SEASONALITY IN PETROLEUM FUTURES SPREADS

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INTRODUCTION

The preponderance of the financial literature concerning spreads tends to focus on intracommodity and calendar spreads. It should be recognized, however, that there are a wide variety of other spreads that are interesting and economically and physically important. The petroleum futures spreads are high on the list among them. This article investigates both the underlying economic and statistical structures of petroleum futures spreads. Some of the petroleum futures spreads may exhibit significant periodicities that are exploitable by simple trading strategies. Therefore, the purpose of this paper is (i) to explore some of the statistical relationships of petroleum futures spreads, especially those related to seasonality in the spreads themselves, and (ii) to determine if the seasonal characteristics could have been profitably exploited through a few relatively simple—but robust—trading rules.

The relationship concerning intercommodity spreads can be complex and difficult to understand and there is a general lack of concrete theoretical foundation that can explain the behavior of these spreads. For this and other reasons, a number of researchers have conducted empirical studies to determine if there are profitable trading opportunities in intercommodity spread trading. Some of these studies include Treasury bills and Treasury bonds (Jones, 1981; Easterwood and Senchack, 1986); gold

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(Rolfo, 1981); gold and Eurodollar turtles (Poitras, 1987); gold and Treasury bill spreads (Monroe and Cohn, 1986); gold and silver spread (Wahab, Cohn, and Lashgari, 1994); Municipal bond and Treasury bond spreads (Arak, Fischer, Goodman, and Daryanani, 1987); index futures spreads (Stoll, 1988; Billingsley and Chance, 1988); soybean complex spreads (Johnson, Zulauf, Irwin, and Gerlow, 1991); spreads in agricultural futures (Barrett and Kolb, 1995); and petroleum futures spreads (Girma, 1994).

This article is concerned exclusively with petroleum futures crack spreads. Since 1984, the crack spread is traded as a single transaction on the New York Mercantile Exchange (NYMEX). 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). The NYMEX publishes booklets that show graphs of a series of crack spread prices for the more popularly traded crack spreads including the "3:2:1 Crack Spread"—three contracts of crude oil short (long), two contracts of unleaded gasoline long (short), and one contract of heating oil long (short); the "1:1:0 Gasoline Crack Spread"—one contract of crude oil short (long) and one contract of unleaded gasoline long (short); and the "1:0:1 Heating Oil Crack Spread"—one contract of crude oil short (long) and one contract of heating oil long (short).

However, these booklets do not provide statistical analysis of the behavior of these spreads over time. Furthermore, the behavior of crack spreads and their effectiveness in managing refiners' gross profit margin, a variation on one of the main objectives of this study, has not been investigated from a financial modeling point of view. Therefore, the purpose of this article is to study the statistical behavior of crack spreads, in particular trading month and trading week seasonality, and to determine if these seasonalities can be exploited using simple trading strategies.

LITERATURE REVIEW

Seasonality in heating oil and gasoline prices is a well-established fact. Supply and demand for these products are influenced by, among others, oncoming production, weather, political situations such as Organization of Petroleum Exporting Countries (OPEC)-generated turmoil (Deaves and Krinsky, 1992), and the economic environment in general. It is known that demand for gasoline peaks in the summer, while demand for heating oil peaks in the winter. Fluctuations and trends in the demand for these products will, of course, affect the demand for crude oil and, thereby, the behavior of the petroleum futures spreads.

Hirschfeld (1983) found that strong seasonality in heating oil, liquid propane, and gasoline and crude oil exhibits seasonality similar to gasoline but less pronounced as a result of the offsetting effects of heating oil. He also found that inventory build-up of heating oil for the winter season begins between June–July and reaches its peak in October–November, whereas this inventory bottoms out in February–March. Gasoline inventory levels peak in February–April and reach a trough in September–October (see also Teweles and Jones, 1987; Siegel and Siegel, 1990).

Cho and McDougall (1990) found that heating oil and unleaded gasoline provide strong support for the existence of a supply of storage curve, while crude shows weak support for the theory of a supply of storage curve. The authors attributed the strong support for the theory in the case of heating oil and unleaded gasoline to seasonal factors in the supply and demand of these markets. Similarly, Siegel and Siegel (1990) pointed out that the seasonality patterns of heating oil and gasoline production cause the two commodities to behave as a "pure asset" for part of the year and a "convenience asset" for the rest of the year.

Abken (1989) found that during winter months, the calendar spread in heating oil futures narrows and becomes negative indicating an inverted price structure or normal backwardation. Abken (1989) divided the data into two sample periods—winter (November–April) and summer (May–October)—finding that the winter subsample spread trades showed more positive profit than the summer subsample spread trades. Furthermore, the summer subsample trade returns were not significantly different from zero. The winter subsample trades—especially those trades long the spot month and the next nearby contract and short distant contracts—showed significantly positive returns at the $\alpha = 0.05$ level of significance. The summer subsample trading profits, however, were not significantly different from zero.

