# Evidence for a Weather Persistence Effect on the Corn, Wheat, and Soybean Growing Season Price Dynamics

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## INTRODUCTION

The growing season weather in the corn, wheat, and soybean production areas of the United States is an important determinant of the U.S. supply of these commodities. The weather and climatology literature strongly suggest that during the summer months there is a degree of persistence in the North American weather patterns. Given this nonrandom character of weather and given that the corn, wheat, and soybean belts are geographically concentrated enough to be dominated by a regional weather phenomenon, their futures markets are hypothesized to reflect this assimilation of nonrandom weather information as nonrandom price fluctuations. An empirical test of this question is the subject of this article.

## THE GROWING SEASON

Most corn in the U.S. corn belt states is planted in May and harvested in October and November. Numerous studies point to midwestern weather conditions in the June through August period as being especially important determinants of national corn yields. See Teigen and Singer (1988), Ash and Lin (1987), Vroomen and Hanthorn (1986), Van Meir (1984), and Lin and Davenport (1982). A recent investigation of the subject by Westcott (1989) focuses on planting dates and June and July precipitation and temperature in the corn belt to explain national corn yields.

As noted by Westcott (1989, p. 18), typical daily water use rates for 110 growing day corn peaks at about the 60th day of growth; the largest water use occurs from about the 40th day to about the 80th day. Therefore, in the corn belt, corn planted in early- to mid-May experiences peak utilization of water in late-June and throughout July. Mid-June and early-August water use rates are also high for earlier and later planted corn, respectively. Westcott also notes that temperature plays an

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important role in crop development, potentially stressing the corn plant at critical stages of crop formation and increasing the evaporation of moisture reserves from the soil.

Soybeans are known to be a more resilient crop, more capable of performing under stress. They have vulnerability in August when the soybeans are flowering and setting and filling pods. See Willimark and Teigen (1985, p. 28). But geographically, the corn and soybean belts are largely located in the same place. Therefore, adverse and/or favorable weather usually affects the national corn and soybean crops in a similar way from year to year.

The growing season for wheat is more difficult to define with precision at the national level. Winter wheat is planted in the fall. Spring wheat is planted in the spring. The harvest season ranges from June in Texas to August in North Dakota. The national wheat crop is more diversified against any persistent weather patterns.

This diversity is illustrated in an empirical study of regional wheat yields by Ash and Lin (1986). Six regions are studied: the Northern Plains, the Southern Plains, the Mountain, the Pacific and lake states, and the Corn Belt. Explanitory variables include March through July precipitation and temperature. Although both temperature and precipitation are frequently significant, the signs and level of significance varies substantially from region to region.

## PERSISTENCE IN THE WEATHER

In the context of the subject of weather and climate, persistence refers to a regional stability in the weather pattern for a time period. While a thorough review of this literature is outside the scope of this article, some examples are given to support the view that regional weather patterns can often be persistent. Namias (1986) finds and summarizes extensive empirical evidence that North American weather, in terms of flow pattern, temperature and precipitation, is significantly persistent in the winter and summer months with a short period of nonpersistence around or just after the equinoxes. Trenberth, Branstator, and Arkin (1988, p. 1643) in an article focused on the origins of the 1988 North American drought state:

"The evidence suggests that persistent global-scale anomalies in the atmospheric circulation set the stage for the [1988] drought in the United States. Large-scale circulation anomalies have also been associated with earlier U.S. droughts. In summer droughts, there has always been upper-level anticyclonic conditions over the United States, usually associated in a wavelike pattern with a deeper than normal upper-level through along the west coast of North America and another anticyclonic region over the central North Pacific...

In general in summer, once anticyclonic conditions prevail over the United States, other more local factors probably help maintain the droughts and produce heat waves. In particular, land-surface processes involving the absence of soil moisture probably have a significant effect. Normally, heating from the sun is partitioned into evapotranspiration and sensible heating of the surface and atmosphere. But in drought conditions, evaporation and plant transpiration are greatly reduced so that nearly all heating is manifested as temperature increases. Moreover, the absence of moisture conspires against widespread precipitation. Heat waves result and a drought becomes, at least in part, self-perpetuating."

## SEASONAL PRICE DYNAMICS

The importance of growing conditions in the late-June through early-July period, accompanied by some potential for the weather influence itself to persist in some fashion, raises an interesting question for corn price dynamics during this period. As stated by Anderson (1985, p. 333):

> "For grains, total annual production is determined by acreage planted and yields. Yields in turn are heavily dependent upon weather conditions at certain times of the growth process. These crucial phases tend to occur at approximately the same times during the calendar year. Consequently, we would expect the resolution of production uncertainty to follow a strong seasonal pattern."

