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THE INTRADAY VARIABILITY OF SOYBEAN FUTURES PRICES: INFORMATION AND TRADING EFFECTS

BY

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The ideas expressed in this article are those of the authors, not the Commodity Futures Trading Commission.

Abstract

THE INTRADAY VARIABILITY OF SOYBEAN FUTURES PRICES: INFORMATION AND TRADING EFFECTS

The variance of soybean futures prices is more than thirty percent higher early and late in the trading day than during the middle of the day. The pattern may be caused by patterns in information arrival or by noise introduced by the very process of trading. In empirical tests, higher variance early in the day is found to be related to information released while the market is closed. Higher variance near the end of the day is found to be unrelated to information effects, but there is evidence that it is due to trading noise.

THE INTRADAY VARIABILITY OF SOYBEAN FUTURES PRICES: INFORMATION AND TRADING EFFECTS

I. Introduction

The variance of soybean futures prices is more than thirty percent higher in the first and last forty-five minutes of trading than during the middle of the trading day. Although this pattern has been noted before,[1] it has been neither explained nor related to studies on price variance in other markets.[2] In this paper, the variance pattern is thoroughly documented and explanatory hypotheses are tested.

A plausible explanation for the relatively high variance early in the day is the incorporation in prices of information (public and private) generated since the previous day's close of trading. Harris (1986) suggests a similar interpretation for the early-day portion of a "U-shaped" pattern observed in intraday stock return variances. Several public information releases affecting the soybean market allow tests of this hypothesis. If information is the source of the high early variance, then the early variance would be relatively higher on the mornings after these releases. Also, the early variance might be relatively higher on Monday mornings if more information is routinely generated during weekends than during weekday close-to-open periods.

The relatively high variance late in the day is less readily attributable to information. For example, there are no relevant public information releases just prior to the last forty-five minutes of trading. Two alternative hypotheses come to mind. First, perhaps information (public and private) generated during the day is not incorporated into prices until late in the day. Several possible reasons for this are suggested in the paper and this hypothesis is tested. Second, perhaps the very process of trading induces volatility through pricing errors, or noise, as suggested by French and Roll (1986). A source of additional noise late in the day is informationless trading by scalpers, traders who routinely close out positions in order to avoid holding positions overnight. The covariance of successive price changes is the basis for a test of this hypothesis.

In the next section the data and methodology are described. In Section III, the intraday variance pattern is shown and hypotheses to explain it are developed and tested. Section IV is a conclusion.

II. Data and Methodology

The Chicago Board of Trade Information Systems Department maintains computer-tape records of the times and prices at every price change, as reported by pit reporters. These data, known as the "Time and Sales File," were obtained for all soybean contracts traded during the period January 1978 through October 1984. During this period seven contract months were trading, January, March, May, July, August, September and November. The results reported here are based on the intraday prices for the next-expiring soybean futures contract in the two months prior to the delivery month, beginning with the March 1978 contract and ending with the November 1984 contract. Only transaction prices were used. The trading day for soybeans futures lasts 225 minutes, from 9:30 a.m. until 1:15 p.m (Central Time). For this study, the trading day was divided into five equal periods of 45 minutes each.[3]

Two questions are of primary interest: On average, is the variability greater in some intraday periods than in others, and, if so, is the relative variability between intraday periods different on certain days due to identifiable factors, such as the arrival of information? The estimated variance of price changes within each period, each day, is taken as the measure of variability. Relative variability between periods each day is measured by the ratios of variances in periods 1, 2, 4 and 5 to the variance in period 3.[4]

Because neither the variances nor the variance ratios are likely to be normally distributed, the non-parametric Kruskal-Wallis test (Lapin (1973)) is the primary test used to determine statistical significance. For this test, the variances or variance ratios are ranked, and the mean rank score within a category (e.g., intraday period) is calculated as the squared sum of the ranks in the category divided by the number of observations in the category. A statistic based on the mean rank score is distributed as a chi-square statistic with degrees of freedom equal to the number of categories minus one.

Parametric tests are also used, under the assumption that the large sample size mitigates the non-normality problem. These tests are based on ordinary least squares regression models with dummy variables for categories.