In summary, a review of the literature suggests the existence of structural relationships determined by supply and demand and other factors and that these structural relationships may permit exploitation by relatively simple trading rules.

DATA AND METHODOLOGY

The data used in modeling and testing the crack spread relationships consist of daily futures prices of crude oil and heating oil contracts from April 1983 to December 1994, and the unleaded gasoline contracts are from December 1984 to December 1994. Unleaded gasoline futures contracts began trading at the NYMEX in December 1984. "3:2:1 Crack

Spread" relationships and trading results are based on data from December 1984 through December 1994. Similarly, "1:1:0 Gasoline Crack Spread" relationships and trading results are based on data from December 1984 through December 1994. Finally, the "1:0:1 Heating Oil Crack Spread" relationships and trading results are based on data from April 1983 through December 1994. The data source is Dow Jones Information Services.

The time series used for this analysis is created by taking daily closing prices for one month from each contract that is deliverable in three months. Specifically, for each trading month the daily closing prices are collected from a contract that is deliverable in three months, and on the first day of the next trading month it will be rolled over to the next contract that is deliverable in three months. For example, if the trading month is January, the daily closing prices would be collected from the contract that is deliverable in April, and on the first day of February it will be rolled over to the contract that is deliverable in May. The choice of three-month contracts provides a high level of liquidity for all contracts and at the same time avoids the volatility known to exist when futures contracts reach their delivery month. Throughout this article trading month and trading week refer to the calendar month and calendar week of the year, respectively. In contrast, the contract month refers to the delivery month of the contract; e.g., the January 1992 crude oil contract refers to the crude oil contract that is deliverable in January 1992.

Since crude oil prices are quoted in terms of dollars per barrel, while unleaded gasoline and heating oil prices are quoted in terms of dollars per gallon, it is necessary to convert all three quotations into the same unit of measure. Therefore, all prices are measured in dollars per barrel, and there are 42 gallons per barrel. The computations of the various crack spreads are as follows:

$$\text{3:2:1 Crack Spread } (CS)_t = \frac{2}{3}(HU)_t + \frac{1}{3}(HO)_t - CL_t \qquad (1)$$

$$\text{1:1:0 Gasoline Crack Spread } (GCS)_t = (HU)_t - CL_t \qquad (2)$$

$$\text{1:0:1 Heating Oil Crack Spead } (HOCS)_t = (HO)_t - CL_t \qquad (3)$$

where the symbols *HU*, *HO*, and *CL* refer to unleaded gasoline, heating oil, and crude oil contracts, respectively. The subscript, t, refers to the time position in the time series; e.g., CL_t is the closing price of crude oil contract at time, t.

A number of statistical procedures are available to investigate the existence of seasonality in the crack spread. The simplest, and, at the same time, the most powerful is the statistical procedure of analysis of variance. Several analysis of variance models and spectral analyses lead to equivalent results and, in certain circumstances, it would be more efficient to use analysis of variance to study time-series characteristics such as periodicity or seasonality (Tukey, 1961). More recently, Gay and Kim (1987) used analysis of variance to show the existence of day of the week and calendar month effects in futures markets using the Commodity Research Bureau (CRB) futures index. The next section investigates the existence of seasonality in trading month of the year and trading week of the year in crack spreads using analysis of variance models.

Analysis of Variance

First, a one-way analysis of variance model is used to investigate the trading month and trading week effects, separately. The average crack spread, y_{ij}, of month (week), i, and year, j, computed from daily prices, can be expressed as

$$y_{ij} = \mu + \beta_i + \varepsilon_{ij} \tag{4}$$

where μ is the mean crack spread, β_i is the month (week) effect, and ε_{ij} is an error term normally distributed with mean zero. The parameter estimates, β_i, measures the average deviation of a given trading month's (week's) average crack spread from December's (week 52's) average crack spreads.

Then, a two-way analysis of variance model is used to investigate whether there are significant interactions between the trading month effects and the trading week effects. The appropriate structural model for the two-way analysis is

$$y_{ijk} = \mu + \beta_i + \gamma_j + (\beta\gamma)_{ij} + \varepsilon_{ijk} \tag{5}$$

where ε_{ijk} is normally distributed with mean zero, μ is the mean crack spread, and the average crack spread, y_{ijk}, of month, i, week, j, and year, k, is computed from daily prices. The parameters are defined as follows: β_i is the trading month effect, γ_j is the trading week effect, and $(\beta\gamma)_{ij}$ is the interaction between trading month and trading week effects.