While Anderson's focus is on volatility, seasonal volatility and Samuelson's (1965, 1976) hypothesis that volatility increases as the maturity of a futures contract approaches, this study focuses on the seasonal randomness, or lack thereof, of these prices. Samuelson (1965) introduced the theoretical relationships between random walk and expected returns models in the theory of efficient markets. Previous and subsequent empirical investigation of the market efficiency literature, for the most part, concludes that the futures markets are in most cases efficient as measured by serial dependence in a time series. Fama (1965, p. 399), after an extensive review of the empirical literature, states:

> "At this date the weight of the empirical evidence is such that economists would generally agree that whatever dependence exists in a series of historical returns cannot be used to make profitable predictions of the future. Indeed for returns that cover periods of a day or longer, there is little in the evidence that would cause rejection of the stronger random walk model, at least as a good first approximation."

On the other hand, there is significant research in the literature that finds exception. For example, Stevenson and Bear (1970, p. 80) in an investigation of corn and soybean serial correlations and analysis of runs, find evidence to "cast considerable doubt on the applicability of this hypothesis to the market for commodity futures." They note similar evidence against the random walk model in the work of Cootner (1964) and Larson (1960).

This study finds some evidence that during the growing season corn, wheat, and soybean prices do not vary as a random walk. It is hypothesized that persistent weather conditions in the growing season arrive with some degree of momentum as suggested by the weather and climate literature and induce similar momentum into commodity price dynamics.

To test the question a simple regression analysis is used:

$$P(t,k) = \text{Alpha} + \text{Beta}^{*}P(t-1,k) + E \qquad (1)$$

where

- $P(t,k)$ Change in futures price on day $t$ during season $k$.
- $t$ Ranges from October 1, 1972 through September 30, 1989.
- $k$ Ranges across 48 time cells per year defined as the 1st through the 7th, 8th through the 15th, 16th through the 23rd, and 24th through the 31st of each calendar month.
- $E$ Randomly distributed error.

The null hypothesis, $B = 0$, is that during the growing season, the weather persistence does not, in fact, induce momentum into the price dynamics. That is, if $P(t - 1, k)$ contains some information about the current state of weather persistence, it does not significantly influence $P(t, k)$. The null hypothesis is rejected during those time periods when Beta is significantly positive.

## THE DATA BASE

The study focuses on a 17-year period beginning October 1, 1972 and ending September 30, 1989. The study period includes major corn belt droughts during the years 1974, 1980, 1983, and 1988. Significant but more localized droughts in the western corn belt occurred in 1975, 1976, and 1977.

To achieve continuity across a 17-year time frame, the observed daily price change is drawn from the actively trading nearby futures contracts of Chicago corn, Chicago soybeans, and Chicago wheat according to the schedule in Table I.

## EMPIRICAL RESULTS

Table II shows significantly positive values for Beta tending to cluster in the growing seasons for corn and soybeans. The season defined by May 24 through August 23 stands out with numerous positive $t$ values at the 10 percent level of significance or better. Of the 24 corn and soybean time cells of this period, all but two are positive and 14 are significantly positive.

These results are in sharp contrast to the statistical character of the corn and soybean market during the rest of the year. Outside of this season 80 time cells are observed with only 13 containing significantly nonzero Beta values. Moreover, of these 13, eight are negative in sign. The nongrowing season statistical results are clearly more sporadic.

The lack of a cluster of significantly positive values of Beta for wheat suggests that either the wheat growing season has less weather persistence and/or that wheat, in its growing season, is less sensitive to weather than is corn or soybeans. On the

**Table I**
**OBSERVED FUTURES CONTRACT SCHEDULE FOR CHICAGO BOARD OF TRADE CORN, SOYBEANS, AND WHEAT**

| Calendar Month | Chicago Board of Trade Futures Contract | | |
|---|---|---|---|
| | Corn | Soybeans | Wheat |
| January | March | March | March |
| February | March | March | March |
| March | May | May | May |
| April | May | May | May |
| May | July | July | July |
| June | July | July | July |
| July | September | September | September |
| August | September | September | September |
| September | December | November | December |
| October | December | November | December |
| November | December | January | December |
| December | March | January | March |

