Stock Prices and Wall Street Weather: Additional Evidence

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Recent empirical research suggests that the weather in New York City has a long history of significant correlation with stock market returns. This prior research (Saunders, 1993) asserts that investor psychology influences asset prices and that the existence of a weather effect casts doubt on the rationality of security markets. This paper provides additional insight into the impact of weather on stock prices by using a variation of the approach used in Saunders (1993). The analysis indicates that the statistically significant test statistics reported by Saunders are dependent on which returns are compared. There is no significant difference between returns on clear sunny days and on cloudy rainy days, contrary to the notion of a weather effect. In addition, the effect noted by Saunders appears in only one of the three periods examined, and the effect is limited to only a few months of the year. Overall, results indicate that the relationship between weather and stock prices is neither as clear nor as strong as previously thought. Certain aspects of the data raise the possibility that there is no such effect.

INTRODUCTION

In a recent paper Saunders (1993) presents evidence regarding the relationship between Wall Street weather and average daily security returns. He finds (pp. 1344-1345) that "the weather in New York City has a long history of significant correlation with major stock indexes" and concludes that "investor psychology influences asset prices" and that these findings "cast doubt on the hypothesis that security markets are entirely rational."[1]

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[1] Considerable attention recently has focused on possible market irrationality. For example, studies of the so-called Blue Monday effect (Pettengill, 1993) and of stock price behavior on Friday the 13th (Kolb and Rodriguez, 1987; Chamberlain, Cheung, and Kwan, 1991) seem to indicate that markets may be subject to psychological influences that reduce market efficiency. Consequently, the notion that weather may influence stock prices, while contrary to traditional assumptions about market efficiency, is not as outlandish as it initially may seem.

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At the time the Saunders study was published, this finding was viewed by the popular business press as another anomaly similar to the January effect or other well-documented stock return effects. For example, in the *Wall Street Journal*:

> Forget the January effect. A professor at the University of Massachusetts has come up with what he believes is a better indicator of when the stock market will rise or fall. Check the weather on Wall Street. (Stecklow, 1993)

The *Wall Street Journal* reports that an editor of the *American Economic Review* stated that the results "fly in the face of advocates of the 'efficient market theory' who believe that economics, not psychology, govern the stock market." *Business Week* also took note of the Saunders study (Koretz, 1994).

In this paper the data used by Saunders are examined further using a variation of his approach. The results indicate that the relationship between weather and stock prices is neither as clear nor as strong as Saunders suggests and that certain aspects of the data contradict such a relationship. Further, additional analysis demonstrates that the statistically significant test statistics reported by Saunders depend on the choices of which returns to compare.

DATA AND METHODOLOGY

The basic thesis of Saunders (1993) is that the weather-influenced mood of brokers and traders who assemble in the same geographic location (namely New York City) may have an impact on security prices. Saunders relies on studies by Persinger (1975), Cunningham (1979), and Howarth and Hoffman (1984) that indicate that sunshine is the most significant factor in explaining positive and negative psychological effects. To capture this factor, cloud cover measurements collected at Central Park and LaGuardia Field, New York City comprise the primary weather variable in Saunders (1993) and in this paper.

Local Climatological Data is published by the National Climatic Data Center in Asheville, North Carolina. This study uses daily observations drawn from January 1, 1927 to December 31, 1992.[2] Return variables for this period are changes in the Dow Jones Industrial Average (January 1, 1927 to December 31, 1992) and changes in the equally weighted and value-weighted indexes included on the daily return tape supplied by the Center for Research in Security Prices at the University of Chicago (July 6, 1962 to December 31, 1992).