Trading Month Effects

Table I provides a summary statistics for trading month of the year effects for the 3:2:1 crack spread, 1:1:0 gasoline crack spread, and 1:0:1 heating

TABLE I

Parameter Estimates for One-Factor Analysis of Variance: Trading Month Effects

Parameter	*3:2:1 Crack Spread* Estimates (Standard Error)	t-Value (p-Value)	*1:1:0 Gasoline Crack Spread* Estimates (Standard Error)	t-Value (p-Value)	*1:0:1 Heating Oil Crack Spread* Estimates (Standard Error)	t-Value (p-Value)
Intercept[a]	3.5062	63.66	3.1838	45.46	4.0876	77.38
	(0.0551)	(0.0001)	(0.0700)	(0.0001)	(0.0528)	(0.0001)
January	0.5785	7.50	1.3358	13.61	−0.8968	−12.11
	(0.0772)	(0.0001)	(0.0981)	(0.0001)	(0.0741)	(0.0001)
February	0.6668	8.40	1.7154	16.99	−1.4312	−18.80
	(0.0794)	(0.001)	(0.1010)	(0.0001)	(0.0761)	(0.0001)
March	0.8055	10.50	2.0010	20.51	−1.5881	−21.62
	(0.0767)	(0.0001)	(0.0976)	(0.0001)	(0.0735)	(0.0001)
April	1.0197	13.12	2.3218	23.50	−1.5374	−21.03
	(0.7770)	(0.0001)	(0.0988)	(0.0001)	(0.0731)	(0.0001)
May	0.8624	11.15	2.0126	20.46	−1.3283	−18.29
	(0.0773)	(0.0001)	(0.0983)	(0.0001)	(0.0726)	(0.0001)
June	0.3544	4.60	1.1035	11.26	−0.9901	−13.67
	(0.0771)	(0.0001)	(0.0980)	(0.0001)	(0.0724)	(0.0001)
July	−0.1313	−1.70	0.1721	1.75	−0.6297	−8.66
	(0.0774)	(0.0901)	(0.0985)	(0.0806)	(0.0728)	(0.0001)
August	−0.0476	−0.62	−0.0305	−0.31	0.0394	0.55
	(0.0765)	(0.5334)	(0.0972)	(0.7542)	(0.0718)	(0.5828)
September	0.0939	1.21	−0.1229	−1.24	0.6419	8.76
	(0.0779)	(0.2279)	(0.0991)	(0.2146)	(0.0732)	(0.0001)
October	0.0276	0.35	−0.4660	−4.68	1.0140	13.83
	(0.0784)	(0.7248)	(0.0997)	(0.0001)	(0.0733)	(0.0001)
November	0.0904	1.12	−0.2574	−2.51	0.7994	10.60
	(0.0808)	(0.2634)	(0.1027)	(0.0123)	(0.0754)	(0.0001)

Notes: In-sample data cover periods from April 1983 to March 1992 and include all contracts that were deliverable through April 1992.
[a]The intercept represents December average crack spread, and all the other months estimates are deviations from December's average crack spread.

oil crack spread. The results show that the null hypothesis that all trading month average crack spread effects are equal to zero is rejected at the $\alpha = 0.01$ level of statistical significance. Column 1 in Table I shows the parameters (trading month of the year), while columns 2 and 3 show the resulting estimates (standard errors of estimates are in parentheses) and the associated t-values (p-values are in parentheses), respectively. The parameter estimates, in Table I, measure the average monthly crack spread deviation from December's average crack spread.

Examination of the 3:2:1 crack spread estimates reveals that the parameter estimates for January through June are significantly greater than zero, and July's estimate is significantly less than zero at the $\alpha = 0.01$ level of statistical significance. On the other hand, parameter estimates for August through November are not significantly different from zero at any conventional level of statistical significance. Similar examination of the 1:1:0 gasoline crack spread parameter estimates and associated statistics, columns 4 and 5, shows that the parameter estimates for January through June are positive and statistically significant at the $\alpha = 0.01$ level of significance, and July's estimate is positive and significant at the $\alpha = 0.10$ level of statistical significance. In contrast, the parameter estimates for August through November are negative, but only October and November estimates are significant at the $\alpha = 0.01$ and $\alpha = 0.05$ levels of statistical significance, respectively. Finally, the 1:0:1 heating oil crack spread parameter estimates and associated statistics, columns 6 and 7, show that the estimates for January through July are negative and statistically significant at the $\alpha = 0.01$ level of significance. The remaining trading month estimates are positive and statistically significant (except August) at the $\alpha = 0.01$ level of significance.

The authors performed multiple comparison tests, not shown here, which reinforce the findings of statistically significant presence of seasonality in trading month average crack spreads shown in Table I. The level of statistical significance for the following discussion is all based on $\alpha = 0.05$ using Scheffe's multiple comparison test procedure. First, the 3:2:1 crack spread trading month averages reach a peak in April and a trough in July, and both are statistically significant. Second, the 1:1:0 gasoline crack spread trading month averages show a peak in April and reach a trough in October. The April average gasoline crack spread is significantly greater than any other trading month's average gasoline spread. The average October gasoline crack spread is the lowest and statistically significant except for September and November. The gasoline crack spread seasonality seems to parallel the seasonality of gasoline inventory levels. Finally, the 1:0:1 heating oil crack spread seasonal behavior is almost a mirror image of the 1:1:0 gasoline crack spread. The heating oil crack spread trading month averages peak in October and reach trough in March, paralleling the heating oil inventory cycle.