Table II
A SEASONALLY PARTITIONED STATISTICAL SUMMARY FOR THE PERIOD OCTOBER 1, 1972 THROUGH SEPTEMBER 30, 1989

| | Corn | | | Soybeans | | | Wheat | | |
|---|---|---|---|---|---|---|---|---|---|
| Time Cell | *N* | Beta | *t* | *N* | Beta | *t* | *N* | Beta | *t* |
| Jan 1– 7 | 69 | −.19 | −1.37 | 69 | −.19 | −1.51 | 69 | .27 | 1.98* |
| Jan 8–15 | 96 | −.11 | −1.19 | 96 | −.03 | − .34 | 96 | −.18 | −2.03** |
| Jan 16–23 | 98 | −.02 | − .18 | 98 | .09 | .92 | 98 | −.08 | − .70 |
| Jan 24–31 | 96 | −.01 | − .07 | 96 | −.22 | −2.22** | 96 | .00 | .00 |
| Feb 1– 7 | 85 | −.02 | − .15 | 85 | .02 | .15 | 85 | −.13 | −1.19 |
| Feb 8–15 | 94 | −.01 | − .12 | 94 | −.24 | −2.44** | 94 | .19 | 1.75* |
| Feb 16–23 | 82 | .33 | 2.87** | 82 | −.06 | − .50 | 82 | −.17 | −1.54 |
| Feb 24–29 | 64 | .51 | 3.83** | 64 | .05 | .39 | 64 | .20 | 1.26 |
| Mar 1– 7 | 85 | −.14 | −1.43 | 85 | −.13 | −1.30 | 85 | .00 | .02 |
| Mar 8–15 | 97 | .06 | .59 | 97 | −.11 | −1.08 | 97 | −.02 | − .16 |
| Mar 16–23 | 97 | −.30 | −2.93** | 97 | −.16 | −1.53 | 97 | −.05 | − .45 |
| Mar 24–31 | 93 | −.10 | −1.08 | 93 | .15 | 1.48 | 93 | .08 | .71 |
| Apr 1– 7 | 81 | −.06 | − .51 | 81 | .02 | .14 | 81 | .04 | .34 |
| Apr 8–15 | 93 | −.05 | − .52 | 93 | −.02 | − .19 | 93 | .13 | 1.19 |
| Apr 16–23 | 92 | −.07 | − .64 | 92 | −.01 | − .09 | 92 | .02 | .18 |
| Apr 24–30 | 85 | .01 | .09 | 85 | .05 | .38 | 85 | .10 | .87 |
| May 1– 7 | 84 | .08 | .74 | 84 | .25 | 2.69** | 84 | .06 | .61 |
| May 8–15 | 97 | .05 | .49 | 97 | −.01 | − .14 | 97 | −.09 | − .81 |
| May 16–23 | 98 | −.03 | − .28 | 98 | .01 | .06 | 98 | .11 | 1.21 |
| May 24–31 | 80 | .07 | .55 | 80 | .27 | 2.27** | 80 | .01 | .05 |
| Jun 1– 7 | 85 | .44 | 4.01** | 85 | .74 | 6.87** | 85 | −.02 | − .18 |
| Jun 8–15 | 97 | .22 | 2.30** | 97 | .04 | .45 | 97 | .14 | 1.31 |
| Jun 16–23 | 97 | .30 | 3.08** | 96 | .29 | 3.03** | 97 | .08 | .79 |
| Jun 24–30 | 85 | −.19 | −1.65 | 84 | −.07 | − .55 | 85 | −.07 | − .61 |
| Jul 1– 7 | 68 | .19 | 1.49 | 68 | .34 | 3.59** | 68 | −.09 | − .80 |
| Jul 8–15 | 97 | .13 | 1.30 | 97 | .21 | 2.15** | 97 | −.17 | −1.74* |
| Jul 16–23 | 97 | .08 | .76 | 97 | .41 | 4.39** | 97 | −.09 | − .89 |
| Jul 24–31 | 97 | .33 | 3.25** | 97 | .22 | 2.14** | 97 | −.09 | − .88 |
| Aug 1– 7 | 85 | .19 | 1.81* | 85 | .27 | 2.69** | 85 | .14 | 1.23 |
| Aug 8–15 | 98 | .04 | .41 | 98 | .13 | 1.16 | 98 | .24 | 2.37** |
| Aug 16–23 | 97 | .14 | 1.46 | 97 | .26 | 2.79** | 97 | −.05 | − .55 |
| Aug 24–31 | 97 | −.04 | − .41 | 97 | −.14 | −1.49 | 97 | −.25 | −2.48** |
| Sep 1– 7 | 68 | .18 | 1.49 | 68 | .03 | .27 | 68 | .00 | − .01 |
| Sep 8–15 | 97 | −.09 | − .96 | 97 | .12 | 1.17 | 97 | −.19 | −1.86* |
| Sep 16–23 | 97 | .04 | .37 | 97 | .04 | .36 | 97 | −.17 | −1.70* |
| Sep 24–30 | 84 | .12 | 1.12 | 84 | .17 | 1.58 | 85 | .20 | 1.79* |
| Oct 1– 7 | 85 | −.25 | −2.35** | 85 | .06 | .58 | 85 | −.21 | −1.97* |
| Oct 8–15 | 96 | −.02 | − .20 | 96 | .20 | 1.94* | 96 | −.03 | − .30 |
| Oct 16–23 | 97 | .01 | .10 | 97 | .13 | 1.29 | 97 | .02 | .24 |
| Oct 24–31 | 98 | .08 | .72 | 98 | −.21 | −2.10** | 98 | .17 | 1.74* |
| Nov 1– 7 | 79 | −.04 | − .35 | 79 | .12 | 1.12 | 79 | −.04 | − .37 |
| Nov 8–15 | 97 | .14 | 1.36 | 97 | .01 | .10 | 97 | −.01 | − .11 |
| Nov 16–23 | 92 | .13 | 1.34 | 92 | .04 | .39 | 92 | −.12 | −1.31 |