The cloud cover data, which constitute the weather variable in this study, are coded by the weather observer as a percentage of average sky cover during the day in ten percent increments. Each day is assigned a whole number in the range 0 to 10, with 0 representing a completely clear day and 10 representing a 100 percent cloudy, and often rainy, day. The primary methodological issue in examining these data is deciding which days to compare. One possibility is to compare returns on completely cloudy (100 percent) days to those on completely clear (0 percent) days. This is an intuitive choice and, without prior analysis of the data, might be expected to give the greatest power in detecting a

[2] Saunders uses data through 1989; an additional three years of data are used in the present study.

weather effect if such an effect exists. If there is concern about measurement error produced by the subjective nature of weather observation, a comparison based on two points on each end of the range (90 percent to 100 percent versus 0 percent to 10 percent) or on three points (80 percent to 100 percent versus 0 percent to 20 percent), may be reasonable. Saunders (1993) compares average returns on the 100 percent days to those on the 0 percent to 20 percent cloudy days. This choice is critical in determining the statistical significance of the weather effect.

EMPIRICAL EVIDENCE

Table 1 presents the results of the multiple range test proposed by Duncan (1975) for each of three stock indexes over three separate time periods. The CRSP value-weighted and equally weighted indexes are not available for the 1927 to 1962 period

Each panel shows average daily changes in the stock indexes for various daily cloud cover (CC) levels, from highest to lowest average return. The statistical significance of the differences in means are indicated by assigning a *Duncan group* code letter; means assigned the same letter are not significantly different at the 5 percent level. The only statistically significant differences are between means that do not share a common group letter.

The strongest evidence in this table for the existence of a weather effect is for the indexes from July 6, 1962 to December 31, 1989. In panel B the Dow Jones average return is statistically different on 10 percent cloud cover days and on 100 percent cloud cover days. Identical results hold for the two CRSP indexes in panels E and G; the only statistically significant differences are for the 10 percent days and the 100 percent days. This evidence of a weather effect, however, is contradicted by returns on the completely clear (0 percent) days. The average return on the 0 percent days is the second lowest of any of the cloud cover groups for the Dow and for the CRSP value-weighted index. The 0 percent mean for the CRSP equally weighted index is in the middle of the range. If there is a weather effect, the average returns on 0 percent days and 100 percent days should differ—the evidence in these three panels shows that they do not. Saunders (1993) compares returns on 0 percent to 20 percent days to those on 100 percent days. This choice is the only comparison during this period that would produce a statistically significant test statistic and does not consider that the returns on the 0 percent days are inconsistent with the existence of a weather effect.[3]

In the January 1, 1927 to July 5, 1962 period (panel C) there is less support for the existence of a weather effect than in the earlier period. The mean Dow Jones return is statistically indistinguishable for all of the cloud cover levels. Returns for the 100 percent days near the low end of the range of average returns may suggest a weather effect, but any such effect is weak during this 35 year period. Saunders argues that the weather effect is weak during this period because the Dow comprises large stocks for which any market inefficiencies should be minimal. It also seems possible, however, that a stronger weather effect could be expected during this period when trading was more heavily concentrated in

[3] The comparison of 10 percent to 20 percent days against 100 percent days also would produce a significant result. It seems unlikely, however, that omission of the 0 percent days would be considered reasonable. The 0 percent to 10 percent versus 100 percent comparison is not statistically significant because the omission of the 20 percent days increases the estimated variance too much.

Table 1—Duncan's Multiple Range Test for Cloud Cover Classifications, 1927-1992

CC	Mean Return	Duncan Group	N
Panel A: Dow Jones Industrial Average, 1/1/90-12/31/92			
7	0.24750	A	74
2	0.23610	A	53
4	0.22710	A	45
5	0.15320	A	44
8	0.08080	A	53
3	0.05030	A	50
0	0.04420	A	76
1	-0.04220	A	60
9	-0.09540	A	63
10	-0.10930	A	175
6	-0.13410	A	67
Panel B: Dow Jones Industrial Average, 7/6/62-12/31/89			
1	0.12080	A	413
2	0.10379	AB	453
3	0.04541	AB	488
9	0.04254	AB	733
4	0.03778	AB	533
7	0.03424	AB	629
8	0.03043	AB	655
6	0.02330	AB	565
5	0.01069	AB	550
0	0.00049	AB	382
10	-0.02941	B	1511
Panel C: Dow Jones Industrial Average, 1/1/27-7/5/62			
6	0.07005	A	808
5	0.06087	A	741
8	0.05630	A	893
1	0.04002	A	753
7	0.03301	A	991
3	0.02388	A	743
0	0.02233	A	491
2	-0.00200	A	628
4	-0.00740	A	825
10	-0.01973	A	1664
9	-0.02030	A	1029
Panel D: CRSP Value-Weighted Index, 1/1/90-12/31/92			
4	0.27630	A	45
7	0.22270	AB	74
2	0.14960	AB	53
3	0.03300	AB	50
8	0.03040	AB	53
0	0.02230	AB	76
5	0.00650	AB	44
1	-0.00620	AB	60
6	-0.01220	AB	67
9	-0.05210	B	63
10	-0.09140	B	175