The analysis of periodicity based on trading month averages provides compelling evidence that a strong seasonality exists in crack spreads. However, the trading month average time horizon may be too long for a trading strategy to exploit these apparent seasonalities. Therefore, it is necessary to examine a shorter time interval such as weekly averages to ascertain whether weekly cross-sectional averages have structural periodicity.

Trading Week Effect

Table II provides summary statistics for trading week of the year effects for the 3:2:1 crack spread, 1:1:0 gasoline crack spread, and 1:0:1 heating oil crack spread. The parameter estimates in Table II measure the deviation of a given week's average crack spread from calendar week 52's average crack spread. The results show that the null hypothesis that all trading week average crack spread effects are equal to zero is rejected at the $\alpha = 0.01$ level of statistical significance. Column 1 in Table II shows the parameters (trading week of the year), while columns 2–5 show the resulting estimates, t-values, p-values, and standard errors of estimates (SEE) for the 3:2:1 crack spread. Similarly, columns 6–9 and columns 10–13 show the parameter estimates, t-values, p-values, and SEE for the 1:1:0 gasoline crack spread and 1:0:1 heating oil crack spread, respectively. The results in Table II show that the structure can be characterized as a periodicity.

For example, in Table II, the 3:2:1 crack spread trading week average estimates show that the highest spread is in week 16, whereas the lowest spread occurs in week 31. Notice that the peak in weekly average crack spread occurs in April and the trough for the weekly average crack spread occurs in late July and these results are consistent with the finding of trading month effects for the 3:2:1 crack spread. Therefore, Table II suggests from an elementary perspective that if a trader takes a short position in the 3:2:1 crack spread in week 16 and closes the position in week 31, the trader will, theoretically, realize a profit of \$4236 (e.g., \$1.4119*3000) on a (rough) average basis. This simple strategy is intriguing, although a more complex trading strategy merits additional investigation. Specifically, can a trader use such a simple strategy of buy (sell) in week, w_1 and sell (buy) in w_2 to generate a reasonable profit, based on historical periodicity?

Table III summarizes the two-way analysis of variance results of trading month effects while controlling for trading week effects, and the interaction between trading month and trading week effects. The hypothesis being tested is that all $\beta_i = 0$, $\gamma_j = 0$, and $(\beta\gamma)_{ij} = 0$. The hypothesis is rejected at the $\alpha = 0.01$ level of statistical significance for all three crack spreads.

The trading month effects, β_i, are significantly greater than zero when controlling for the effect of trading week and interaction at the α

