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Differences Among Commodities in Real Price Variability and Drift

Richard Heifner and Randal Kinoshita

Abstract. Many farm products exhibit price variabilities over long time intervals that range between 10 and 20 percent when measured as standard deviations of annual rates of change. Price variability is notably higher for onions, rice, wool, oats, potatoes, grapefruit, and oranges, and lower for snap beans, tobacco, green peas, milk, broccoli, processing tomatoes, and strawberries. Price variability was higher during 1977-93 than during 1949-72 for grains, soybeans, and peanuts, lower for grapes, potatoes, processing tomatoes, and hogs, and about the same for other crops and livestock. Real prices fell between 1948 and 1993 for 29 of 30 commodities studied, with poultry, eggs, wool, snap beans, grains, and cotton exhibiting the largest rates of decline.

Keywords. Commodity prices, price trends, price variability, real prices

Differences among commodities in price variability and longterm price trends are important for private decisions about investments in farming and farm product marketing and for public decisions about farm programs. Knowledge of such differences can further our understanding of the fundamental changes underway in agriculture. This article uses price data going back for some commodities to as early as 1900 to describe and compare year-to-year price variability and changes in real price levels for 30 farm commodities selected to represent a cross section of U.S. agriculture.

Underlying this comparison of commodity differences is the notion that price variability is a natural and persistent characteristic of agricultural prices that can be quantified but not fully explained. Reducing price variability has been a longterm concern of agricultural policymakers, the goal of many government programs, and a focus of intense study (see Newbery and Stiglitz, for example).¹ Previous authors have found evidence of increasing price variability in U.S. agriculture during recent decades (see Edwards, Dalziel, Miller et al., and Myers and Runge). One of our objectives is to determine if increases in price

variability broadly characterize U.S. agriculture or are confined to certain commodities.

Long price series are needed to detect persistent differences among commodities in price behavior. Fortunately, the National Agricultural Statistics Service and its predecessor agencies have reported prices for several major crops since before 1900, for most livestock since 1924, and for most fruits and vegetables since 1939. This analysis uses prices from as early as 1900 to the extent that they are available, but gives greatest attention to 1948-93.

Edwards noted that real wheat prices declined over much of the twentieth century. He pointed out that the decline was not continuous and the rate of decline that one measures depends upon the year one chooses as a starting point. Our analyses follow the spirit of Edwards' work. We cover 30 commodities, use annual rates of change to facilitate intercommodity comparisons, and include statistical tests of our assumptions and the differences observed between commodities and over time. We show that real prices for many agricultural commodities have declined over long periods, that price variability has changed for certain commodities, and that differences among commodities in price variability are persistent.

Data

Rates of change in real prices are used to show changes over long periods in real purchasing power, provide unit-free comparisons among commodities, and assure stationarity. Continuously compounded annual rates of change were calculated by taking first differences of logarithms

$$r_{t-1,t} = \log x_t - \log x_{t-1},$$

where $r_{t-1,t}$ is the rate of change in price from period $t-1$ to period t , x_t is the price in year t , and x_{t-1} is the price in year $t-1$.² This measure facilitates comparing price changes in different directions and over periods of different lengths. It is additive—the change over a period of length n

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¹Sources are listed in the References section at the end of this article.

²The continuously compounded rate of change over a year can be converted to the simple annual rate of change by taking the antilog and subtracting 1. For example, the simple rate of change corresponding to a 0.05 compounded rate of change is the natural antilog of 0.05 minus 1, which is 0.05127.

equals the sum of the changes over the n subperiods

$$r_{0n} = \log x_n - \log x_0 = \sum_{t=1}^n (\log x_t - \log x_{t-1}) = \sum_{t=1}^n r_{t-1,t}$$

Thus, a given rate of change in one year followed by an equal but opposite rate of change in the next year returns the series to its original level. Another advantage of using continuous annual rates of price change is that the standard deviation of such changes is the measure of price volatility used in options pricing models (See Black). This allows the price variabilities reported here to be compared with those reported in the options pricing literature.

