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Volatility in Wheat Spot and Futures Markets, 1950–1993: Government Farm Programs, Seasonality, and Causality

SUSAN J. CRAIN and JAE HA LEE*

ABSTRACT

We explore how wheat spot and futures market volatility has been impacted by government farm programs during the 1950–1993 period. We find that changing volatility in both markets is highly associated with changing farm programs. The mandatory allotment programs of the 1950s and early 1960s (1/3/50–4/10/64) were associated with low volatility, while the voluntary programs initiated in the mid 1960s seem to have induced high volatility (4/11/64–12/22/85). Both market-driven loan rates and conservation reserve programs appear to have helped volatility revert to lower levels since the mid 1980s (12/23/85–12/30/93). We also examine seasonality and causality in conjunction with the farm programs.

WE EXPLORE HOW WHEAT spot and futures price volatility has been impacted by government farm programs. Many studies have examined the effects of various farm policies (McKinnon (1967), Blakeslee (1980), Miranda and Helmberger (1988)), while numerous other studies have analyzed commodity market volatility (Anderson (1985), Milonas (1986), Kenyon *et al.* (1987), Najand and Yung (1991)). However, the direct impact of government farm policies on market volatility has received limited attention. This is surprising since a primary goal of farm programs is to stabilize prices of farm commodities such as corn, wheat, and cotton and hence protect farmers' income. Volatility in response to farm policy should be of ongoing concern to market participants and regulators.

We examine the impact of the thirteen farm programs, listed in the Appendix, on the wheat spot and futures market volatility for the period from January 1950 through December 1993. The instruments of government farm policy have varied considerably during this 43-year period. However, the stated goals of the policy have remained unchanged: (1) conservation of national resources, (2) assistance in the marketing of agricultural commodities, (3) regulation of interstate and foreign commerce, and (4) stabilization of commodity prices and farm income. The focus of our study is price stabiliza-

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tion. We hypothesize and find that various elements of each farm policy have affected wheat spot and futures prices over the sample period.

We examine the individual impact of government farm policies on wheat spot and futures volatility to determine the relative importance of each program. We find that there are approximately three subperiods that have distinguishable volatility magnitudes: (1) 1/3/50–4/10/64, (2) 4/11/64–12/22/85, and (3) 12/23/85–12/30/93. We seek possible explanations for the existence of these discernable patterns in volatility over time in terms of the implications of farm programs in each subperiod. Specifically, we discuss mandatory versus voluntary acreage allotments, high versus low loan rates, and implementation of a conservation reserve program. Detailed description of these variables will be provided later.

What other possible causes might there be for the observed intertemporal differences in volatility? To answer this question, we examine the variability in weather during the 43-year period and its impact on wheat volatility. Specifically, we measure both temperature and precipitation to test their impact on wheat volatility and find virtually no evidence. Also, we examine the possible correlation between the farm programs and the variability in weather. The lack of correlation implies that government programs caused most of the observed movements in volatility.

We consider two other issues in conjunction with government farm programs: seasonality and causality. Seasonality is due largely to imbalance between supply and demand. We hypothesize and find that volatility is higher than normal during the harvest time since large price declines are induced by large supply. Each farm program has different implications for controlling this imbalance. For example, if a program provides farmers with less incentive to market their products during the harvest time, weaker seasonality will be observed. We attempt to examine how seasonality changes across the farm programs. Lastly, we explore the Granger (1969, 1980) causal relationship between the wheat spot and futures markets. Similar to previous studies for other markets, we find that the futures volatility causes the spot volatility. However, it is interesting to note that this causality is evident only during the recent farm program periods (12/23/85–12/30/93). This may be due to general trends of more market-oriented programs toward free markets in recent years.

We use daily prices of wheat cash and futures during the 1950–1993 period to examine the wheat spot and futures volatility. We estimate the volatility of daily returns across thirteen government program periods and conduct tests of homoskedasticity across farm policies. We also test homoskedasticity between the spot and futures markets within each program. The individual impact of farm programs is investigated, followed by a further investigation of the impact of weather on volatility. Finally, we examine the link between the spot return volatility and the futures return volatility employing tests for Granger causality as well as seasonal volatility patterns across the farm programs.

The remainder of the paper is organized as follows. In Section I, we explain our set of government farm programs and describe the spot and futures data examined. In Section II, we estimate the wheat spot and futures return volatility and examine the implications of farm programs for volatility. The relative importance of each farm program is explored in Section III. In Section IV, attention is turned to seasonality and the causal relationship between the spot and futures volatility. Our results are summarized in Section V.

I. Data

A. Government Farm Programs

We consider the thirteen government farm programs listed in the Appendix. Two pieces of legislation form the basis of the programs over the sample period. They are the Agricultural Adjustment Act of 1938 and the Agricultural Act of 1949. The former established a national acreage allotment, marketing quotas, and a referendum.[1] The latter established a price support scale varying between 75 and 90 percent of parity, based on supply.[2] These programs were aimed at preventing surplus and shortage, maintaining normal supply, and providing orderly marketing. Subsequent legislation consists of amendments to these two acts.

The Agricultural Act of 1954 required the Commodity Credit Corporation to set a range of maximum and minimum levels of wheat. The Agricultural Act of 1956 included the "Soil Bank Act," which prevented excessive supply through an acreage reserve and a conservation reserve.[3] The Agricultural Act of 1961 included price supports supplementary to existing legislation. The Agricultural Act of 1962 was supplementary to the existing acreage allotments.

The Agricultural Act of 1964 abolished the mandatory wheat-marketing certificate program and adopted a voluntary program. Marketing quotas were no longer in effect and referendums were no longer held. Under the mandatory program, farmers were mandated to conform to acreage allotments and marketing quotas unless the referendum failed. Under the voluntary program, farmers could voluntarily choose to comply with acreage allotments if they wished to receive price supports. The Food and Agriculture Act of 1965 was initially a 4-year program but was extended through 1970. It dropped export certificates within the voluntary certificate program. The Agricultural Act of 1970 replaced acreage diversions on specific crops with a general set-aside: no specific crops had to be cut back.

The Agriculture and Consumer Protection Act of 1973 was a 4-year program that replaced price support payments with target prices. Deficiency payments

[1] An acreage allotment sets the number of acres multiplied by the national average yield per acre in the 10 preceding years to make available a quantity of wheat equal to a normal year's domestic consumption and exports plus required carryover. Marketing quotas are to regulate the quantity that each farmer can market during the season to bring supplies in line with requirements. A referendum is a vote by farmers to approve or disapprove marketing quotas.