TABLE II

Parameter Estimates for One-Factor Analysis of Variance: Trading Week Effects

	3:2:1 Crack Spread				1:1:0 Gasoline Crack Spread				1:0:1 Heating Oil Crack Spread			
Parameter	*Estimate*	*t-Value*	*p-Value*	*SEE*	*Estimate*	*t-Value*	*p-Value*	*SEE*	*Estimate*	*t-Value*	*p-Value*	*SEE*
Intercept Week[a]	3.39	21.04	0.0001	0.1611	3.12	15.24	0.0001	0.2050	3.99	26.38	0.0001	0.1513
0	0.71	2.94	0.0033	0.2424	1.41	4.56	0.0001	0.3083	−0.83	−3.67	0.0002	0.2253
1	0.68	3.46	0.0006	0.1960	1.34	5.37	0.0001	0.2493	−0.73	−3.95	0.0001	0.1859
2	0.75	3.82	0.0001	0.1960	1.46	5.85	0.0001	0.2493	−0.75	−4.06	0.0001	0.1859
3	0.62	3.14	0.0017	0.1960	1.34	5.38	0.0001	0.2493	−0.91	−4.91	0.0001	0.1859
4	0.79	4.01	0.0001	0.1960	1.61	6.47	0.0001	0.2493	−0.99	−5.32	0.0001	0.1859
5	0.82	4.19	0.0001	0.1960	1.86	7.46	0.0001	0.2493	−1.37	−7.37	0.0001	0.1859
6	0.70	3.59	0.0003	0.1960	1.66	6.66	0.0001	0.2493	−1.35	−7.27	0.0001	0.1859
7	0.81	3.98	0.0001	0.2029	1.78	6.89	0.0001	0.2581	−1.28	−6.64	0.0001	0.1927
8	0.78	3.94	0.0001	0.1974	1.77	7.04	0.0001	0.2510	−1.33	−7.10	0.0001	0.1871
9	0.80	4.09	0.0001	0.1960	1.92	7.69	0.0001	0.2493	−1.53	−8.24	0.0001	0.1859
10	0.85	4.34	0.0001	0.1960	1.97	7.90	0.0001	0.2493	−1.52	−8.17	0.0001	0.1859
11	1.02	5.20	0.0001	0.1967	2.17	8.67	0.0001	0.2502	−1.42	−7.61	0.0001	0.1865
12	1.12	5.67	0.0001	0.1974	2.33	9.28	0.0001	0.2510	−1.44	−7.69	0.0001	0.1871
13	1.05	5.31	0.0001	0.1981	2.26	8.95	0.0001	0.2519	−1.49	−7.97	0.0001	0.1865
14	1.07	5.40	0.0001	0.1974	2.26	9.02	0.0001	0.2510	−1.43	−7.75	0.0001	0.1843
15	1.14	5.76	0.0001	0.1974	2.40	9.55	0.0001	0.2510	−1.47	−7.96	0.0001	0.1848
16	1.25	6.39	0.0001	0.1960	2.59	10.38	0.0001	0.2493	−1.45	−7.93	0.0001	0.1833
17	1.12	5.71	0.0001	0.1967	2.35	9.39	0.0001	0.2502	−1.38	−7.50	0.0001	0.1837
18	0.98	5.00	0.0001	0.1960	2.05	8.23	0.0001	0.2493	−1.25	−6.80	0.0001	0.1833
19	0.98	5.02	0.0001	0.1960	2.06	8.25	0.0001	0.2493	−1.22	−6.67	0.0001	0.1833
20	0.93	4.76	0.0001	0.1960	2.02	8.09	0.0001	0.2493	−1.20	−6.53	0.0001	0.1833
21	0.84	4.18	0.0001	0.2012	1.86	7.26	0.0001	0.2558	−1.15	−6.12	0.0001	0.1877
22	0.59	3.00	0.0027	0.1981	1.30	5.17	0.0001	0.2519	−0.82	−4.40	0.0001	0.1853
23	0.42	2.14	0.0324	0.1960	1.12	4.48	0.0001	0.2493	−0.99	−5.38	0.0001	0.1833
24	0.49	2.50	0.0124	0.1960	1.18	4.72	0.0001	0.2493	−0.87	−4.73	0.0001	0.1833
25	0.45	2.29	0.0223	0.1960	1.15	4.61	0.0001	0.2493	−0.92	−5.01	0.0001	0.1833
26	0.12	0.62	0.5383	0.2029	0.53	2.04	0.0413	0.2581	−0.70	−3.71	0.0002	0.1883
27	0.03	0.16	0.8699	0.1981	0.33	1.30	0.1934	0.2519	−0.59	−3.17	0.0015	0.1853
28	0.03	0.16	0.8766	0.1960	0.29	1.15	0.2502	0.2493	−0.48	−2.63	0.0085	0.1833
29	−0.09	−0.47	0.6408	0.1960	0.11	0.45	0.6548	0.2493	−0.52	−2.84	0.0045	0.1833

TABLE II (Continued)

Parameter Estimates for One-Factor Analysis of Variance: Trading Week Effects

	3:2:1 Crack Spread				1:1:0 Gasoline Crack Spread				1:0:1 Heating Oil Crack Spread			
Parameter	Estimate	t-Value	p-Value	SEE	Estimate	t-Value	p-Value	SEE	Estimate	t-Value	p-Value	SEE
30	−0.11	−0.54	0.5913	0.1960	0.04	0.16	0.8753	0.2493	−0.42	−2.28	0.0229	0.1833
31	−0.16	−0.81	0.4166	0.1960	−0.21	−0.83	0.4077	0.2493	−0.07	−0.38	0.7060	0.1833
32	0.00	0.00	0.9993	0.1960	−0.01	−0.05	0.9594	0.2493	0.02	0.10	0.9168	0.1833
33	0.37	1.88	0.0603	0.1960	0.34	1.35	0.1778	0.2493	0.43	2.34	0.0196	0.1833
34	0.15	0.76	0.4480	0.1960	0.07	0.28	0.7773	0.2493	0.28	1.54	0.1228	0.1833
35	0.18	0.91	0.3648	0.1995	−0.07	−0.27	0.7843	0.2538	0.61	3.25	0.0012	0.1865
36	0.28	1.38	0.1679	0.1995	0.03	0.10	0.9194	0.2538	0.72	3.86	0.0001	0.1865
37	0.20	1.03	0.3022	0.1960	−0.05	−0.18	0.8559	0.2493	0.71	3.85	0.0001	0.1833
38	0.18	0.91	0.3610	0.1960	−0.18	−0.73	0.4643	0.2493	0.94	5.15	0.0001	0.1833
39	0.15	0.75	0.4549	0.1960	−0.28	−1.11	0.2690	0.2493	0.99	5.38	0.0001	0.1833
40	0.06	0.32	0.7499	0.1995	−0.53	−2.10	0.0363	0.2538	1.12	6.03	0.0001	0.1859
41	0.20	0.98	0.3264	0.1995	−0.37	−1.47	0.1428	0.2538	1.17	6.28	0.0001	0.1859
42	0.17	0.83	0.4067	0.1995	−0.33	−1.29	0.1957	0.2538	1.02	5.51	0.0001	0.1859
43	0.12	0.62	0.5366	0.1996	−0.33	−1.30	0.1953	0.2538	0.90	4.82	0.0001	0.1859
44	0.24	1.19	0.2327	0.1995	−0.15	−0.59	0.5534	0.2538	0.93	5.01	0.0001	0.1859
45	0.19	0.95	0.3405	0.1995	−0.21	−0.82	0.4103	0.2538	0.92	4.94	0.0001	0.1859
46	0.25	1.26	0.2084	0.2012	−0.13	−0.50	0.6192	0.2558	0.89	4.71	0.0001	0.1883
47	0.11	0.53	0.5973	0.2118	−0.32	−1.19	0.2333	0.2694	0.84	4.27	0.0001	0.1963
48	0.20	1.04	0.3000	0.1960	0.12	0.46	0.6423	0.2493	0.22	1.16	0.2463	0.1859
49	0.10	0.50	0.6154	0.1960	0.05	0.19	0.8524	0.2493	0.05	0.24	0.8083	0.1859
50	0.03	0.17	0.8631	0.1960	−0.05	−0.19	0.8493	0.2493	0.04	0.21	0.8323	0.1859
51	0.20	0.95	0.3429	0.2069	0.14	0.55	0.5846	0.2632	0.16	0.84	0.4010	0.1953

