	3.186
T. # of obs.	202	215	196	202	204	211	204	200

Crack Spread Ratio: 1:0:1

Closing Crack Spread Values Unit: dollars/barrel

Mean	2.377	2.504	2.707	1.995	4.783	3.998	3.119	2.735
Standard Deviation	0.482	0.241	0.201	0.803	0.562	0.312	0.604	0.443
Kurtosis	5.840	-0.310	13.939	0.625	2.295	-0.221	-1.447	-0.948
Skewness	-2.250	-0.246	2.492	-1.194	1.496	0.313	0.117	0.166
Max	2.866	3.029	4.176	2.934	6.886	4.812	4.294	3.665
Min	0.055	1.830	2.397	-0.318	3.925	3.217	2.115	1.948
T. # of obs.	202	215	196	202	204	211	204	200

* Skewness and Kurtosis are the standardized three and fourth moments. Kurtosis has been centered about the expected value of 3 applicable to the null hypothesis of normality.

Table III. Aggregate Trade Performance of 3:2:1 Crack Spread Ratio*

3:2:1 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $): 0.03 Units: dollars/barrel

Long crack position (if CL>0, long open and short close minus transaction fee)

Filter (in cents)	0	3	6	10	15	20
# of profitable trades	310	241	187	117	72	33
% of profitable trades	43.54%	45.73%	49.08%	54.17%	60.00%	67.35%
Mean	-0.0188	-0.0086	0.0001	0.0117	0.0271	0.0525
Standard Deviation	0.1622	0.1632	0.1691	0.1721	0.1795	0.2033
Kurtosis	3.6858	4.4219	4.8803	4.4394	5.4195	9.5681
Skewness	0.3639	0.5023	0.4307	-0.0822	-0.7569	-1.5131
Minimum	-0.8850	-0.8850	-0.8850	-0.8850	-0.8850	-0.8850
Maximum	0.8536	0.8536	0.8536	0.6660	0.5988	0.5988
Aggregate Profit	-13.4188	-4.5530	0.0488	2.5330	3.2560	2.5728
T. Number of Trades	712	527	381	216	120	49
t-value	-3.0995	-1.2152	0.0148	1.0012	1.6555	1.8075

3:2:1 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $): 0.03 Units: dollars/barrel

Short crack position (if CL<0, short open and long close minus transaction fee)

Filter (in cents)	0	-3	-6	-10	-15	-20
# of profitable trades	333	262	192	125	80	53
% of profitable trades	46.25%	49.16%	52.32%	53.42%	61.07%	65.43%
Mean	-0.0117	-0.0054	0.0062	0.0106	0.0355	0.0493
Standard Deviation	0.1919	0.1873	0.1964	0.2085	0.2222	0.2626
Kurtosis	5.4559	5.6698	5.8903	7.0841	6.2309	4.7008
Skewness	-0.1910	-0.2373	-0.2103	-0.3666	0.0900	-0.0592
Minimum	-1.0494	-1.0494	-1.0494	-1.0494	-1.0044	-1.0044
Maximum	0.9806	0.9416	0.9416	0.9416	0.9416	0.9416
Aggregate Profit	-8.4504	-2.8954	2.2736	2.4710	4.6474	3.9916
T. Number of Trades	720	533	367	234	131	81
t-value	-1.6415	-0.6697	0.6042	0.7747	1.8275	1.6888

* See Notes to Table I. Aggregate profit is calculated by multiplying the mean value by the total number of trades. The t-value is for a test of the hypothesis that the mean profit equals zero. Using a one-tailed test, the limiting t-value for testing at the 5% level is 1.645.