[2] Parity is the price support system to bring farmer income into a comparable range as nonfarmers.

[3] Farmers are restricted not to plant anything for an acreage reserve on a year-to-year basis, while they should plant only grass and trees (no crops) for a conservation reserve during the following 10 years.

were made to farmers at rates equal to the target price less the greater of either the market price or loan rate.[4] To reduce the government stockpile of wheat, loan rates were purposely established below the market price.[5] The Food and Agriculture Act of 1977 was a 4-year program that continued the dual target and loan rate system. The Agriculture and Food Act of 1981 continued the two-tier system of target prices and loans with slight modification. The Food Security Act of 1985 established a conservation reserve program that bore much resemblance to the Soil Bank program of the 1950s. Finally, the Food, Agriculture, Conservation, and Trade Act of 1990 continued the existing program with several refinements.

B. Wheat Spot Data

Daily prices of No. 2 hard and dark wheat are obtained for the sample period of 1/3/50–12/30/93 from the Annual Statistical Reports of the Kansas City Board of Trade. High and low prices are given and are shown in cents per bushel. Cash traders on the floor of the Kansas City Board of Trade bid on railroad cars of grain that are presented daily. Cash bids for specific cars reflect quality and protein levels. At the end of the trading day, a "Basis Committee" determines that day's basis for a scale of protein levels ranging from the lowest grade, called ordinary, to the highest grade of 1400. The low cash price reported reflects the low bid basis for ordinary and the high cash price reported reflects the high bid basis for 1400.

Since both the low and high cash prices are the most representative spot prices which incorporate market consensus, we can use either of these two for our study. We chose to use the low cash price in the empirical tests.[6] The Kansas City cash price is used for this study because the Kansas City spot market is considerably more liquid than the Chicago spot market. In fact, Chicago cash trades were extremely infrequent for several months in a row during the early years of the sample period.

C. Wheat Futures Data

Daily closing prices for the Chicago Board of Trade (CBOT) wheat contract are obtained from three sources: (1) 1/3/50–12/19/68: Annual Report of CBOT, (2) 12/20/68–8/18/92: Technical Tools Database, and (3) 8/19/92–12/30/93: *Wall Street Journal*. The nearby contract is generally the most liquid and thus is used in this study. Wheat grades deliverable at par in Chicago include No. 2 hard red winter, No. 2 dark northern spring, No. 2 soft red, and No. 1 northern

[4] The loan rate is a price at which farmers can get a loan from the government using an agricultural commodity as collateral.

[5] If the market price is higher than the loan rate, farmers have an incentive to market their products, rather than give them to the government, to pay off the loan. Consequently, the government stockpile tends to decline with lower loan rates.

[6] We found that the high price was occasionally reported as the same as the low price in the Annual Statistical Reports. This could introduce potential downward bias if the high price is used. Due to this bias, the average of low and high prices may also be distorted.

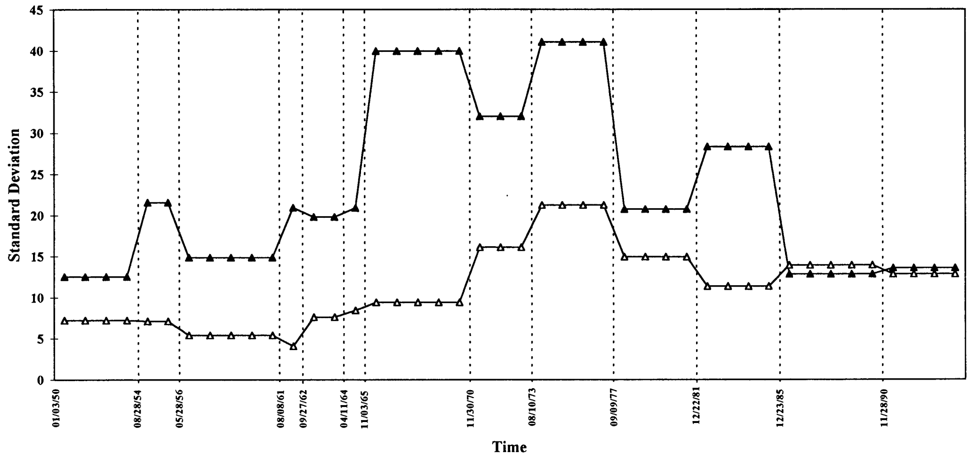

Figure 1. Wheat spot and futures volatility across government farm programs. Standard deviations of daily returns for each of the thirteen government farm programs from January 3, 1950 through December 30, 1993 are reported for both spot (*solid triangle*) and futures (*open triangle*). The reported standard deviations are the calculated values times 10^3.

spring. Since cash prices for this study are collected on No. 2 hard red winter and No. 2 dark northern spring, and the spot price differential between Kansas City and Chicago consists primarily of transportation charges, our futures data and cash data are comparable.

II. Volatility across Government Farm Programs

Our volatility measure is the standard deviation of returns. Specifically, we calculate standard deviations of daily log returns for each of the thirteen government farm programs, listed in the Appendix, during the January 3, 1950–December 30, 1993 period. Both the spot and futures return standard deviations are shown in Figure 1 and also reported in Table I. The results suggest that volatility, both spot and futures, has changed over the past 43 years and it seems to be related to changing farm programs. Both the spot and futures markets exhibit low volatility in the 1950s through early 1960s. From the mid 1960s, the spot volatility remained high until the mid 1980s and then declined sharply to maintain low volatility through 1993. The futures volatility also remained high until the mid 1980s, and although relatively high, it remained stable through 1993.

Are the variances equal across the thirteen government program periods and between spot and futures prices? The Brown-Forsythe-modified Levene (B-F-L) test statistics for homoskedasticity are reported in Table I.[7] The spot volatility changes significantly across program periods. The futures volatility also exhibits significant heteroskedasticity across farm programs. Both the

[7] Conover, Johnson, and Johnson (1981) compare over 50 methods for testing variance homogeneity and find that this test is both one of the most powerful and quite robust to nonnormality.