Notes: In-sample data cover periods from April 1983 to March 1992 and include all contracts that are deliverable through April 1992.
[a]The intercept represents the average crack spread for week 52 and all other estimates are deviations from wk 52's average crack spread.

TABLE III

Summary Statistics of Analysis of Variance: Trading Month Effects, Trading Week Effects, and Interaction Effects

Source	*DF*	*Sum of Squares*	*Mean Squares*	*f-Value*	*p-Value*
		A. 3:2:1 Crack Spread			
Trading month	11	12.42	1.13	1.82	0.0457
Trading week	52	37.00	0.71	1.15	0.2215
Month (week)	6	1.31	0.22	0.35	0.9098
		B. 1:1:0 Gasoline Crack Spread			
Trading month	11	37.10	3.37	3.38	0.0001
Trading week	52	77.43	1.49	1.49	0.0131
Month (week)	6	1.55	0.26	0.26	0.9557
		C. 1:0:1 Heating Oil Crack Spread			
Trading month	11	43.83	3.98	6.39	0.0001
Trading week	52	49.25	0.95	1.52	0.0101
Month (week)	6	1.38	0.23	0.37	0.8988

= 0.01 level of statistical significance for the 1:1:0 gasoline crack spread (Table IIIB) and the 1:0:1 heating oil crack spread (Table IIIC), and at the $\alpha = 0.05$ level of significance for the 3:2:1 crack spread (Table IIIA). The trading week effects, γ_j, are greater than zero when controlling for trading month effects and interaction at the $\alpha = 0.05$ level of statistical significance for the 1:1:0 gasoline crack spread (Table IIIB) and the 1:0:1 heating oil crack spread (Table IIIC). For the 3:2:1 crack spread (Table IIIA), the trading week effect is not significantly different from zero when controlling for the trading month effects and the interaction. Finally, the interaction effect is not significantly different from zero for all three crack spreads. If the interaction effects were significant, no conclusion could be made for the individual effects alone; therefore, the conclusion would only be stated in terms of joint effects of trading month and trading week (see Box, Hunter, and Hunter, 1978). Since the interactions between trading month and trading week effects are not statistically significant, the result of trading month parameter estimates and trading week parameter estimates can be used separately or jointly in developing trading strategies.

TRADING STRATEGIES

This section examines simple buy (sell) and hold trading strategies to test if the observed seasonalities can be exploited for profitable purposes. Spe-

TABLE IV

Possible Trade Entry Weeks

	Enter Long Trade	*Enter Short Trade*
3:2:1 crack spread	Weeks 28–32	Weeks 13–17
1:1:0 gasoline crack spread	Weeks 39–43	Weeks 12–17
1:0:1 heating oil crack spread	Weeks 9–13	Weeks 39–43

cifically, the profitability of six holding periods' trading strategies are investigated occurring at 3, 5, 8, 10, 12, and 15 weeks, respectively. Analysis of seasonalities, in the last section, indicates that a long (short) position in crack spread can be profitable when the spread is at a trough (peak). On the basis of this analysis, a summary of one set of possible trade entry weeks for long (short) trades is developed and is shown in Table IV. The basic strategy is to take a long position in crack spreads (buy refined product(s) and sell crude oil) in those weeks where crack spreads are lowest and take a short position in crack spreads (sell refined product(s) and buy crude oil) in the weeks where crack spreads are highest, and hold the position for a specified holding period and then unwind. In addition, the following criteria have to be met before taking a long (short) position in crack spread. First, take only one long (short) position at a time on any given contract. Second, select those contracts that are deliverable after the holding period expires to avoid a forced closure and rolling over to another contract. Third, for long (short) positions, select the contract with the lowest (highest) spread and that also meets the above criteria. Fourth, long (short) trades are spread over a five- to six-week period around the peak (trough) and only one position per week is taken. Finally, since the decision to enter a trade is made based on the average weekly crack spread, the mid-week is judged to be the appropriate time to enter and exit trades, and all entries and exits are made on Wednesday.