III. The Pattern of Intraday Variability

A. The Basic Pattern

The basic pattern of intraday variability is shown in Table 1. The mean variances, as shown in the third column of the table, follow a "U-shaped" pattern. As shown by the mean variance ratios in the sixth column, on average the variance in the first and last periods is thirty-six and thirty-one percent, respectively, greater than the midday variance. The mean rank scores of the variances and the variance ratios correspond to the pattern of the means. The null hypotheses,

$$H_o\colon \ \bar{v}_1 = \bar{v}_2 = \bar{v}_3 = \bar{v}_4 = \bar{v}_5 \ , \qquad (1)$$

and

$$H_o\colon \ \frac{\bar{v}_1}{\bar{v}_3} = \frac{\bar{v}_2}{\bar{v}_3} = \frac{\bar{v}_3}{\bar{v}_3} = \frac{\bar{v}_4}{\bar{v}_3} = \frac{\bar{v}_5}{\bar{v}_3} \qquad (2)$$

where $\bar{v}_i$, i = 1, . . ., 5, is the mean variance in period i, are rejected at high levels of significance by the non-parametric test.

Parametric tests are reported in Table 2. The regression models are

$$v_{it} = a_3 + a_1 D_{1t} + a_2 D_{2t} + a_4 D_{4t} + a_5 D_{5t} + e_{it} \qquad (3)$$

and

$$\frac{v_{it}}{v_{3t}} = b_1 + b_2 D_{2t} + b_4 D_{4t} + b_5 D_{5t} + u_{it} \; . \qquad (4)$$

In (3) and (4), the subscripts indicate the intraday period. Thus in (3), the intercept is the period three mean variance; in (4) the intercept is the period one mean variance ratio. D_{it} is the dummy variable for period i on day t and v_{it} is the variance in period i on day t.

The F test for the joint significance of the coefficients from these regressions confirm the non-parametric result of rejection of the hypotheses of equal variances and variance ratios. In model (3) the t tests show that the period one and period five variances are significantly higher than the period three variance and that the period two and period four variances are not significantly different from the period three variance. In model (4), the t-tests show that the period one variance ratio is significantly different from the variance ratio in each other period. Also, the additional F-tests in model (4) show that the period five variance ratio is significantly different from the period 2 and the period 4 variance ratio.

B. Explanations of Higher Variability Near the Opening

Possible explanations of the variability pattern involve the pattern of information arrival, market continuity and market efficiency. In an efficient market, prices change only in response to new information. However, a great deal of information is generated when U.S. futures markets are closed, and although some limited around-the-clock trading opportunities exist in certain markets (see Lachenaver (1986) and Powers (1983)), futures prices can fully reflect available information only after the market opens.

In such discontinuous markets, the amount of information to be absorbed and reflected in the price would, on average, be greater at the opening than at other times during the day. Unless the information gets fully reflected in the opening price or price range (which is not included in the variance estimate in this study), the price variance would be higher early in the day than during the rest of the day. Thus, the absence of a continuous market may be a simple explanation of at least the early-day portion of the variability pattern.

The idea of continuous information and discontinuous markets leads to additional tests for information as the source of the higher early-day variability. Clearly, certain types of information are more nearly continuous than others. These include public information (in French and Roll's nomenclature) such as changes in the weather and political events as well as private information such as the quantity of grain arriving at elevators. This type of information continues to develop on market holidays and weekends, and thus may result in a greater accumulation of information to be reflected in prices on Monday mornings than on other weekdays. French and Roll document this effect with interday data, although the increase in variance due to this effect is less than they expect. For example, they find that the variances of returns on a large sample of common stocks from Friday close to Monday close is 10.7% greater than the variance of weekday close-to-close returns, on average. Similarly, a greater ratio of period 1 to period 3 variance might be expected on Monday morning in futures markets because of the greater amount of continuously-developing information to be absorbed.

However, much information is not generated and disseminated continuously but is a function of social institutions such as "nine-to-five" workdays. The major information generators and disseminators for the soybean market (both public and private) work a five-day week in the U.S. Non-continuous information added to continuously-developing information may cause relatively high variances in period 1 on days other than Mondays.