Table I

Tests of Homoskedasticity of Wheat Spot and Futures Volatility across Government Farm Programs

Daily return standard deviations (times 10^3) are reported for both spot (σ_{spot}) and futures (σ_{fut}) for each of the thirteen government farm programs during the period from January 3, 1950 to December 30, 1993. The Brown-Forsythe-modified Levene (B-F-L) test statistics for equality of the variances across the government farm program periods are reported. The B-F-L statistics for equality between the spot and futures variances and the ratios between the two variances are also reported within each program period.

Government Farm Programs	Spot (σ_{spot})	Futures (σ_{fut})	Std. Dev. Ratio ($\sigma_{\text{spot}}/\sigma_{\text{fut}}$)	B-F-L Statistics (H_0: $\sigma_{\text{spot}} = \sigma_{\text{fut}}$)
(1) 01/03/50–08/27/54	12.523	7.222	1.734	84.77***
(2) 08/28/54–05/27/56	21.554	7.101	3.035	81.45***
(3) 05/28/56–08/07/61	14.841	5.421	2.738	308.75***
(4) 08/08/61–09/26/62	20.920	4.065	5.146	97.24***
(5) 09/27/62–04/10/64	19.800	7.630	2.595	101.73***
(6) 04/11/64–11/02/65	20.901	8.436	2.478	106.15***
(7) 11/03/65–11/29/70	39.953	9.398	4.251	435.67***
(8) 11/30/70–08/09/73	32.027	16.113	1.988	153.88***
(9) 08/10/73–09/08/77	41.023	21.233	1.932	186.92***
(10) 09/09/77–12/21/81	20.732	14.932	1.388	30.35***
(11) 12/22/81–12/22/85	28.303	11.356	2.492	240.63***
(12) 12/23/85–11/27/90	12.822	13.911	0.922	13.64**
(13) 11/28/90–12/30/93	13.584	12.837	1.058	1.98
Overall	25.390	12.238	2.075	1213.54***
B-F-L Statistic: (H_0: $\sigma_1 = \sigma_2 = \ldots = \sigma_{13}$)	145.61***	196.02***		

** and *** indicate that the null hypothesis of homoskedasticity is rejected at the 0.1 and 0.01 percent levels, respectively.

spot and futures markets appear to have been significantly (at the 0.01 percent level) affected by the government farm programs.

As is clear from Figure 1, the spot volatility and the futures volatility generally tend to rise and fall in a similar manner. It is also interesting to note that the spot volatility is constantly higher than the futures volatility for most of the sample period. This unusual phenomenon may be attributed partly to the fact that the wheat spot market has become substantially less liquid as private transactions between independent buyers and sellers (not through the

One of the first studies in finance to apply this test was Lockwood and Linn (1990). The Brown-Forsythe-modified Levene test statistic is

$$F = \frac{\sum_{j=1}^{J} n_j(\bar{D}_{.j} - \bar{D}_{..})^2}{\sum_{j=1}^{J}\sum_{t=1}^{n_j}(D_{tj} - \bar{D}_{.j})^2}\,\frac{(N-J)}{(J-1)},$$

where $D_{tj} = |R_{tj} - \hat{M}_{.j}|$; R_{tj} is the return for day t, group j; $\hat{M}_{.j}$ is the sample median return for group j computed over the n_j days included in the test; $\bar{D}_{.j} = \sum_{t=1}^{n_j}(D_{tj}/n_j)$ is the mean absolute deviation (from the median) for group j; and $\bar{D}_{..} = \sum_{j=1}^{J}\sum_{t=1}^{n_j}(D_{tj}/N)$ is the grand mean, and $N = \sum_{j=1}^{J} n_j$. The statistic is distributed $F_{J-1,N-J}$ under the null hypothesis.

exchange) have been more prevalent for the last several decades. The futures trading volume currently far exceeds the exchange-based spot trading volume according to spot exchange officials. Also related to liquidity might be the fact that since the spot market is for immediate delivery, suppliers and buyers may not have time to respond to the price. For example, if a big buy-order comes in and the price rises, suppliers will not have time to increase the quantity supplied. In the futures market, they would have time to arrange increased supply, thus dampening the price rise. The same would apply to a big sell-order hitting the spot market. For these reasons, our exchange-based spot price data may therefore tend to be volatile.

Table I reports the B-F-L statistics for equality between the spot and futures variances and the ratios between the two variances within each farm program period and over the entire sample period. Except for the December 1985–December 1993 period, the spot volatility is significantly higher than the futures volatility at the 0.01 percent level. For the whole sample period, the spot volatility is more than two times the futures volatility, and the difference between the two is significant at the 0.01 percent level. The standard deviation ratio for each program is also significant at the 0.01 percent level.

In summary, the government farm programs seem to have influenced the wheat spot and futures market volatility over the 1950–1993 period. The null hypothesis that the variances are equal across farm programs is rejected at the 0.01 percent level for both the spot and futures markets. The spot volatility is significantly higher than the futures volatility over the sample period and within each farm program.

III. Which Government Farm Programs Induce Volatility

A. Primary Evidence

In Section II, we showed that volatility in the spot and futures markets is generally associated with government farm programs. Of course, the impact of individual farm programs on market volatility should not be alike. Attention is now turned to the question of which programs have induced more and which have induced less than average volatility. We estimate a regression in which the dependent variable is $|R_t - \bar{R}| - E|R_t - \bar{R}|$ where $R_t = \ln(P_t/P_{t-1})$ is the daily log return, $\bar{R}$ is the average daily log return, and $E|R_t - \bar{R}|$ is the mean of $|R_t - \bar{R}|$ over the sample period. We define G_{jt} to be 1 if day t is under government farm program j and zero otherwise. Our regression format is

$$|R_t - \bar{R}| - E|R_t - \bar{R}| = \sum_{j=1}^{13} a_j G_{jt} + e_t \qquad (1)$$

We do not include an intercept term in the regression in order to capture changes in volatility across programs. Specifically, as described in previous studies (for example, Ederington and Lee (1993)), if log returns are normally distributed with constant mean but time-varying variance,

Table II

The Impact of Government Farm Programs on the Daily Return Volatility in the Wheat Spot and Futures Markets

Coefficients a_j of the regression $|R_t - \bar{R}| - E|R_t - \bar{R}| = \sum_{j=1}^{13} a_j\, G_{jt} + e_t$ are reported. $R_t = \ln(P_t/P_{t-1})$ is the daily log return where P_t is the closing price on day t. R is the average daily log return. $E|R_t - \bar{R}|$ is the mean of $|R_t - \bar{R}|$ over the sample period. G_{jt} is a dummy variable which equals 1 if day t is included in the period of government farm program j; 0 otherwise. The reported coefficients and standard errors are the actual values times 10^3.