Table IV. Aggregate Trade Performance of Other Crack Spread Ratios

8:5:3 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $) 0.03 Units: dollars/barrel

Long crack position (if Δ*CL>0*, long open and short close minus transaction fee)

Filter (in cents)	0	3	6	10	15	20
# of profitable trades	312	245	189	118	72	33
% of profitable trades	43.82%	46.49%	49.61%	54.63%	60.00%	67.35%
Mean	-0.0193	-0.0094	-0.0011	0.0103	0.0260	0.0508
Standard Deviation	0.1576	0.1584	0.1643	0.1671	0.1735	0.1947
Kurtosis	3.3991	4.0443	4.4341	3.9896	4.9600	9.1779
Skewness	0.3734	0.5074	0.4249	-0.0424	-0.6628	-1.3852
Minimum	-0.8369	-0.8369	-0.8369	-0.8369	-0.8369	-0.8369
Maximum	0.8008	0.8008	0.8008	0.6156	0.5811	0.5811
Aggregate Profit	-13.7320	-4.9707	-0.4062	2.2149	3.1249	2.4883
t-value	-3.2651	-1.3666	-0.1267	0.9020	1.6439	1.8254

8:5:3 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $) 0.03 Units: dollars/barrel

Short crack position (if Δ*CL<0*, short open and long close minus transaction fee)

Filter (in cents)	0	-3	-6	-10	-15	-20
# of profitable trades	333	261	191	126	80	52
% of profitable trades	46.25%	48.97%	52.04%	53.85%	61.07%	64.20%
Mean	-0.0109	-0.0045	0.0072	0.0117	0.0355	0.0498
Standard Deviation	0.1872	0.1832	0.1924	0.2043	0.2201	0.2600
Kurtosis	5.4452	5.7253	5.9612	7.1946	6.4241	4.8753
Skewness	-0.1163	-0.1592	-0.1425	-0.2895	0.1233	-0.0304
Minimum	-1.0039	-1.0039	-1.0039	-1.0039	-1.0039	-1.0039
Maximum	0.9612	0.9441	0.9441	0.9441	0.9441	0.9441
Aggregate Profit	-7.8251	-2.4054	2.6560	2.7407	4.6558	4.0329
t-value	-1.5580	-0.5689	0.7205	0.8771	1.8482	1.7233

1:1:0 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $) 0.03 Units: dollars/barrel

Long crack position (if Δ *CL>0*, long open and short close minus transaction fee)

Filter (in cents)	0	3	6	10	15	20
# of profitable trades	329	251	196	124	74	35
% of profitable trades	46.21%	47.63%	51.44%	57.41%	61.67%	71.43%
Mean	-0.0153	-0.0023	0.0097	0.0235	0.0359	0.0663
Standard Deviation	0.2096	0.2118	0.2181	0.2236	0.2380	0.2825
Kurtosis	5.5657	6.7510	7.6480	7.2585	7.6839	10.7787
Skewness	0.3108	0.4659	0.4564	-0.2991	-1.2760	-2.1240
Minimum	-1.2700	-1.2700	-1.2700	-1.2700	-1.2700	-1.2700
Maximum	1.2764	1.2764	1.2764	1.0692	0.7402	0.7402
Aggregate Profit	-10.9128	-1.2112	3.6888	5.0782	4.3046	3.2490

t-value	-1.9512	-0.2491	0.8666	1.5453	1.6512	1.6430

1:1:0 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $): 0.03 Units: dollars/barrel

Short crack position (if $\Delta CL<0$, short open and long close minus transaction fee)

Filter (in cents)	0	-3	-6	-10	-15	-20
# of profitable trades	337	258	188	124	79	49
% of profitable trades	46.81%	48.41%	51.23%	52.99%	60.31%	60.49%
Mean	-0.0187	-0.0128	-0.0021	0.0013	0.0350	0.0452
Standard Deviation	0.2406	0.2311	0.2390	0.2527	0.2487	0.2932
Kurtosis	5.4598	5.4483	5.6236	6.5820	4.5300	3.3303
Skewness	-0.6201	-0.6908	-0.6398	-0.8842	-0.2113	-0.3090
Minimum	-1.4498	-1.4498	-1.4498	-1.4498	-1.0086	-1.0086
Maximum	1.1360	0.9220	0.9220	0.9220	0.9220	0.9220
Aggregate Profit	-13.4526	-6.8154	-0.7854	0.3136	4.5802	3.6612
t-value	-2.0837	-1.2772	-0.1716	0.0811	1.6089	1.3874