Six such non-continuously generated information series are relevant to the soybean market. Both the USDA weekly Soybean Export Sales Report and the weekly Soybean Crush Report from the National Soybean Processors Association are released after the close of the soybean futures market on Thursday. The USDA also releases four reports on a less regular basis. The Crop Production Report is released once a month in August through November, usually around the 9th through 12th of the month. The quarterly grain stocks report occurs in January, April, June and October, on various days of the week. The Prospective Planting Report is released monthly, January through April, usually on Monday or Thursday. The Agricultural Supply and Demand Report is released monthly, on various days of the week. The dates of each of these reports during the study period were obtained.

If the greater variance in period 1 is the result of the market's adjustment to information developed while the market is closed, then the average variance ratio in period 1 should be greater on Mondays, Fridays (following the export Sales and Crush Reports) and on the days following the other reports. Also, on these days the later periods either would not have higher average variance or the average variance would decline from the high level of period 1.[5]

Table 3 shows the variance ratios by intraday period for Mondays, days following reports and all other days. The Mondays following Friday reports are included in the Report category rather than the Monday category. Thus, the Monday variance ratio reflects only the typical accumulation of weekend information, not information contained in reports.

On Mondays and on days following reports the first period mean variance ratio is approximately ten percent higher than the first period mean variance ratio on other days. The non-parametric test rejects the hypothesis that the variance ratios in the first period are equal. For the other intraday periods, the variance ratios are more nearly equal for all days, and the test fails to reject the equality hypothesis.

It is interesting that the first period variance ratios for Mondays and days following reports are approximately equal, an indication that, on average, the price effect of weekend information equals the price effect of the reports. Also, the fact that period 2 variance ratios on Mondays and days following reports are not statistically higher than period 2 variance ratios on other days indicates that the market fully reflects the information within the first period.

Regression tests of the information effect are reported in Table 4. The regression model is

$$\frac{v_{it}}{v_{3t}} = a_o + a_1 \text{ Monday} + a_2 \text{ Report} + e_{it} \quad , \tag{5}$$

where Monday and Report are dummy variables for Mondays and days following report days, respectively. The regression was run separately for each intraday period. The t tests show that Mondays and days following report days each have significantly higher variance ratios than other days only in period 1. Also, the F test for the joint influence of both days is significant only in period 1.

C. Explanations of Higher Variability Near the Close

The increase in variance toward the end of the day is less readily attributable to information. For example, there are no public information releases before or during this period. A hypothesis that most readily comes to mind, particularly in light of the French-Roll hypothesis, is the increased trading near the end of the trading day by traders who do not want to hold positions overnight. Such trading need not be based on information -- only a desire to offset positions.

One type of trader who has a clear incentive to get out of positions by the end of the day is the "scalper" (see Working (1967) and Silber (1984)). During the trading day, these traders provide liquidity services, so it is in their economic interest to trade continuously during the day. Their trading volume depends largely on order flow from outside the pit. Thus, during most of the day, the scalpers' trading volume would follow the volume induced by whatever information prompts outside market participants to submit buy and sell orders. However, as the end of the day approaches, these "locals" have an added incentive to trade, namely, to get out of their positions. Thus, locals holding positions near the end of the day can be observed to trade more aggressively to offset in order to avoid carrying the positions overnight. If the very process of trading, in the absence of new information, can generate variability then end-of-day trading by scalpers is a likely explanation for an increase in variability.

However, information could also contribute to the increased variability if information-based trading were concentrated near the end of the trading day. Although there is no obvious reason for this, four possibilities are considered below.

One possibility is that intermediaries may base cash-market transactions on futures settlement prices. If this practice is widespread, then intermediaries have an incentive to place their futures orders as near as possible to the close so that their positions are more perfectly hedged. The futures settlement price might be selected for price basing simply because it is widely reported. Thus, any information contained in the orders that these traders transmit to the pit would not be introduced into the market until near the close.

A second hypothetical reason for end-of-day information trading is centralization of hedging decisions in large grain merchandising firms. If the overall cash position of such firms becomes known with increasing precision as reports from subsidiary operations (for example, grain elevators) flow into headquarters, then the firms might rationally delay futures market hedging until as much information as possible is collected and analyzed.