The above strategy has two components. The first uses the in-sample data to test if the observed seasonalities can be exploited using the trade entry points listed in Table IV. The second uses the same entry weeks that were used for in-sample trade (Table IV) to find out if historical peaks and troughs can be employed to conduct profitable trades outside of the learning period. The out-of-sample data are used to address the second component and to compare the profitability of in-sample and out-of-sample trades. In both cases the same trade entry weeks are used and they are fixed for all the years in question. The outcomes of these trades are reported by holding period as shown in Table V.

TABLE V

Results of Simple Buy (Sell) and Hold Trading Strategies Where All Entry Weeks Are Fixed for All Trading Years

	Holding Periods					
	3 weeks	*5 weeks*	*8 weeks*	*10 weeks*	*12 weeks*	*15 weeks*
	A. In-Sample Trading Results (April 1983–March 1992)					
3:2:1 CS						
Average profit	$451	$817	$905	$1056	$1035	$843
SD	2403	2181	1788	1622	1673	2457
Number of trades	70	69	65	65	58	56
t-Value	1.57	3.12	4.08	5.25	4.71	2.57
1:1:0 GCS						
Average profit	−$33	$201	$105	$537	$919	$874
SD	1830	1879	2244	2267	2476	3426
Number of trades	77	72	67	67	58	58
t-Value	−0.15	0.91	0.38	1.94	2.83	1.94
1:0:1 HOCS						
Average profit	$266	$203	$477	$463	$246	$394
SD	1542	1649	2103	2351	2315	2446
Number of trades	86	84	81	81	76	76
t-Value	1.60	1.10	2.04	1.77	0.93	1.40
	B. Out-of-Sample Trading Results (May 1992–December 1994)					
3:2:1 CS						
Average profit	$424	$278	−$59	$647	$740	$718
SD	814	615	2543	1145	1063	1449
Number of trades	31	29	28	28	25	25
t-Value	2.902	2.433	−0.123	2.989	3.482	2.477
1:1:0 GCS						
Average profit	$328	$90	$152	$190	$403	$928
SD	897	867	908	2118	1102	1433
Number of trades	33	32	31	31	29	29
t-Value	2.099	0.585	0.929	0.499	1.966	3.486
1:0:1 HOCS						
Average profit	$242	$567	$401	$386	$178	−$142
SD	1355	1016	919	1267	1224	1457
Number of trades	32	30	30	30	29	29
t-Value	0.133	3.060	2.390	1.670	0.783	−0.526

Notes: CS = crack spread; GCS = gasoline crack spread; HOCS = heating oil crack spread. In-sample trades include all contracts deliverable through April 1992 and out-of-sample trades include all contracts deliverable from May 1992 to December 1994.

Trading Results

Ranges of profitability in the crack spreads shown in Table V are quoted in dollars; the profits are based on the sale (purchase) of three crude oil contracts and the purchase (sale) of an appropriate number of heating oil and unleaded gasoline contracts. (The NYMEX specification for one contract of crude oil is 1000 barrels, and one contract of heating oil and one contract of unleaded gasoline is 42,000 gallons each). For example, profits for a long position in the 3:2:1 crack spread are measured as follows:

$$\$Profit = 3000\left\{\frac{1}{3}(HO_t - HO_0) + \frac{2}{3}(HU_t - HU_0) - (CL_t - CL_0)\right\}$$

where HU_t, HO_t, and CI_t are the prices of unleaded gasoline, heating oil, and crude oil at the time of unwinding, and HU_0, HO_0, and CL_0 are the prices of unleaded gasoline, heating oil, and crude oil at the entry time of trade, respectively.

The results of these simple trading strategies for in-sample data and out-of-sample data are summarized in Table V. If the markets for petroleum futures are efficient, the 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.