1:0:1 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $): 0.03 Units: dollars/barrel

Long crack position (if CL>0, long open and short close minus transaction fee)

Filter (in cents)	0	3	6	10	15	20
# of profitable trades	292	229	169	96	59	27
% of profitable trades	41.01%	43.45%	44.36%	44.44%	49.17%	55.10%
Mean	-0.0259	-0.0213	-0.0190	-0.0118	0.0097	0.0249
Standard Deviation	0.1477	0.1482	0.1501	0.1556	0.1520	0.1531
Kurtosis	1.1349	0.8767	0.7487	0.8338	0.6499	1.2042
Skewness	0.4022	0.3553	0.3952	0.4779	0.5026	0.6501
Minimum	-0.4952	-0.4952	-0.3934	-0.3832	-0.3180	-0.3180
Maximum	0.5924	0.4962	0.4962	0.4774	0.4642	0.4490
Aggregate Profit	-18.4308	-11.2366	-7.2312	-2.5574	1.1588	1.2204
t-value	-4.6763	-3.3020	-2.4674	-1.1186	0.6959	1.1384

1:0:1 Spread, Aggregate Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction fee (in $): 0.03 Units: dollars/barrel

Short crack position (if $\Delta CL<0$, short open and long close minus transaction fee)

Filter (in cents)	0	-3	-6	-10	-15	-20
# of profitable trades	361	273	202	134	81	52
% of profitable trades	50.14%	51.22%	55.04%	57.26%	61.83%	64.20%
Mean	0.0022	0.0093	0.0229	0.0290	0.0365	0.0574
Standard Deviation	0.1773	0.1769	0.1842	0.1905	0.2272	0.2603
Kurtosis	4.2853	5.2914	5.6045	6.7158	5.3097	4.6278
Skewness	0.4701	0.4789	0.4243	0.2582	0.2393	0.1371
Minimum	-0.9960	-0.9960	-0.9960	-0.9960	-0.9960	-0.9960
Maximum	0.9808	0.9808	0.9808	0.9808	0.9808	0.9808
Aggregate Profit	1.5540	4.9446	8.3916	6.7858	4.7818	4.6524

t-value	0.3267	1.2107	2.3787	2.3283	1.8388	1.9856

* See Notes to Table III.

Table V

Aggregate Trade Performance of 3:2:1 Crack Ratio Using $0.04 and $0.05 as the Transaction Fees

3:2:1 Long Crack Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction Fee (in $) = 0.04 $/barrel

Filter (in cents)	0	3	6	10	15	20
# of profitable trades	289	224	173	107	68	33
% of profitable trades	40.59%	42.50%	45.41%	49.54%	56.67%	67.35%
Mean	-0.0288	-0.0186	-0.0099	0.0017	0.0171	0.0425
Standard Deviation	0.1622	0.1632	0.1691	0.1721	0.1795	0.2033
Aggregate Profit	-20.5388	-9.8230	-3.7612	0.3730	2.0560	2.0828
t-value	-4.7442	-2.6218	-1.1393	0.1474	1.0454	1.4633

3:2:1 Short Crack Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction Fee (in $) = 0.04 $/barrel

Filter (in cents)	0	-3	-6	-10	-15	-20
# of profitable trades	310	242	181	119	76	49
% of profitable trades	43.06%	45.40%	49.32%	50.85%	58.02%	60.49%
Mean	-0.0217	-0.0154	-0.0038	0.0006	0.0255	0.0393
Standard Deviation	0.1919	0.1873	0.1964	0.2085	0.2222	0.2626
Aggregate Profit	-15.6504	-8.2254	-1.3964	0.1310	3.3374	3.1816
t-value	-3.0401	-1.9025	-0.3711	0.0411	1.3124	1.3461