A third reason that would account for information-based trading near the close is anticipatory hedging of grain expected to be purchased or sold from the time the futures market closes until it opens the next morning. During harvest, farmers deliver grain to elevators throughout the day and well into the night. Firms may estimate the grain likely to be purchased overnight and take short futures positions near or at the close in order to hedge these purchases. International firms may trade near the close in anticipation of export sales agreements completed after the market closes. Firms involved in such anticipatory hedging may wait until late in the trading day to place these hedge orders in order to take advantage of as much information as possible and to minimize the time exposure from holding the anticipatory futures positions.[6]

A fourth possibility is trading based on the anticipated, or known, content of a news release, such as a crop report. Traders may forecast these releases and be willing to trade on the forecast (see Conklin (1982) and Dinehart (1987)). The reliability of such forecasts may improve as the news release approaches, so that trading based on the forecast is delayed until the end of the trading day just prior to the release. News leaks, intentional or unintentional, also are more likely near the time of the release, so any related trading would be near the close on the release day.

Thus, even though the firms acquire information throughout the day, the effect of some information may not be felt in the futures pit until near the close. The information-based trading attributable to the first three reasons described above would increase during the harvest season, so the increase in variability toward the end of the day would be seasonal. Information-based trading near the close due to anticipation or knowledge of news releases would lead to increased relative variability on report days.

Table 5 contains evidence on seasonality. The mean variance ratios, although significantly different by the joint test, do not correspond to the anticipated seasonal effect. Although there are some higher variance ratios during the September through December period, there are anomalies, such as March, June and July. This test was repeated with all days of reports excluded, in case a news anticipation effect obscured a seasonality effect. However, the results were not essentially different. Parametric tests were no more revealing.

Table 6 contains evidence on the "news anticipation" effect. The data are categorized into report days, Fridays and all other days. Fridays are considered separately in order to isolate any news anticipation effect from any increased tendency to close out positions prior to the weekend. Although there is a significant difference, the highest mean variance ratio is on Friday and the lowest is on report days. Parametric tests were consistent with these results. This evidence is inconsistent with a news anticipation effect in the last period. In fact, this evidence is more supportive of trading itself as the source of higher variance since it is plausible that scalpers are more anxious to close out positions on Fridays than on other days.

A more direct test of the trading noise hypothesis is based on the covariance of successive price changes. Roll (1984) has shown that in an efficient market, the covariance of successive price changes is negative due to the tendency for transactions to occur at bids and asks with equal probability. Moreover, unlike the variance, the covariance is insensitive to information arrival as long as successive changes in the equilibrium price are uncorrelated, (i.e., if the market is efficient and information arrives randomly).

Thus, when information arrival is the primary cause of higher price variance, the serial covariance will be little changed from its "normal" level. However, if trading noise is the primary cause of higher variance, then the assumption of market efficiency no longer holds. Trading noise, or overreaction of traders, implies positive serial covariance.[7]

Table 7 shows the average serial covariance by intraday period. The serial covariance is least negative in period five. This result is consistent with positive covariance due to trading noise shifting the usual negative covariance toward zero. The non-parametric test indicates statistical significance.

Table 8 shows a dummy variable regression model for tests of serial covariance differences during the day. The t tests indicate that the covariances in periods 1 and 2 are not significantly different from the period three covariance, but the periods 4 and 5 covariances are significantly higher, with the period 5 covariance the highest. The F test shows that the serial covariance in period 5 is significantly less negative than the serial covariance in period 1.

These tests for the separate influences of information and trading effects are by no means conclusive. A principal difficulty is that end-of-day information effects, if such exist, probably are based on private information. Future research should focus on the link between private information and transaction price behavior (see Glosten (1987)).

IV. Conclusion

The intraday variability of soybean futures returns has a well-defined "U-shaped" pattern. The variance of price changes in the first and last forty-five minute periods is over 30 percent higher than the variance in midday periods.

The relatively high variance early in the day is attributable to the lack of a continuous (24-hour) market. Non-continuous markets force discrete rather than continuous information processing. The first leg of the "U" results as the non-continuous market absorbs information at the beginning of the trading day.

However, there is no evidence of a similar information effect to explain the relatively high variance late in the day. This lack of evidence leaves the hypothesis of noise induced by the very process of trading as a plausible explanation. Also, the results of a test for a trading noise effect based on the serial covariance of price changes are consistent with trading noise as the source of the late-day variance. The most likely source of increased trading noise near the end of the day is the practice of many traders, particularly scalpers, of not holding positions overnight.