	Coefficient Estimates with Standard Errors (in Parentheses)	
	Spot	Futures
G_{1t}	−7.709 (0.519)***	−3.318 (0.224)***
G_{2t}	−2.719 (0.892)**	−3.186 (0.382)***
G_{3t}	−5.974 (0.513)***	−4.523 (0.222)***
G_{4t}	−2.858 (1.095)*	−5.389 (0.473)***
G_{5t}	−2.275 (0.947)*	−3.051 (0.408)***
G_{6t}	−1.496 (0.935)	−2.926 (0.404)***
G_{7t}	9.733 (0.521)***	−1.494 (0.225)***
G_{8t}	7.909 (0.713)***	3.522 (0.308)***
G_{9t}	14.089 (0.580)***	7.955 (0.251)***
G_{10t}	−1.227 (0.566)*	2.952 (0.244)***
G_{11t}	3.766 (0.585)***	0.320 (0.252)
G_{12t}	−6.933 (0.526)***	1.657 (0.227)***
G_{13t}	−6.231 (0.665)***	1.626 (0.287)***
Adj. R^2	0.134	0.173

*, **, and *** indicate significance at the 5, 0.5, and 0.01 percent levels, respectively.

$1.2533\,(a_j + E|R_t - \bar{R}|)$ represents an estimate of the standard deviation on days under farm program j (hereafter referred to as G_j).[8] By comparing the regression coefficients, we now can determine which program has induced either significantly higher or lower than average volatility. Table II shows the regression results.

The farm programs in order of decreasing impact on the wheat spot volatility are: G_9, G_7, G_8, G_{11}, G_{10}, G_6, G_5, G_2, G_4, G_3, G_{13}, G_{12}, and G_1. In particular, G_7 through G_{11} (11/3/65–12/22/85) are associated with much greater volatility than the rest of the farm programs. We also estimate equation (1) for the wheat futures market. Regression results as shown in Table II are not much distinguishable from those for the spot market, except that the futures volatility remains high during the 12/23/85–12/30/93 period. The farm programs in order of decreasing impact are: G_9, G_8, G_{10}, G_{12}, G_{13}, G_{11}, G_7, G_6, G_5, G_2, G_1, G_3, and G_4. Like the spot market, G_9 (8/10/73–9/8/77) has the greatest impact on the futures volatility. Also, futures volatility is relatively low for the 1/3/50–4/10/64 period, and it is high afterwards.

[8] For a more detailed discussion, see Schwert (1989) and Schwert and Seguin (1990).

The general picture emerging from our evidence suggests that there are three subperiods of programs with discernable volatility patterns: (1) 1/3/50–4/10/64 (low volatility), (2) 4/11/64–12/22/85 (high volatility), and (3) 12/23/85–12/30/93 (low volatility). It appears that two potential variables characterize the subperiod of high volatility. First, the Agricultural Act of 1964 abolished the mandatory wheat-marketing program and initiated a voluntary program.[9] Under the mandatory program, farmers were in essence able to "govern their own" through the marketing quota vote. However, the voluntary program involved the lowest level of united farmer participation in the production decision process. In other words, the government told the farmer how much he could individually plant in wheat acres to receive price support, and he then chose whether to participate. Conversion from mandatory to voluntary participation, which implies more "individual" control but much less "collective" control, seems to have induced more volatility in the wheat market.

Second, the loan rate, at which farmers borrow money from the government using their agricultural products as collateral, was substantially lowered beginning in the middle of 1964.[10] The government generally lowers the loan rate to reduce the stockpile of wheat. Farmers are encouraged to market their products to pay off the loan when the market price significantly exceeds the loan rate. Since there is no incentive for farmers to default and give their products to the government, the government's stockpile tends to decrease with a lower loan rate. Therefore, while the stockpile becomes more manageable, a wheat spot price far higher than the loan rate during this period implies that farmers were selling their products in the open market with heavy trading volume. Furthermore, there might have been a big downward movement of the spot price toward the loan rate which is generally considered a "fair" price. For these reasons, volatility must have increased.[11]

In regards to the wheat spot volatility, why did it sharply decline under G_{12} and G_{13} (12/23/85–12/30/93)? One possible reason for this may be the Food Security Act of 1985. This legislation established a conservation reserve program which is very similar to the Soil Bank program of the 1950s. Namely, the government attempted to prevent excessive supply of agricultural commodities through the conservation reserve by taking crop acres out of production for 10 years. The low volatility may have been caused by this conservation reserve program, and the impact of this program might persist until the mid 1990s.

Another reason for the low volatility during the 1985–1993 period may be loan rates. The 1977 and 1981 legislations recognized the importance of maintaining competitiveness in the world market by allowing a reduction in the loan rate if the average market price fell in the previous year within 105 percent of the loan level. The relevant loan rates were still determined by

[9] Although this Act was signed on April 11, 1964, the program did not apply to the 1964 crop. This may explain why volatility shows only a slight increase for G_6.

[10] For detailed information, see "History of Agricultural Price-Support and Adjustment Programs, 1933–84" published by Economic Research Service of the U.S. Department of Agriculture.

[11] The impact of loan rate on volatility was also recognized by Kenyon *et al.* (1987).

market regulators. However, the 1985 legislation strengthened the market orientation by establishing a basic loan rate at 75–85 percent of the simple average of the season prices received by producers during the five preceding marketing years, dropping the high and low. This implies that the loan rates were largely determined by *market forces*. The 1990 Act continued the calculation based on an 85 percent figure. This newly implemented market-oriented loan rate policy could partly explain why the spot volatility sharply declined in 1985 and remained low through 1993.