New York, and the actions of traders in other parts of the United States and in Europe and Asia would not eliminate a weather effect.

The results for the period from January 1, 1990 to December 31, 1992 (shown in panels A, D, and F) also weakly suggest a weather effect. The 100 percent returns are near

Table 1—Duncan's Multiple Range Test for Cloud Cover Classifications, 1927-1992 (cont.)

CC	Mean Return	Duncan Group	N
Panel E: CRSP Value-Weighted Index, 7/6/62-12/31/89			
1	0.12484	A	414
2	0.09426	AB	453
9	0.05381	AB	733
8	0.03809	AB	655
5	0.03552	AB	550
7	0.03316	AB	629
3	0.03137	AB	488
4	0.03114	AB	533
6	0.01626	AB	565
0	0.01403	AB	382
10	-0.02421	B	1510
Panel F: CRSP Equally Weighted Index, 1/1/90-12/31/92			
7	0.20050	A	74
4	0.17190	A	45
0	0.15120	A	76
2	0.14220	A	53
8	0.10180	A	53
3	0.09280	A	50
6	0.05870	A	67
5	0.04690	A	44
1	0.01960	A	60
10	0.00330	A	175
9	-0.02370	A	63
Panel G: CRSP Equally Weighted Index, 7/6/62-12/31/89			
1	0.17557	A	414
2	0.14775	AB	453
5	0.07753	ABC	550
9	0.07675	ABC	733
8	0.06816	BC	655
0	0.05862	BC	382
7	0.04702	BC	629
4	0.04698	BC	533
3	0.04452	BC	488
6	0.03876	BC	565
10	0.01599	C	1510

Each panel presents the results of the multiple range test described in Duncan (1975). The average returns for the cloud cover classifications are ordered, and averages with the same Duncan group letter are not significantly different. See the text for further discussion

the low end of the range of average returns. The only statistically significant differences in these panels are between the 90 percent and 100 percent day returns and the 40 percent day returns in panel D.

Saunders uses a multiple regression approach to control for possible month effects and day-of-the-week effects, as well as possible autocorrelation induced by nonsynchronous trading. The model estimated by Saunders is:

$$(1)\ R_t = \beta_0 + \beta_1 R_{t-1} + \sum_{i=2}^{12} \tau_i M_{it} + \sum_{i=2}^{6} \delta_i D_{it} + \alpha C_t + \varepsilon_t,$$

where:

R = The percentage daily index change;

M = A month dummy (with June omitted);
D = A day dummy (with Tuesday omitted); and
C = A cloud cover variable coded as -1 if cloud cover is 100, 1 if cloud cover is 0 percent to 20 percent, and 0 otherwise.

In order to assess the consistency of the zero cloud cover days with the existence of a weather effect, the following variation of Saunders' model is estimated:

$$(2)\ R_t = \beta_0 + \beta_1 R_{t-1} + \sum_{i=2}^{12} \tau_i M_{it} + \sum_{i=2}^{6} \delta_i D_{it} + \alpha_1 D0 + \alpha_2 D1020 + \alpha_3 D3090 + \varepsilon_t,$$

where:

D0 = An indicator variable equal to 1 when cloud cover is zero;
D1020 = An indicator variable equal to 1 when cloud cover is 10 percent to 20 percent;
D3090 = An indicator variable equal to 1 when cloud cover is 30 percent to 90 percent; and
R, M, D = As defined above.