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FOOTNOTES

1. See American Soybean Association (1985).

2. See French and Roll (1986) and Harris (1986).

3. A portion of the study was replicated for an unequal division of the day which allowed longer midday periods in order to more nearly equalize the number of observations in each period. These results are virtually indistinguishable from the results based on an equal division. Consequently, only the results from the equal division are reported.

4. Price-change and return (percentage price change) results are essentially indistinguishable, so only price-change results are reported. The data are screened to eliminate obviously erroneous prices, and whole periods are eliminated if the variance equals zero, exceeds 0.01, or is based on less than nine observations. Finally, days are eliminated if any periods for the day are eliminated. This has the effect of eliminating all days in which trading was halted due to a limit price move.

5. It is possible that the market takes longer than one 45 minute period to fully reflect the information. The tests will reveal this.

6. In fact, several grain traders we talked with indicated they did most of their hedging early in the morning and did not generally engage in anticipatory hedging just before the close. However, this is a small sample. A possibility not directly tested in this paper is that commodity pools may trade near the close if their technical systems are based on closing prices. However, Scott Irwin indicated that most commodity pool advisors trade in morning time periods based on the previous day's close.

7. French and Roll (1986) argue that for returns over long periods (e.g., one or more days) noise would induce negative serial covariance as prices overshoot and then correct back to equilibrium. However, they also argue that the shorter the return measurement period, the more likely it is that the overshooting would create positive covariance. For intraday transaction to transaction data, the positive covariance effect is most plausible.

TABLE 1

VARIANCES AND VARIANCE RATIOS BY INTRADAY PERIOD[a]

Intra-day Period[b]	Avg. No. Price Changes Per Period[c]	Variances[d]			Variance Ratios[f]		
		Mean	Std. Err.	Mean Rank Score[e]	Mean	Std. Err.	Mean Rank Score[g]
9:30-10:15	136	3.00	0.03	4753	1.361	0.016	4073
10:15-11:00	90	2.42	0.02	3879	1.081	0.012	2684
11:00-11:45	76	2.35	0.03	3767	N.A.	N.A.	N.A.
11:45-12:30	88	2.33	0.02	3806	1.045	0.008	2458
12:30-13:16	145	2.95	0.03	4818	1.312	0.013	4010
Chi-Square				322.98[h]			999.24[h]

NOTES:

a. Data from the two months prior to the delivery month for all soybean contracts traded from January 1978 through October 1984. There are 1653 days, thus observations of variance for each intraday period.

b. Each period is 45 minutes in length except the last 5, which extends one additional minute in order to include transactions reported within seconds after the close.

c. Average number of observations in each period for estimation of variance.

d. Multiply mean and standard error by 10^{-5}.

e. Highest rank = 5 x 1653 = 8265.

f. Ratio of variance in indicated period to variance in the third period.

g. Highest rank = 4 x 1653 = 6612.

h. Significant at 0.01.

TABLE 2

REGRESSION TESTS ON VARIANCE AND VARIANCE RATIOS

Model:[a] $$v_{it} = a_3 + a_1 D_1 + a_2 D_2 + a_4 D_4 + a_5 D_5 + e_{it} \quad (3)$$

	a_3	a_1	a_2	a_4	a_5
Coefficient	2.35*	0.65*	0.07	-0.02	0.60*
t	43.15	8.47	0.89	0.25	7.84
$F(a_1 = a_2 = a_4 = a_5 = 0)$		38.30*			

Model: $$\frac{v_{it}}{v_{3t}} = b_1 + b_2 D_2 + b_4 D_4 + b_5 D_5 + u_{it} \quad (4)$$

	b_1	b_2	b_4	b_5
Coefficient	1.36*	-0.28*	-0.32*	-0.05*
t	104.98	15.25	17.22	2.67

$F(b_2 = b_4 = b_5 = 0)$	151.69*
$F(b_2 = b_4)$	3.91
$F(b_2 = b_5)$	158.16*
$F(b_4 = b_5)$	211.80*

NOTES:

a. Subscripts indicate intraday periods. $D_1 \ldots D_5$ are dummy variables for periods.

* Indicates significance at 0.01.