Marketing year average prices received by farmers from 1900 (or the earliest year available) to 1993,

were analyzed for the 30 commodities listed in table 1.³ The price data are primarily from USDA's *Agricultural Statistics*, various issues, and from *Historical Statistics of the United States Colonial Times to 1970*. The most recent prices are from USDA's *Agricultural Prices, 1992 Summary*, selected monthly issues of *Agricultural Prices* during 1993 and 1994, and *Crop Values, 1993 Summary*.⁴

US average prices are calculated by weighting State prices by production prior to 1944 and by

³Marketing years for crops begin at the start of harvest and extend into the next calendar year for many commodities. Marketing years have been changed occasionally in the past and vary by State for some commodities. Marketing years for livestock coincide with calendar years except that marketing years begin in the preceding December for hogs, broilers, and eggs.

⁴For information on how the prices were collected, see USDA, *Major Statistical Series of the U.S. Department of Agriculture*.

Table 1—Changes in real levels of selected commodity prices and price indexes, with comparisons, 1949-1993

Commodity	Nominal prices		Real prices		Real price changes	
	1948	1993	1948	1993	Total, percent	Annual, percent
Wheat, \$/bu	1 98	3 20	9 95	2 57	-74 21	-3 01
Rice, \$/cwt	4 88	9 00	24 52	7 21	-70 57	-2 72
Corn, \$/bu	1 28	2 60	6 43	2 08	-67 59	-2 50
Oats, \$/bu	72	1 40	3 60	1 12	-68 54	-2 59
Grain sorghum \$/bu	1 28	2 41	6 43	1 93	-69 96	-2 67
Soybeans, \$/bu	2 27	6 50	11 40	5 21	-54 31	-1 74
Cotton, cents/lb	30 38	54 30	152 62	43 53	-71 48	-2 79
Tobacco, cents/lb	48	1 75	2 42	1 40	-42 07	-1 21
Peanuts, cents/lb	10 50	29 80	52 75	23 89	-54 72	-1 76
Oranges, \$/box ¹	1 75	5 04	8 79	4 16	-52 66	-1 70
Grapefruit, \$/box ¹	83	4 28	4 17	3 53	-15 24	-0 38
Grapes, \$/ton	38 50	289 00	193 42	231 66	19 77	0 40
Strawberries, \$/cwt	22 20	52 50	111 53	42 08	-62 27	-2 17
Broccoli, \$/cwt	9 38	25 90	47 12	20 76	-55 94	-1 82
Lettuce, \$/cwt	4 04	16 00	20 30	12 83	-36 81	-1 02
Onions, \$/cwt	2 64	15 80	13 26	12 67	-4 51	-0 10
Tomatoes, fresh, \$/cwt	6 10	31 60	30 65	25 33	-17 34	-0 42
Potatoes, \$/cwt	2 53	6 22	12 71	4 99	-60 77	-2 08
Beans, snap, \$/ton	122 22	178 00	614 01	142 69	-76 76	-3 24
Peas, green, \$/ton	90 05	251 00	452 40	201 20	-55 53	-1 80
Tomatoes, proc., \$/ton	27 92	60 10	140 27	48 18	-65 65	-2 37
Cattle, \$/cwt	22 20	73 32	111 53	58 77	-47 30	-1 42
Steers, Choice, \$/cwt ²	28 88	76 36	143 27	61 21	-60 04	-2 04
Hogs, \$/cwt	23 10	45 26	116 05	36 28	-68 74	-2 58
Lambs, \$/cwt	22 80	64 81	114 54	51 95	-54 64	-1 76
Milk, \$/cwt	4 88	12 83	24 52	10 28	-58 05	-1 98
Wool, cents/lb	49 20	50 00	247 17	40 08	-83 78	-4 04
Broilers, cents/lb	36 00	33 96	180 86	27 22	-84 95	-4 21
Turkeys, cents/lb	46 80	38 90	235 12	31 18	-86 74	-4 49
Eggs, cents/dozen	47 20	62 39	237 13	50 01	-78 91	-3 46
Crops, index	255	531	1281 1	425 6	-66 77	-2 45
Livestock, index	315	779	1582 5	625 4	-60 54	-2 07
All commodities, index	287	653	1441 8	523 4	-63 70	-2 25
Prices paid, index	260	1346	1306 2	1079 0	-17 40	-0 42