We now seek more evidence on changes in volatility across farm programs. As discussed above, we hypothesize that there are three major factors that influence wheat volatility: loan rates, whether the program is mandatory or voluntary, and whether a soil reserve program is in effect. First, the basic way we explore how loan rates affect wheat volatility is the following. In the Agricultural Adjustment Act of 1938, it is stipulated that a producer can obtain a loan during the marketing year which, for wheat, runs from July 1 to June 30. Although loan rates remain constant over the marketing year time frame, in most of the 43 years of this study, the loan rate changed from one year to the next.[12] For a given marketing year we first estimate the average market price and compare it with the constant loan rate to draw implications for volatility. We hypothesize that the loan rate serves to truncate the probability distribution of the open market price because the market price would be unlikely to fall much below the loan rate. This means a loan rate closer to the market price must reduce volatility. We regress the absolute return deviation from the mean, $|R_t - \bar{R}|$, on the ratio of the average market price to the loan rate. We also consider a dummy for whether the program was mandatory, $Dmandatory_t$ (= 1 if day t belongs to a mandatory program; 0 otherwise), and a dummy for whether a reserve program was in effect, $Dreserve_t$ (= 1 if day t belongs to a reserve program; 0 otherwise). Our regression model is

$$|R_t - \bar{R}| = a_0 + a_1 \frac{AMP_t}{LR_t} + a_2 Dmandatory_t + a_3 Dreserve_t + e_t \quad (2)$$

where AMP_t is the average market price during the marketing year that day t belongs to and LR_t is the loan rate on day t which is constant during the whole marketing year.

Estimates of equation (2) are reported in Table III. The loan rate coefficient, a_1, is significantly positive at the 0.01 percent level, for the spot as well as futures regressions, implying that high volatility is associated with low loan rates (in comparison to market prices). In general, the government lowers loan rates to reduce the stockpile of wheat, but the decline in loan rates appears to encourage farmers to trade their products more actively to take advantage of more profitable market prices, which leads to high volatility. Also, both a_2 and

[12] Loan rates were obtained from the Knight Ridder Commodity Research Bureau Commodity Year Book. Except for the 7/1/65–6/30/69, 7/1/84–6/30/86, and 7/1/90–6/30/92 periods, the loan rate has changed every marketing year.

Table III

More Evidence on Changes in Wheat Volatility across Government Farm Programs: Loan Rates, Program Provisions, Temperature, and Precipitation

Estimates of the following regressions are reported using daily data from 1/3/50 through 12/30/93:

$$|R_t - \bar{R}| = a_0 + a_1 \frac{AMP_t}{LR_t} + a_2 Dmandatory_t + a_3 Dreserve_t + e_t$$

$$|R_t - \bar{R}| = b_0 + b_1 |Temp_t - \overline{Temp}| + u_t$$

$$|R_t - \bar{R}| = c_0 + c_1 |Preci_t - \overline{Preci}| + w_t$$

$R_t = \ln(P_t/P_{t-1})$ is the daily log return where P_t is the closing price on day t. $\bar{R}$ is the average daily log return. $\mathrm{AMP_t}$ is the average market price during the marketing year that day t belongs to and $\mathrm{LR_t}$ is the loan rate on day t which is constant during the marketing year. $Dmandatory_t = 1$ if day t belongs to a mandatory program; 0 otherwise. $Dreserve_t = 1$ if day t belongs to a reserve program; 0 otherwise. $Temp_t$ and $Preci_t$ are temperature and precipitation on day t, respectively, and $\overline{Temp}$ and $\overline{Preci}$ are average monthly temperature and precipitation over the whole sample period, respectively. "Northern" and "Southern" columns show the results for the Northern and Southern Plains. The reported coefficients are the actual values times 10^3.

Independent Variable and Coefficient		Coefficient Estimates: Spot		Coefficient Estimates: Futures	
Panel A					
Intercept	(a_0)	16.492***		3.341***	
AMP_t/LR_t	(a_1)	2.964***		5.090***	
$Dmandatory_t$	(a_2)	−5.231***		−2.809***	
$Dreserve_t$	(a_3)	−7.473***		-1.293***	
Adj. R^2		0.0780		0.1923	
Panel B					
		Northern	Southern	Northern	Southern
Intercept	(b_0)	17.066***	16.926***	8.984***	8.728***
$\lvert Temp_t - \overline{Temp}\rvert$	(b_1)	−0.456	−0.561	−0.155	−0.092
Adj. R^2		0.0032	0.0025	0.0018	0.0003
Intercept	(c_0)	14.793***	15.853***	7.678***	8.321***
$\lvert Preci_t - \overline{Preci}\rvert$	(c_1)	1.638***	−0.138	1.489***	0.244*
Adj. R^2		0.0021	−0.0001	0.0090	0.0003

*, **, and *** indicate significance at the 5, 0.5, and 0.01 percent levels, respectively, in one-tailed t-tests.

a_3 are significantly negative at the 0.01 percent level. The implication is that mandatory programs and reserve programs induce low volatility. In fact, the explanatory power of $Dmandatory_t$ and $Dreserve_t$ is considerably high. When equation (2) is estimated with AMP_t/LR_t alone, the adjusted R^2 is 0.0270 and 0.1662 for spot and futures, respectively, and it increases to 0.0780 and 0.1923 when mandatory and reserve dummy variables are included. Consequently, loan rates, mandatory versus voluntary, and reserve provisions of farm programs seem to play an important role in explaining the impact of government farm programs on wheat market volatility.

B. Confirmatory Evidence

One obvious question regarding the observed differences in volatility across the farm programs is whether there have been some other possible causes. Has something else, which is independent but coincidental with the farm programs, induced the pattern? Attempting to answer this question, we first examine how variability in weather is associated with wheat volatility. Specifically, we obtain average monthly temperature and precipitation data for the Northern Plains (North Dakota, South Dakota, Nebraska, and Kansas) and for the Southern Plains (Oklahoma and Texas) from the Economic Research Service of the United States Department of Agriculture.[13] We then estimate the following models:

$$|R_t - \bar{R}| = b_0 + b_1|Temp_t - \overline{Temp}| + u_t \tag{3}$$

$$|R_t - \bar{R}| = c_0 + c_1|Preci_t - \overline{Preci}| + w_t \tag{4}$$

While these equations are estimated using daily data for R_t, $Temp_t$ and $Preci_t$ represent the average temperature and precipitation respectively that month. $\overline{Temp}$ and $\overline{Preci}$ are average monthly temperature and precipitation over the whole sample period respectively.[14] This specification reflects our judgement that it is weather conditions over an extended period, not day-to-day fluctuations, that impact prices. The regression results are reported in Table III for both the Northern and Southern Plains. The results indicate that variability in temperature and precipitation has not induced wheat spot and futures volatility during our 43-year sample period. All the adjusted R^2's are negligible (less than 1 percent), and many coefficients have wrong signs. Only the precipitation coefficient (c_1) is statistically significant (at the 0.01 percent) for both spot and futures for the Northern Plains, but the explanatory power is still very small.