Table II—Continued

| Time Cell | Corn | | | Soybeans | | | Wheat | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Beta | t | N | Beta | t | N | Beta | t |
| Nov 24–30 | 73 | .06 | .50 | 73 | −.07 | − .58 | 73 | .02 | .13 |
| Dec 1– 7 | 85 | −.27 | −2.51** | 85 | −.24 | −2.21** | 85 | −.09 | − .87 |
| Dec 8–15 | 97 | .08 | .76 | 97 | .20 | 1.95* | 97 | .10 | .94 |
| Dec 16–23 | 97 | −.13 | −1.35 | 97 | −.19 | −2.18** | 97 | −.17 | −1.86* |
| Dec 24–31 | 73 | −.05 | − .47 | 73 | .03 | .19 | 74 | .07 | .55 |

*Significant at the 10% level, two tail test.
**Significant at the 5% level, two tail test.

former point, Namias (p. 1369) notes a lack of persistence in his data during both the spring and fall equinox period. On the latter point, it is hypothesized that this phenomenon may result in part from wheat generally being a hardier plant. Also, at the national level, wheat is more geographically diversified. There are five somewhat distinct regions: hard red winter, soft red winter, hard red spring, durham, and white wheat. Wheat growth and maturity is more diversified across time. (Wheat harvest begins in Texas in June and ends in N.D. in August.) Wheat, therefore, is probably more diversified against any persistence that may be present in weather patterns. Still, the fact that 10 of 12 coefficients are positive during the March 24 through June 23 period does suggest that there may be a weak weather influence underlying this period, a period that is a reasonable approximation of the wheat growing season.

Table III presents more aggregated statistical results that focus on the growing seasons of each of the three crops versus the rest of the year and the total sample. Price momentum is especially significant in corn and soybeans in the growing season, May 24 through August 23, with *t* values of 5.71 and 8.58, respectively. A split aggregation into two nongrowing season periods, January 1 through May 23 and August 24 through December 31, shows essentially random price motion during these periods. Note that the growing season influence is strong enough to demonstrate significant results at the total data level in corn and soybeans.

Table III
A SEASONALLY PARTITIONED STATISTICAL SUMMARY FOR THE PERIOD OCTOBER 1, 1972 THROUGH SEPTEMBER 30, 1989

| Time cell* | Corn | | | Soybeans | | | Wheat | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Beta | t | N | Beta | t | N | Beta | t |
| Period 1 | 1686 | .00 | − .15 | 1686 | .00 | .11 | 1657 | −.01 | − .23 |
| Growing | 1083 | .17 | 5.71** | 1081 | .25 | 8.58** | 1082 | .07 | 2.34** |
| Period 2 | 1512 | .01 | .23 | 1512 | .02 | .95 | 1544 | −.04 | −1.40 |
| Total | 4281 | .08 | 5.11** | 4279 | .13 | 8.88** | 4283 | .00 | − .06 |

*Period 1 is January 1 through May 23 for corn and soybeans and November 1 through March 23 for wheat. The growing season is May 24 through August 23 for corn and soybeans and March 24 through June 23 for wheat. Period 2 is August 24 through December 31 for corn and soybeans and June 24 through October 31 for wheat.
**Significant at the .05 level, two tail test.

In wheat, aggregation across the March 24 through June 23 period discussed above results in significantly positive results with a $t$ value of 2.34. A lower value of Beta for wheat during its growing season, .07 versus .17 for corn and .25 for soybeans, reinforces the hypothesis that the weather is less persistent during this season and/or the national wheat crop is more spatially and temporally diversified against any persistent weather influence. Like corn and soybeans, the nongrowing season price dynamics appear to be essentially random. Contrary to the corn and soybean results, the growing season influence is not strong enough to create significant results at the total wheat data level.

### CONCLUSION

Strong empirical evidence of nonrandom seasonal price dynamics is found in corn, wheat, and soybean futures prices during the period October 1972 through September 1989. The season of the nonrandom price motion aligns well with the growing season of all three commodities. The weather and climatology literature asserts that weather patterns are to some extent persistent in North America during the summer months. This study finds that these nonrandom weather events do transfer a nonrandom influence into corresponding commodity prices during their respective growing seasons.

These results suggest that producers, merchandisers, speculators, and others that own these commodities during their respective growing seasons may well benefit from strategies that take positions on the basis of a continuation of existing price trends.

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