¹Final year is 1992

²Composite of Chicago prices 1935-50, Omaha prices 1951-69, and Nebraska direct prices for 1970-93

quantity sold from 1944 to 1993. Prices for grains prior to 1979 include allowances for loans outstanding and government purchases, where applicable. Cotton prices are for all cotton, gross weight prior to 1964 and net weight since, and include allowances for unredeemed loans during 1974-78. Orange and grapefruit prices are returns per box at the packinghouse door. Prices at the processing plant door are used for snap beans, green peas, and tomatoes for processing. Prices are on an f o b basis for lettuce, onions, and tomatoes for fresh use. Strawberry and broccoli prices apply to both processing and fresh markets. Choice steer prices are for Chicago delivery from 1935 to 1950, Omaha delivery from 1951 to 1969, and Nebraska direct for 1970 to 1993, as reported by the Agricultural Marketing Service.

The available price series vary in length for the different commodities. Prices for wheat, corn, oats, cotton, tobacco, potatoes, and wool begin in 1900. Rice prices start in 1904, soybean prices in 1924, and grain sorghum prices in 1929. The series begin in 1924 for grapes, in 1929 for citrus fruits, and in 1939 for most vegetables. Livestock prices, except for Choice steers, are average prices received by farmers and they begin in 1924. Egg, turkey, and broiler prices begin in 1909, 1929, and 1934, respectively. Milk prices are prices of all milk wholesale beginning in 1910. Prices for 1993 are preliminary for all commodities.

Prices were deflated using the implicit gross domestic product (GDP) deflator (1987=100). Deflating has only a minor effect on measures of short-term variability because year-to-year changes in inflation rates generally have been small compared with year-to-year commodity price changes.⁵ The implicit price deflator was obtained for recent years from the *Economic Report to the President*, selected issues. The deflator was extended backward to earlier years using GNP deflators, and Consumer Price Index estimates prior to 1929, reported in *Business Statistics, 1961-88*, a supplement to the *Survey of Current Business*, and in the *Historical Statistics of the United States From Colonial Times to 1970*.

Historical Declines in Real Prices

Twenty-nine of the 30 commodities analyzed exhibited declines in real prices between 1948 and 1993 (table 1). The total percentage declines are large for many commodities—over 80 percent for

turkeys, broilers, and wool, and about 70 percent for the grains and cotton, for example.⁶ The corresponding average annual rates of decline were over 4 percent for turkeys, broilers, and wool, over 3 percent for eggs and snap beans, and 2½ to 3 percent for the grains, cotton, and hogs. Prices for the remaining commodities declined at a 1 to 2½ percent rate except for onions and processing tomatoes where the rate was less than 1 percent. Grapes exhibited a slight increase.

To provide a broad gauge of farm price changes for comparison, we include base 1910-14 indexes of prices received by farmers for crops, livestock, and all commodities and prices paid by farmers (bottom of table 1). To eliminate the effects of general price inflation on the indexes, they too were divided by the implicit GDP deflator. This measure shows a total decline between 1948 and 1993 in real prices of all farm commodities of 63.70 percent and an average rate of decline of 2.25 percent. The average rate of decline was 2.45 percent for crops and 2.07 percent for livestock. Prices paid by farmers declined at a 0.42 percent rate.

Real prices of most agricultural commodities have declined during much of the twentieth century. Table 2 shows average rates of change in real prices for three 24-year intervals starting in 1901, and for the 21-year interval 1973-93. The 1901-24 interval includes only the seven commodities for which prices were reported as early as 1900. Real prices for wheat, oats, and potatoes declined during this early period while real prices for corn, cotton, tobacco and wool increased.