3:2:1 Long Crack Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction Fee (in $) = 0.05 $/barrel

Filter (in cents)	0	3	6	10	15	20
# of profitable trades	264	203	158	100	64	31
% of profitable trades	37.08%	38.52%	41.47%	46.30%	53.33%	63.27%
Mean	-0.0388	-0.0286	-0.0199	-0.0083	0.0071	0.0325
Standard Deviation	0.1622	0.1632	0.1691	0.1721	0.1795	0.2033
Aggregate Profit	-27.6588	-15.0930	-7.5712	-1.7870	0.8560	1.5928
t-value	-6.3888	-4.0284	-2.2933	-0.7063	0.4352	1.1190

3:2:1 Short Crack Trade Performance 1996-1999, Grouped by Filter Size

Net of Transaction Fee (in $) = 0.05 $/barrel

Filter (in cents)	0	-3	-6	-10	-15	-20
# of profitable trades	287	222	168	111	71	44
% of profitable trades	39.86%	41.65%	45.78%	47.44%	54.20%	54.32%
Mean	-0.0317	-0.0254	-0.0138	-0.0094	0.0155	0.0293
Standard Deviation	0.1919	0.1873	0.1964	0.2085	0.2222	0.2626
Aggregate Profit	-22.8504	-13.5554	-5.0664	-2.2090	2.0274	2.3716
t-value	-4.4388	-3.1354	-1.3464	-0.6925	0.7973	1.0034

* See Notes to Table III.

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The Crack Spread:
Day Trading the Oil Futures Complex

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ABSTRACT

This paper provides empirical evidence on the profitability of a day trading strategy based on open-to-close reversals in the crack spread relationship. The day trading strategy is found to be capable of identifying crack spread trading opportunities that are profitable after appropriate adjustment has been made for transactions costs. Empirical evidence is also provided on the components of the crack spread, confirming the seasonal price behavior observed in previous studies of heating oil and gasoline futures contracts. The profitability of the trading rule provides support for the hypothesis of price over-shooting in the crude oil futures market.

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ENDNOTES

1. The crack spread has received some attention in the trade literature, e.g., Szymczak (1988), Schap (1990, 1991).

2. Since 1984, the New York Mercantile Exchange (NYMEX) has allowed crack spreads to be traded in a single transaction. The only NYMEX (1989) requirement for crack spread trades is that the number of contracts of crude oil short (long) should be equal to the number of product futures contracts long (short). Thus, traders and refiners can design any crack spread ratios based on their own production yields as long as they fulfil the above balanced contract requirement.

3. For example, assume $X = 20$. If $\Delta CL = -25¢$, then $\{-\Delta CL\} = 25 > X$. A short crack spread would be placed. To see why the over-shooting hypothesis requires that $\Delta SV = -\Delta CL > X$ implies a short crack remember that the crude oil price enters the crack spread with a minus sign. If the crude oil price overshoots a ***fall*** in the equilibrium crack spread value then the spread will be favorable to refinery operations, the profitable position will be to buy the feedstock and sell the by-products, i.e., lock-in the refining margin. In the discussion of the trading strategy, long the crack spread would involve shorting crude oil at the open and then, five minutes later, going long the by-products at the opening prices for those contracts.

4. This is roughly consistent with Simon (1999) where a round trip transactions cost of $103.50 was used for a long term soy crush spread trade.

5. This point is illustrated by a market anecdote: 'The floor is in on the open and the public is in on the close'. This means that it is not possible for a off-exchange trader to effectively execute trades at the open. If the opening price persists, then the off-exchange trader could execute trades at the open but only traders on the floor can set the opening price. Modern technology has provided much closer access to opening price trading than previously, but it is still the case that the opening price is set by two (or more) traders on the exchange floor.