TABLE 3

VARIANCE RATIOS BY INTRADAY PERIOD FOR MONDAYS, DAYS FOLLOWING REPORTS, AND ALL OTHER DAYS

Intraday Period	Day Category[a]	No. of Days	Mean	Std. Err.	Mean Rank Score	Chi-Square
9:30-10:15	Monday	280	1.441	0.035	920	
	Report	452	1.420	0.030	886	
	Other	920	1.308	0.023	769	31.25*
10:15-11:00	Monday	280	1.079	0.017	855	
	Report	452	1.069	0.013	854	
	Other	920	1.089	0.020	804	4.55
11:45-12:30	Monday	280	1.030	0.015	818	
	Report	452	1.057	0.015	859	
	Other	920	1.044	0.012	813	2.92
12:30-13:16	Monday	280	1.266	0.023	803	
	Report	452	1.317	0.025	836	
	Other	920	1.323	0.020	829	0.89

NOTES:

a. "Monday" includes all Mondays except Mondays following Friday reports. "Report" includes all days following reports, including Mondays following Friday reports.

* Significant at .01.

TABLE 4

ADDITIONAL TESTS FOR INFORMATION EFFECT

Regression Tests

Model[5]

$$\frac{v_{it}}{v_{3t}} = a_o + a_1 \text{ Monday} + a_2 \text{ Report} + e_{it} \qquad (5)$$

Intraday Period	a_o (t)	a_1 (t)	a_2 (t)	$F(a_1=a_2=0)$
9:30-10:15	1.31* (59.52)	0.13* (2.93)	0.11* (2.94)	6.74*
10:15-11:00	1.09* (66.33)	-0.01 (0.28)	-0.02 (0.68)	0.24
11:45-12:30	1.04* (92.38)	-0.01 (0.61)	0.01 (0.66)	0.56
12:30-13:16	1.32* (73.31)	-0.06 (1.54)	-0.01 (0.19)	1.22

NOTES:

a. "Monday" includes all Mondays except Mondays following Friday reports. "Report" includes all days following reports, including Mondays following Friday reports.

* Significant at .01.

TABLE 5

VARIANCE RATIO IN LAST PERIOD BY CALENDAR MONTH

Calendar Month	No. of Days	Mean	Std. Err	Mean Rank Score	Chi-Square
January	91	1.269	.037	810	
February	100	1.258	.038	801	
March	124	1.332	.041	860	
April	125	1.294	.034	850	
May	139	1.260	.025	831	
June	253	1.351	.034	879	
July	281	1.389	.053	818	
August	146	1.147	.027	648	
September	135	1.334	.044	850	
October	125	1.376	.050	862	
November	78	1.279	.033	867	
December	55	1.324	.065	841	
					26.45*

NOTES:

* Significant at .01.

TABLE 6

VARIANCE RATIOS IN LAST PERIOD ON REPORT AND NON-REPORT DAYS

Day Category[a]	No. of Days	Mean	Std. Err	Mean Rank Score	Chi-Square
Friday	298	1.36	.03	886	
Report	152	1.24	.03	770	
Other	1202	1.31	.02	818	
					7.06*

NOTES:

a. "Report" includes the days of all reports including reports on Fridays. "Friday" includes only Fridays on which reports were not released.

* Significant at .01.

TABLE 7

SERIAL COVARIANCE BY INTRADAY PERIOD

Intraday Period	Mean[a]	Std. Err[a]	Mean Rank Score	Chi-Square
9:30-10:15	-0.578	.016	3851	
10:15-11:00	-0.536	.023	4140	
11:00-11:45	-0.555	.019	4065	
11:45-12:30	-0.454	.016	4418	
12:30-13:16	-0.426	.018	4547	
				88.58*

NOTES:

a. $\times 10^{-5}$

* Significant at .01.

TABLE 8

REGRESSION TESTS FOR SERIAL COVARIANCE DIFFERENCES

Model: $Cov_{it} = a_3 + a_1 D_{1t} + a_2 D_{2t} + a_4 D_{4t} + a_5 D_{5t} + e_{it}$

	a_3	a_1	a_2	a_4	a_5
Coefficient	-0.555	-0.023	0.019	0.101	0.129
t	(27.25)*	(0.80)	(0.65)	(3.51)*	(4.47)*
$f(a_1=a_5)$	18.60*				

NOTES:

1. Subscripts indicate intraday period.

* Indicates significant at .01.