The 1925-48 interval uses data from the first year when livestock prices were widely reported, and spans the Depression, the drought of the thirties, and World War II. Real prices for food grains, tobacco, peanuts, potatoes, meat animals, milk, and eggs rose during this interval while real prices for feed grains, soybeans, cotton, grapes, and wool declined.

The 1949-72 interval covers the period between mid-century and the U.S. abandonment of the gold standard. Real prices declined during this interval for 27 of the 30 commodities analyzed. Rates of decline exceeded 4 percent for broilers, turkeys, eggs, and wool and exceeded 3 percent for wheat, cotton, and snap beans. The decline in soybean

⁵Between 1948 and 1993 the inflation rate, as measured by changes in logarithms of the GDP deflator, averaged 4.08 percent with a standard deviation of 2.38 percent, and a maximum of 9.57 percent.

⁶The total percent change equal $100 \times (\text{1993 price} - \text{1948 price}) / \text{1948 price} - 100$ while the annual rate of change is calculated by the formula above. Note that only the initial price and the final price are needed to calculate total or average change, but that the intermediate prices are needed to calculate the standard deviation of price changes and the standard error of the estimated average price change.

Table 2—Average annual rates of change in real prices, selected commodities and time intervals, percent

Commodity	1901-1924	1925-1948	1949-1972	1973-1993
Wheat	-0 20	0 08	-3 27	-2 71
Rice	—	0 21	-1 44	-4 18
Corn	1 50	-1 05	-1 93	-3 16
Oats	-0 46	-0 14	-2 74	-2 42
Grain sorghum	—	—	-2 50	-2 87
Soybeans	—	-2 17	-0 05	-3 67
Cotton	0 71	-0 66	-3 23	-2 29
Tobacco	1 23	2 05	-0 52	-2 01
Peanuts	—	0 65	-1 44	-2 13
Oranges	—	—	-0 99	-2 55 ¹
Grapefruit	—	—	2 13	-3 39 ¹
Grapes	—	-1 77	3 28	-2 89
Strawberries	—	—	-2 46	-1 83
Broccoli	—	—	-2 19	-1 40
Lettuce	—	—	-1 32	-0 67
Onions	—	—	-0 96	-1 32
Tomatoes, fresh	—	—	0 91	-1 95
Potatoes	-1 18	1 49	-2 04	-2 12
Beans, snap	—	—	-3 62	-2 82
Peas, green	—	—	-1 87	-1 72
Tomatoes, proc	—	—	-1 82	-3 01
Cattle	—	3 73	-1 07	-1 83
Steers, Choice	—	—	-2 12	-1 94
Hogs	—	2 96	-2 44	-2 75
Lambs	—	1 28	-1 76	-1 75
Milk	—	1 45	-1 87	-2 00
Wool	0 98	-0 60	-4 20	-3 86
Broilers	—	—	-6 69	-1 38
Turkeys	—	—	-5 89	-2 89
Eggs	—	0 54	-4 55	-2 22
Crops, index	—	—	-2 75	-2 11
Livestock, index	—	—	-2 09	-2 04
All commod , index	—	1 07	-2 42	-2 06
Prices paid, index	—	0 19	-0 73	-0 07

-Data not available
¹1973-1992

prices was negligible. Real prices for grapefruit, grapes, and tomatoes for fresh use increased.

Real prices for all 30 commodities declined during 1973-93 with 20 of the 30 commodities exhibiting rates of decline exceeding 2 percent annually. The rate of decline exceeded 4 percent for rice and 3 percent for wool, soybeans, grapefruit, corn, and processing tomatoes. Rates of decline were less than during 1949-72 for poultry, eggs, wheat, and cotton, and greater for rice, corn, soybeans, tobacco, peanuts, oranges, grapefruit, and tomatoes.