The results of the holding period trading strategies are shown in two parts: Table VA shows the in-sample trading results and Table VB shows the out-of-sample trading results. Table VA shows that crack spread seasonal trades, on average, generate gross positive profits for all holding periods, except the 1:1:0 gasoline crack spread three-week holding period (measured before transaction costs). Here it can be seen that the average gross profits per trade for the 3:2:1 crack spread and the 1:1:0 gasoline crack spread are generally increasing with increasing holding period, except for the 1:1:0 gasoline spread eight-week holding period profit. The 1:0:1 heating oil crack spread average gross profits per trade are positive and tend to be high for eight-week and ten-week holding periods and lower for other holding periods. The null hypothesis that the average trading profit is zero can be rejected for the 3:2:1 crack spread at the $\alpha = 0.01$ level of statistical significance for all holding periods longer than three weeks. In all cases, the t-value is computed in the usual way, i.e., t = (average profit)/[standard deviation/(number of trades)$^{1/2}$]. The 1:1:0 gasoline crack spread average gross profits per trade are significant at the $\alpha = 0.01$ level of statistical significance for 12-week holding periods, and the 10-week and 15-week average holding period profits per trade are significant at the $\alpha = 0.10$ level of significance. In contrast, for the 1:0:1 heating oil crack spread only the eight-week and ten-week holding period average profits per trade are significant at the $\alpha = 0.01$ and $\alpha = 0.10$ levels of significance, respectively; all other holding period profits are not significantly different from zero. Overall, the in-sample trading results in Table VA show that simple buy (sell) and hold strategies are highly profitable especially for the 3:2:1 crack spread. The 1:1:0 gasoline spread trades are profitable for holding periods greater than eight weeks, while the 1:0:1 heating oil spread trades are profitable in the intermediate holding periods. When average transaction costs, per round-turn, of $100 are subtracted from the average profit per trade, the 3:2:1 crack spread average profits per trade are still significantly greater than zero at the α = 0.01 level of statistical significance for all holding periods greater than three weeks. The 1:1:0 gasoline crack spread average profits per trade are also significant at α = 0.01 and α = 0.10 for 12-week and 15-week holding periods, respectively. On the other hand, the 1:0:1 heating oil crack spread average profits after transaction costs are not significant at the α = 0.10 level of statistical significance.

Table VB shows the out-of-sample trading results of the strategies by taking long (short) positions on crack spreads in the entry weeks shown in Table IV. The profitability of the out-of-sample trades is very similar to the in-sample trading results with two exceptions. First, the 3:2:1 crack spread shows a negative average profit per trade for the eight-week holding period, a positive profit for the five-week holding period but not significant, and a positive and significant profit for the three-week holding period. On the other hand, the 1:0:1 heating oil crack spread shows, on average, a negative profit per trade for the 15-week holding period and a significantly positive average profit per trade at the α = 0.01 level of statistical significance for the five-week holding period. Second, the standard deviations of the profits are much lower for the out-of-sample trades than for the in-sample trades. Examination of actual trades reveals that the higher standard deviation of the in-sample trades is primarily the result of oil shocks in 1986 and 1990. The 3:2:1 crack spread average profits per trade, after transaction costs of $100 per round-turn trade, are significantly different from zero at the α = 0.01 level of statistical significance for all holding periods except the five-week and eight-week holding periods. Similarly, the 1:1:0 gasoline crack spread average profits per trade for the 15-week holding periods and the 1:0:1 heating oil crack spread average profits per trade for the 5-week holding periods are significantly greater than zero at the α = 0.01 level of statistical significance.

In summary, analysis of Table V shows that statistically significant profits can be generated using simple buy (sell) and hold strategies based on a study of long-term periodicity. First, the 3:2:1 crack spread average profit per trade, after transaction costs of $100 per trade, is significantly greater than zero at α = 0.01 in four of six holding periods. Second, the

1:1:0 gasoline spread out-of-sample average profit per trade, after transaction costs, is also significant at $\alpha = 0.01$ in one of six holding periods. In contrast, the in-sample period average profits are significant at $\alpha = 0.01$ in two of six holding periods. Finally, the 1:0:1 heating oil crack spread in-sample average profit per trade, after transaction costs, is not significant at $\alpha = 0.10$ for all holding periods, whereas the out-of-sample period average profit per trade is significant at $\alpha = 0.10$ in two of six holding periods.

CONCLUSIONS

This research shows that there is a structurally significant periodicity in petroleum futures spreads. It also demonstrates that historically simple buy (sell) and hold trading strategies can be profitable and in many instances are significantly greater than zero after transaction costs of $100 for round-turn trade are taken into account. For example 3:2:1 crack spread in-sample trades are significantly profitable for all holding periods greater than three weeks at the $\alpha = 0.01$ level of statistical significance. The 1:1:0 gasoline crack spread in-sample trades (average profits per trade) are significantly different from zero at the $\alpha = 0.10$ level of significance for holding periods greater than ten weeks. Thus, the 1:1:0 gasoline crack spread trading results are more likely to be profitable if longer holding periods are used. In contrast, the 1:0:1 heating oil crack spread in-sample trading profits are not significant at the $\alpha = 0.10$ level of statistical significance.

The profitability of the out-of-sample trades, after transaction costs of $100 per round-turn trade, is similar to the profitability of the in-sample trades with the following exception. First, the 3:2:1 crack spread out-of-sample trades show significant profits for a three-week holding period and a loss for an eight-week holding period. Second, the 1:0:1 heating oil crack spread out-of-sample trades show significant profits at the $\alpha = 0.01$ level of statistical significance for five-week holding periods and at $\alpha = 0.10$ for eight-week holding periods. Third, the variances of the out-of-sample trading profits are much lower than the variances of the in-sample trading profits, and the higher variance of the in-sample trading profits is due primarily to the 1986 and 1990 oil shocks. Finally, because relatively naive and simple trading strategies can be profitable, it is likely that more sophisticated analyses might produce even better results.

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