One limitation of the weather regressions (3) and (4) is that they do not allow any role for weather expectations of wheat traders. It is likely that today's

[13] The National Climatic Data Center of the National Oceanic and Atmospheric Administration collects average precipitation and temperature data from a total of 344 climatic divisions of the 48 contiguous states. The Economic Research Service computes a weight for each division based on both geographic area and harvested acres. The averages for this study are weighted by harvested acres which reflect variations in the intensity of crop agriculture in the region. The Northern and Southern Plains consist of major states for wheat products.

[14] For example, the temperature on 6/8/83 is compared to the average June temperature over the entire sample period. In this manner we can more accurately assess variability in temperature that can affect crop production and induce price volatility. Given the June average of say 50 degrees, both 60 and 40 degrees will be considered to have the same level of variability, while different variability will be assessed if we use the overall (January through December) average of say 30 degrees.

trading strategies reflect market participants' expectations about upcoming weather conditions. Consequently, today's wheat spot and futures volatility should be affected by the market's weather expectations. To address this issue, we also estimate regressions in which temperature and precipitation variables lead the R_t by one month. For example, when $|R_t - \bar{R}|$ is for May 1950, we use $|Temp_t - \overline{Temp}|$ and $|Preci_t - \overline{Preci}|$ for June 1950 in the regressions. The regression results (not reported to save space but available upon request) are very similar to those reported in Table III, confirming that the wheat market volatility is not closely associated with the weather variability. This evidence, which is somewhat surprising, could be due to the fact that wheat is a particularly hardy plant contrary to other crops like corn or soybeans.

To scrutinize the issue of possible correlation between variability of weather and the farm programs (for example, the highest weather variability during G_9 and the second highest during G_8, etc.), we compute average $|R_t - \bar{R}|$, $|Temp_t - \overline{Temp}|$, and $|Preci_t - \overline{Preci}|$ within each farm period. We then conduct correlation analyses between wheat volatility and temperature variability and between wheat volatility and precipitation variability. There is no evidence that weather variability is coincident with the farm programs for both the Northern and Southern Plains. Since wheat volatility could lag weather variability, we also conducted correlation analysis between wheat volatility and lagged weather variability, say wheat volatility during G_2 versus weather variability during G_1, and so on, and no correlation is detected. Given this evidence, we can be reassured that government programs induced most of the observed intertemporal changes in wheat spot and futures volatility.

IV. Seasonality and Causality in Relation to Government Farm Programs

A. Seasonality

Wheat volatility is subject to seasonality since a large supply during the harvest time leads to large price declines and hence higher than normal price volatility. In fact, many studies, Anderson (1985), Kenyon *et al.* (1987), and Milonas (1991) among others, report seasonal volatility patterns in the wheat spot and futures markets. Changes in the farm programs would have implications for seasonality. For example, if a farm program entails low supply of wheat to the market, weaker seasonality will be observed. Out of the three subperiods of programs described above, subperiod 2 (4/11/64–12/22/85) is characterized by substantially low loan rates compared to market prices. Since a lower loan rate implies more marketing of products, i.e., more supply, seasonality tends to be stronger. Also, the Soil Bank Act in subperiod 1 and the conservation reserve program in subperiod 3, which were designed to prevent excessive supply of products, may lead to weaker seasonality. To explore these

Table IV

Government Farm Programs and Seasonality

Coefficients b_k of the regression $|R_t - \bar{R}| - E|R_t - \bar{R}| = \sum_{k=1}^{12} b_k M_{kt} + e_t$ are reported for (1) the whole sample period, (2) subperiod 1 (1/3/50–4/10/64), (3) subperiod 2 (4/11/64–12/22/85), and (4) subperiod 3 (12/23/85–12/30/93). $R_t = \ln(P_t/P_{t-1})$ is the daily log return where P_t is the closing price on day t. $\bar{R}$ is the average daily log return. $E|R_t - \bar{R}|$ is the mean of $|R_t - \bar{R}|$ over the sample period or each subperiod. M_{kt} is a dummy variable which equals 1 if day t is included in month k; 0 otherwise. The reported coefficients are the actual values times 10^3.

	Coefficient Estimates							
	Spot				Futures			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
M_{1t}	−1.847**	−2.445**	−1.043	−1.623*	−1.022**	−0.904**	−0.686	1.476*
M_{2t}	−1.900*	−1.389	−2.023	−1.549*	−0.646*	−0.038	−0.747	−1.011
M_{3t}	−1.505*	−1.423*	−1.433	−0.991	0.002	0.844**	−0.173	−0.603
M_{4t}	−0.577	−1.565*	0.107	−0.539	0.017	0.278	−0.369	0.729
M_{5t}	2.562***	2.812***	2.188	2.873***	0.655*	1.157***	0.114	1.189
M_{6t}	3.336***	3.211***	2.846*	4.517***	0.880**	0.221	0.760	2.184**
M_{7t}	−0.065	0.593	−1.464	2.194**	1.871***	0.743**	1.755**	4.028***
M_{8t}	0.985	−0.815	1.710	1.625*	0.348	−0.386	0.933*	−0.261
M_{9t}	−0.432	0.366	−0.784	−1.356	−0.132	−0.476	0.379	−1.189
M_{10t}	0.166	−0.536	0.893	−1.095	−0.759*	−0.788**	−0.820	−0.808
M_{11t}	0.005	1.515*	−0.686	−1.296	−0.706*	−0.419	−1.031*	−0.724
M_{12t}	−1.042	−0.005	−0.923	−2.951***	−0.623*	−0.304	−0.339	−2.101**
Adj. R^2	0.0051	0.0150	0.0017	0.0460	0.0073	0.0169	0.0043	0.0294

*, **, and *** indicate significance at the 5, 0.5, and 0.01 percent levels, respectively.

issues, we estimate the following model:

$$|R_t - \bar{R}| - E|R_t - \bar{R}| = \sum_{k=1}^{12} b_k M_{kt} + e_t \qquad (5)$$

where M_{kt} is 1 if day t belongs to month k and zero otherwise.