Because the indicator variables exclude the 100 percent cloud cover condition, the coefficients on the indicator variables are measures of the difference in average returns between the 100 percent cloud cover days and the days indicated by a coding of 1 for each of the variables after controlling for the other factors in the model. This specification of the model is motivated by Saunders' observation that while returns in the 0 percent to 20 percent range of cloud cover observations seem to differ from returns on the 100 percent cloud cover days, returns in a broad range of 30 percent to 90 percent show no evidence of a weather effect. By coding these groups of observations separately, the descriptive validity of the Saunders model should be improved.

The results of estimating equation (2) are shown in Table 2. Consistent with the Table 1 results, coefficients on D1020 are positive and significant for all of the indexes for the 1962-1989 period but not for the 1927-1962 period. The coefficients on D0 are negative, however, but not significantly different from zero for any index during the 1962-1989 period. This result is somewhat at odds with Table 1, which documents that the zero cloud cover days have slightly higher average returns than the 100 percent cloud cover days. When the other factors included in the model are controlled, the sign of this difference reverses, although the size of the difference is not significant after controlling for other factors. Also included in Table 2 is the 1990 to 1992 period; the results for this period are consistent with those for the 1962-1989 period.[4] Table 2 once again indicates that the weather affect is limited to the post-1962 period and that returns on completely clear days and on completely cloudy days are statistically indistinguishable, inconsistent with the existence of a weather effect.

[4] As in Saunders, the Table 2 analysis is repeated after excluding days with large index changes, defined alternatively as 1/2 percent, 1 percent, and 2 percent. For each of these analysis the qualitative results are unchanged; in particular, the coefficient on D0 is uniformly negative but not statistically significant.

Table 2—Selected Parameter Estimates for Regressions on Daily Changes in Stock Indexes, New York City, 1927-1992

	1/1/27-7/5/62	7/6/62-12/31/89			1/1/90-12/31/92		
Explanatory Variable	DJIA	DJIA	CRSP Value-Weighted	CRSP Equally Weighted	DJIA	CRSP Value-Weighted	CRSP Equally Weighted
Lagged return	0.03314 (3.31)**	0.07881 (6.57)**	0.18484 (15.64)**	0.34981 (31.05)**	-0.02998 (0.82)	0.09300 (2.55)**	0.31577 (9.08)**
January	-0.00032 (-0.53)	0.00102 (1.81)*	0.00081 (1.67)*	0.00190 (4.39)**	0.00155 (0.96)	0.00098 (0.73)	0.00253 (2.52)**
Monday	-0.00257 (-6.83)**	-0.00157 (-4.31)**	-0.00198 (-6.31)**	-0.00246 (-8.74)**	0.00181 (1.73)*	0.00107 (1.22)	-0.00057 (-0.88)
Cloud cover = 0%	0.00006 (0.110)	-0.00041 (-0.80)	-0.00035 (-0.79)	-0.00022 (-0.55)	-0.00040 (-0.34)	-0.00074 (-0.76)	0.00017 (0.24)
Cloud cover = 10-20%	0.00042 (0.94)	0.00148 (3.62)**	0.00129 (3.65)**	0.00127 (4.07)**	0.00274 (2.45)**	0.00218 (2.32)*	0.00135 (1.94)*
Cloud cover = 30-90%	0.00043 (1.26)	0.00071 (2.43)**	0.00068 (2.70)**	0.00057 (2.56)**	0.00206 (2.44)**	0.00180 (2.56)**	0.00103 (1.98)*
N	9968	6910	6910	6910	759	759	759
R^2	0	0.016	0.049	0	0.038	0.046	0.167
F	4.90	5.72	18.64	68.00	1.53	1.86	7.86

Coefficient estimates are for equation (2) in the text. *t*-statistics are in parentheses
* Significant at the 5 percent level, one tailed test
** Significant at the 1 percent level, one tailed test

One other effect that may be relevant to this analysis is the possible interaction between month effects and the weather effect. Intuition suggests that weather is probably not independent of month, and statistics confirm this; a contingency table of weather against month has a χ^2 statistic of 755.78, highly significant when compared to a χ^2 distribution with 110 degrees of freedom.