We first run regression (5) for the whole sample period for both spot and futures. The results are shown in column 1 in Table IV. The wheat spot volatility in May and June is significantly higher than other months, while January, February, and March exhibit relatively low volatility. This evidence confirms that volatility has a seasonal pattern: high volatility during the harvest period (summer) and low volatility in winter. The seasonality effects seem, however, far less important than the government farm programs in explaining changing volatility: the adjusted R^2 for seasonality is less than 1 percent, while that for farm programs is over 13 percent. Similar results were obtained from the wheat futures market as summarized in Table IV.

We estimate equation (5) for each of the three subperiods to see if seasonal patterns in volatility change across the farm programs. The results are shown in Table IV. While the explanatory power of seasonality is still weak, subperiod 3 shows the highest adjusted R^2. Inconsistent with our conjecture that a low loan rate leads to strong seasonality, the seasonal pattern in volatility does not seem particularly prominent in subperiod 2. With seasonality being a natural characteristic of the wheat markets, the market-oriented loan rate system in subperiod 3 seems more exposed to seasonality. To formally test whether the government programs affect seasonality, we conducted an F-test of the null hypothesis that there is no difference in the coefficients across the three subperiods.[15] The null was rejected at the 0.01 percent level for both spot and futures, implying that seasonality changes across farm programs.

B. Causality

We explore how volatility in one market is linked to volatility in the other. Numerous studies, Chan, Chan, and Karolyi (1991), Lee and Linn (1994), and Crain and Lee (1995), among others, find that the futures volatility generally leads the spot volatility in the equity, interest rate, and foreign exchange markets. We are interested in possible causal links between the wheat spot and futures markets in the Granger (1969, 1980) sense during our sample period. Also, if the causal relation exists, does the degree of causality vary across the farm programs?

We test whether volatility on day t in the spot market is related to past volatility in the futures market. We also test whether futures volatility is related to past spot volatility. Specifically, we estimate the following regression model to investigate the relation between $V_{t,S}$ and the k lagged values of $V_{t,S}$ and $V_{t,F}$:

$$V_{t,S} = a_0 + \sum_{p=1}^{P} a_{1p} V_{t-p,S} + \sum_{p=1}^{P} a_{2p} V_{t-p,F} + e_{t,S} \tag{6}$$

where t covers all trading days during the sample period, p represents the number of lags, and $V_{t,S}$ and $V_{t,F}$ represent the absolute values of the mean adjusted spot and futures returns on day t, respectively. Similarly, $V_{t,F}$ is the dependent variable when we test whether $V_{t,F}$ is Granger-caused by past $V_{t,S}$.[16]

The results for models including up to 10 lags are presented in Table V for the whole sample period (column 1). The F-statistic for the null that the lagged coefficients of $V_{t,F}$ are equal to zero is used to test whether past $V_{t,F}$ Granger-causes $V_{t,S}$. The null hypothesis that the futures volatility does not Granger-cause the spot volatility is uniformly rejected at the 0.01 percent level for all lags (lag 1 through lag 10) with the F-value decreasing as the number of lags increases. In contrast, the spot volatility appears to Granger-cause the futures

[15] For a detailed description of the F-test, see J. Johnston (1984, pp. 221–225).

[16] See Judge *et al.* (1985, pp. 654–701) for a detailed description of Granger causality tests.

Table V

Government Farm Programs and Causality

The null that the futures volatility (V_F) does not Granger-cause the spot volatility (V_S) is tested using the model $V_{t,S} = a_{oS} + \sum_{p=1}^{P} a_{1p}V_{t-p,S} + \sum_{p=1}^{P} a_{2p}V_{t-p,F} + e_{t,S}$. $V_{t,S(F)}$ is the absolute value of the mean adjusted spot (futures) log return from day $t-1$ to day t. Conversely, $V_{t,F}$ is used as the dependent variable for the null that V_S does not Granger-cause V_F. F-tests of the joint hypothesis that the coefficients of $V_{t-p,F}$ equal zero are reported when $V_{t,S}$ is the dependent variable, while F-tests of the joint hypothesis that the coefficients of $V_{t-p,S}$ equal zero are reported for the dependent variable $V_{t,F}$. The results are reported for (1) the whole sample period (1/3/50–12/30/93), (2) subperiod 1 (1/3/50–4/10/64), (3) subperiod 2 (4/11/64–12/22/85), and (4) subperiod 3 (12/23/85–12/30/93).

Number of Lags	Null ~ Futures Volatility (V_F) Does Not Granger-Cause Spot Volatility (V_S) (1)	(2)	(3)	(4)	Null ~ Spot Volatility (V_S) Does Not Granger-Cause Futures Volatility (V_F) (1)	(2)	(3)	(4)
1	79.388***	2.308	11.974**	87.070***	37.320***	1.546	1.560	11.567**
2	38.063***	2.730	6.003**	41.850***	17.662***	2.404	1.381	6.560**
3	22.556***	2.395	3.612*	27.010***	6.798***	1.518	1.196	3.917*
4	16.259***	2.307	3.034*	20.748***	4.867**	0.947	1.593	2.345
5	11.644***	2.227*	2.380*	16.246***	2.864*	0.648	1.150	1.840
6	9.366***	2.287*	1.994	13.300***	2.912*	0.596	1.197	2.177*
7	7.960***	2.315*	1.944	11.231***	2.340*	0.535	1.066	2.248*
8	7.848***	2.261*	2.116*	11.469***	1.872	0.450	0.989	1.523
9	6.622***	2.021*	1.852	10.000***	1.487	0.399	0.846	1.604
10	5.952***	1.875*	1.948*	8.777***	1.476	0.375	0.937	1.242

*, **, and *** indicate significance at the 5, 0.5, and 0.01 percent levels, respectively.

volatility only for lags 1 through 3 at the 0.01 percent level. The causal relationship is still found for lag 4 at the 0.5 percent level, and a low degree of causality for a few more lags.

Our evidence for the whole sample period (1950–1993) is basically consistent with previous studies. The wheat futures market has carried out its price discovery role by transferring volatility to the spot market. Now we address the question of whether this causal relationship has been affected by the farm programs. We estimate equation (6) for the three program subperiods. The results are summarized in Table V. The causal relationship in subperiod 3 (1985–1993) is remarkably strong, while subperiods 1 and 2 exhibit only weak causality. The wheat spot and futures markets were almost disjointed from each other in terms of volatility transfer from January 1950 through December 1985. During the recent program periods, however, the two markets have been closely linked to each other. One possible reason for price discovery taking place only in subperiod 3 may be due to more market-oriented programs in the spirit of free markets and hence more closely aligned spot and futures prices. The null hypothesis of the same regression coefficients across the three subperiods was uniformly rejected at the 0.01 percent levels in F-tests for lag 1 through lag 10, implying causality is affected by farm programs.