To control for the possible interaction of weather and month, the following variation of Saunders' model is estimated on a monthly basis from 1962 to 1989 where the weather effect appears to be strongest:

$$(3)\ R_t = \beta_0 + \beta_1 R_{t-1} + \sum_{i=2}^{6} \delta_i D_{it} + \alpha_1 D0 + \alpha_2 D1020 + \alpha_3 D3090 + \varepsilon_t,$$

where the variables are as described earlier. This equation is identical to equation (2), except that the month indicator variables are not needed.

The results are documented in Table 3.[5] The absence of a statistically detectable difference between zero cloud cover and 100 percent cloud cover days is an effect that is uniform across the monthly regressions. The coefficient on D0 is negative for seven of the regressions and positive for five of the regressions and is not statistically different from zero in any of the 12 regressions. The difference between the 100 percent cloud cover days and the 10 percent to 20 percent days, which is strong in Table 2, is less obvious in Table 3. The effect is strongest in April, May, and December, weaker in January, March, August, and September, and nonexistent in the other five months. Comparing the results for D1020 to the results for the nonsynchronous trading effect, which appears to be uniformly strong, and to the results for the Monday effect, which appears strongly in six of the 12 regressions and less strongly in four of the other six months, shows that the weather effect is of lesser magnitude and importance than these other effects. Figure 1 illustrates the relation between cloud cover and weather by month. Although the figure does not control for the factors included in the regression model used for Table 3, the general impression of the relationship is that it is inconsistent and weak in many of the months, consistent with the findings in Table 3.

SUMMARY AND CONCLUSION

Results presented in this paper indicate that the relationship between security returns and Wall Street weather is neither as clear nor as strong as Saunders (1993) suggests. There is no difference between returns on clear sunny days and on cloudy or rainy days. Other factors also raise questions about the existence of a weather effect on stock returns. For example, the effect does not appear for the pre-1962 period. If there is such an effect, it arose sometime after 1962. Why such an effect should be limited to the recent past is unclear. Also, it appears that the effect is often weak, appearing in only a few months of the year. Again, the reason why such an effect should exist in some months but not others is unclear.

There is some evidence that there may be a relationship between weather and stock returns. In Table 1 average returns on 100 percent cloudy days are at or near the low end

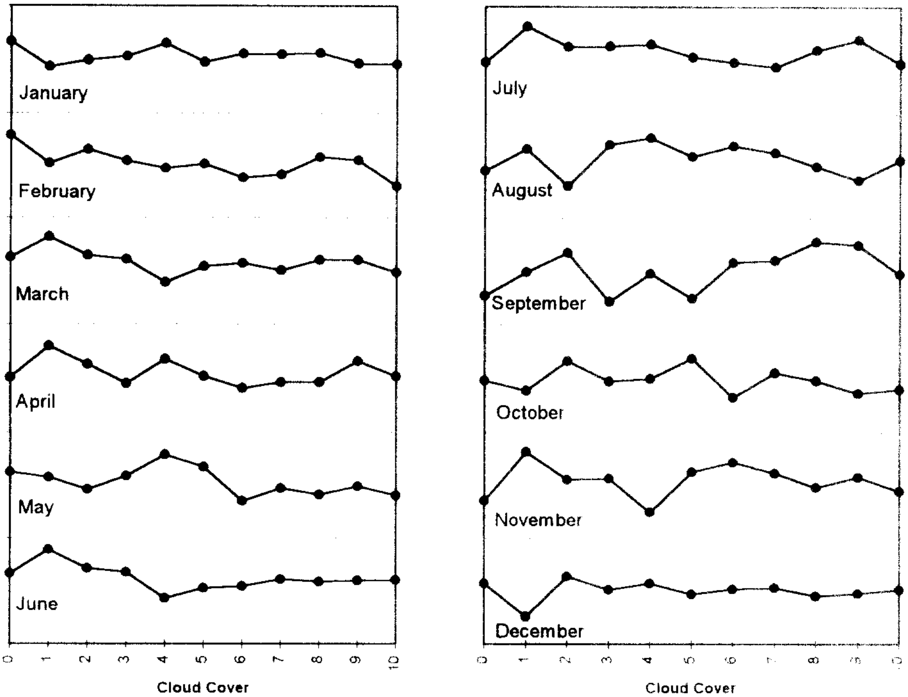
[5] The dependent variable for Table 3 is the CRSP value-weighted return. Results are similar when the Dow Jones Industrial Average and the CRSP equally weighted return are used as dependent variables.