V. Summary

We explore how government farm programs impacted volatility in the wheat spot and futures markets during the 1950–1993 period. We also address the issue of seasonality and causality in these markets in conjunction with the farm programs. Our most important findings may be summarized as follows.

First, there has been a high degree of association between changing farm programs and changing spot and futures volatility. In particular, the thirteen farm programs during our sample period seem to be classified into three subperiods: (1) 1/3/50–4/10/64, (2) 4/11/64–12/22/85, and (3) 12/23/85–12/30/93. Both spot volatility and futures volatility were substantially higher during subperiod 2, while they were lowest during subperiod 1. The spot volatility sharply declined during subperiod 3, possibly due to a conservation reserve program and a more market-oriented loan rate policy. The futures volatility remained low and stable during subperiod 3, but still relatively high compared to subperiod 1. It appears the mandatory allotments of the 1950s and early 1960s contributed to low volatility, and the voluntary programs initiated in the mid 60s along with a considerably lower loan rate (compared to market price) might have increased volatility. In fact, the government examined, in 1990, a pilot program that replicates the marketing quotas of the mandatory allotment years. Our evidence suggests that mandatory, rather than voluntary, programs may be more effective for wheat price stabilization. Our investigation of other possible causes for the observed intertemporal differences in volatility, such as variability in temperature and precipitation, seems to reassure that the farm programs induced most of the volatility movements.

Second, seasonal patterns exist in the wheat spot and futures markets. May through August, which represent the harvest period, exhibit higher volatility than other months in both markets. However, the seasonality effects on volatility do not seem to be as important as the impact of farm programs. Explanatory power of seasonality is far less than farm programs. When seasonality is examined across the farm programs, subperiod 3 shows higher explanatory power than the other subperiods but is still relatively low.

Finally, there is clear evidence that volatility is transferred from the futures market to the spot market. Volatility in the spot market today is significantly related to past volatility in the futures market up to at least 10 days ago, although more recent past volatility shows greater impact. The spot volatility also Granger-causes the futures volatility but only up to lag 3 or 4. The impact of futures on spot is bigger and more persistent than the impact of spot on futures. It is interesting to note that this causal relationship is remarkably strong in subperiod 3 but very weak in subperiods 1 and 2. This phenomenon may be due to more market-driven farm policies in recent years and hence more closely aligned spot and futures prices.

Appendix

Government Farm Programs

	Title	Date Signed
(1)	Agricultural Act of 1949	October 31, 1949
(2)	Agricultural Act of 1954	August 28, 1954
(3)	Agricultural Act of 1956	May 28, 1956
(4)	Agricultural Act of 1961	August 8, 1961
(5)	Food and Agriculture Act of 1962	September 27, 1962
(6)	Agricultural Act of 1964	April 11, 1964
(7)	Food and Agriculture Act of 1965	November 3, 1965
(8)	Agricultural Act of 1970	November 30, 1970
(9)	Agriculture and Consumer Protection Act of 1973	August 10, 1973
(10)	Food and Agriculture Act of 1977	September 9, 1977
(11)	Agriculture and Food Act of 1981	December 22, 1981
(12)	Food Security Act of 1985	December 23, 1985
(13)	Food, Agriculture, Conservation, and Trade Act of 1990	November 28, 1990

REFERENCES

Anderson, R., 1985, Some determinants of the volatility of futures prices, *Journal of Futures Markets* 5, 331–348.

Blakeslee, L., 1980, Post World War II government policy impacts on the U.S. wheat sector, Technical bulletin, College of Agriculture Research Center, Washington State University.

Chan, K., K. C. Chan, and G. Karolyi, 1991, Intraday volatility in the stock index and stock index futures markets, *Review of Financial Studies* 4, 657–684.

Conover, W., M. Johnson, and M. Johnson, 1981, A comparative study of tests for homogeneity of variances with applications to continental shelf bidding data, *Technometrics* 23, 251–261.

Crain, S., and J. Lee, 1995, Intraday volatility in interest rate and foreign exchange spot and futures markets, *Journal of Futures Markets* 15, 395–421.

Ederington, L., and J. Lee, 1993, How markets process information: news releases and volatility, *Journal of Finance* 48, 1161–1191.

Granger, C., 1969, Investigating causal relations by econometric models and cross-spectral methods, *Econometrics* 37, 423–438.

Granger, C., 1980, Testing for causality: a personal viewpoint, *Journal of Economic Dynamics and Control* 2, 329–352.

Johnston, J., 1984, *Econometric Methods* (McGraw-Hill, New York), 221–225.

Judge, G., W. Griffiths, R. Hill, H. Lutkepohl, and T. Lee, 1985, *The Theory and Practice of Econometrics* (Wiley, New York), 654–701.

Kenyon, D., K. Kling, J. Jordan, W. Seale, and N. McCabe, 1987, Factors affecting agricultural futures price variance, *Journal of Futures Markets* 7, 73–91.

Lee, J., and S. Linn, 1994, Intraday and overnight volatility of stock index and stock index futures returns, *Review of Futures Markets* 13, 1–29.

Lockwood, L., and S. Linn, 1990, An examination of stock market return volatility during overnight and intraday periods, 1964–1989, *Journal of Finance* 45, 591–601.

McKinnon, R., 1967, Futures markets, buffer stocks, and income stability for primary producers, *Journal of Political Economy* 75, 844–861.

Milonas, N., 1986, Price variability and the maturity effect in futures markets, *Journal of Futures Markets* 6, 443–460.

Milonas, N., 1991, Measuring seasonalities in commodity markets and the half-month effect, *Journal of Futures Markets* 11, 331–345.

Miranda, M., and P. Helmberger, 1988, The effects of commodity price stabilization programs, *American Economic Review* 78, 46–58.

Najand, M., and K. Yung, 1991, A GARCH examination of the relationship between volume and price variability in futures markets, *Journal of Futures Markets* 11, 613–621.

Schwert, G., 1989, Why does stock market volatility change over time, *Journal of Finance* 44, 1115–1153.

Schwert, G., and P. Seguin, 1990, Heteroskedasticity in stock returns, *Journal of Finance* 45, 1129–1155.