Table 3 — Selected Parameter Estimates for Monthly Regressions on Daily Changes in CRSP Value-Weighted Index, New York City, 1962-1989

Explanatory Variable	January	February	March	April	May	June	July	August	September	October	November	December
Lagged return	0.14963	0.13067	0.14629	0.23460	0.28140	0.22662	0.29172	0.24690	0.20216	0.13511	0.15090	0.18422
	(3.59)**	(2.98)**	(3.58)**	(5.64)**	(6.88)**	(5.68)**	(7.22)**	(6.27)**	(4.92)**	(3.33)**	(3.51)**	(4.72)**
Monday	0.00063	-0.00291	-0.00275	-0.00184	-0.00399	-0.00268	-0.00116	-0.00120	0.00009	-0.00220	-0.00373	-0.00303
	(0.058)	(-2.87)**	(-2.96)**	(-1.91)*	(-3.88)**	(-2.92)**	(-1.25)	(-1.26)	(0.079)	(-1.30)	(-3.15)**	(-3.09)**
Cloud cover =0%	0.00131	0.00083	-0.0059	0.00057	0.00253	0.00187	-0.00023	-0.00179	-0.00003	-0.00283	-0.00165	-0.00072
	(0.95)	(0.064)	(-0.50)	(0.40)	(1.47)	(1.08)	(-0.13)	(-0.99)	(-0.02)	(-1.55)	(-0.97)	(-0.59)
Cloud cover =10-20%	0.00176	0.00093	0.00180	0.00265	0.00297	-0.00014	0.00022	0.00142	0.00129	0.00103	-0.00045	0.00254
	(1.50)	(0.90)	(1.64)	(2.49)**	(2.52)**	(-0.13)	(0.18)	(1.12)	(1.12)	(0.56)	(-0.36)	(2.32)*
Cloud cover =30-90%	-0.00021	0.00096	0.00002	0.00076	0.00206	0.00066	0.00005	0.00076	0.00097	0.00071	0.00047	0.00127
	(-0.25)	(1.33)	(0.35)	(1.02)	(2.27)*	(0.83)	(0.05)	(0.77)	(1.12)	(0.49)	(0.54)	(1.81)*
N	572	515	588	557	570	575	580	615	567	614	557	587
R^2	0.031	0.060	0.045	0.071	0.121	0.074	0.116	0.076	0.053	0.028	0.051	0.075
F	3.29	4.03	3.42	5.28	9.68	5.62	9.38	6.24	3.88	2.14	3.71	5.87

Coefficient estimates are for equation (3) in the text. *t*-statistics are in parentheses
* Significant at the 5 percent level, one tailed test
** Significant at the 1 percent level, one tailed test

Figure 1—Average Daily Returns and Cloud Cover by Month, 1962-1989



of the range of returns for each of the periods and stock indexes which suggests such an effect. The evidence presented here, however, suggests that any such effect is not dependable. While security markets may not be entirely rational, as Saunders suggests, the conclusions that "the weather in New York City has a long history of significant correlation with major stock indexes" and that "investor psychology influences asset prices" seem too strong, given the evidence presented in this paper.

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