These declines in real prices are consistent with the hypothesis that increases in productivity have outpaced increases in demand allowing larger quantities to be produced and consumed at lower real prices. However, the year-to-year variability in prices makes it impossible to project rates of decline for individual commodities with much certainty, as will be shown below.

Historical Differences Among Commodities in Price Variability

The standard deviations of real price changes are reported in table 3 for the same intervals as shown in table 2. In addition, the last column of the table shows standard deviations for 1977-93, which excludes the years of unusually high price volatility during the mid-seventies. The 1977-93 standard deviations are shown in fig. 1 with the commodities ordered according to their respective price variabilities. Standard deviations of price changes by decade are displayed in table 4.

Price variability was higher prior to 1949 than it has been since for most crops where price data for the earlier years are available. For example, corn, cotton, and potato price variability exceeded 30 percent from 1901 to 1924 and corn, oats, soybean, potato, and grape price variability exceeded 30 percent from 1925 to 1948. Hog price variability has been substantially less in recent years than

Table 3—Standard deviations of rates of change in real prices, selected commodities and time intervals, percent

Commodity	1901-24	1925-48	1949-72	1973-93	1977-93
Wheat	18 00	25 43	10 97	24 84	17 70
Rice	—	22 79	9 79	32 72	29 97
Corn	41 64	31 86	12 45	21 65	19 74
Oats	23 11	32 43	9 14	26 27	26 25
Grain sorghum	—	—	13 49	20 95	19 06
Soybeans	—	33 08	10 11	20 61	18 72
Cotton	31 74	27 97	13 27	17 68	14 60
Tobacco	22 26	22 30	4 94	5 59	4 05
Peanuts	—	23 80	5 18	10 14	11 12
Oranges	—	—	25 32	21 22 ¹	23 51 ¹
Grapefruit	—	—	32 89	22 76 ¹	24 80 ¹
Grapes	—	34 35	25 15	13 74	14 21
Strawberries	—	—	8 78	7 28	7 70
Broccoli	—	—	5 60	6 43	6 55
Lettuce	—	—	14 46	15 27	15 17
Onions	—	—	39 73	36 48	34 79
Tomatoes, fresh	—	—	9 23	9 55	10 62
Potatoes	37 47	49 67	36 78	25 91	25 10
Beans, snap	—	—	4 55	9 43	3 36
Peas, green	—	—	4 27	11 10	4 52
Tomatoes, proc	—	—	10 18	11 49	6 89
Cattle	—	13 27	13 11	13 35	11 75
Steers, Choice	—	—	11 17	10 58	9 49
Hogs	—	25 44	18 77	16 50	13 48
Lambs	—	13 80	10 74	10 91	11 36
Milk	—	8 80	6 37	6 08	5 24
Wool	27 36	28 14	27 05	33 29	26 41
Broilers	—	—	9 73	15 39	10 13
Turkeys	—	—	10 95	18 32	12 18
Eggs	—	14 28	13 91	15 88	12 24
Crops, index	—	—	4 93	12 77	7 96
Livestock, index	—	—	7 94	9 29	6 99
All commodities, index	—	12 13	5 70	9 19	5 85
Prices paid, index	—	4 14	1 95	3 01	2 27

—Data not available

¹Final year is 1992

prior to 1949 while price variability for cattle and lambs is down slightly

Most grains and soybeans exhibited price variabilities below 10 percent during the 1950's and 1960's (see app table 1) Price variabilities for these commodities jumped to the 20 percent range or higher in the seventies, and have remained high during the eighties and nineties Rice and oats prices have been particularly volatile during this recent period

Several commodities have exhibited price variabilities exceeding 20 percent during many decades These include onions, potatoes, wool, oranges, and grapefruit At the other extreme are milk, tobacco, processing vegetables, broccoli, and strawberries where price variability has been consistently below 10 percent Price variabilities for meat animals and eggs have been in the 10-20 percent range since 1949 Variabilities of the indexes of prices received are smaller than the averages of the variabilities of the included

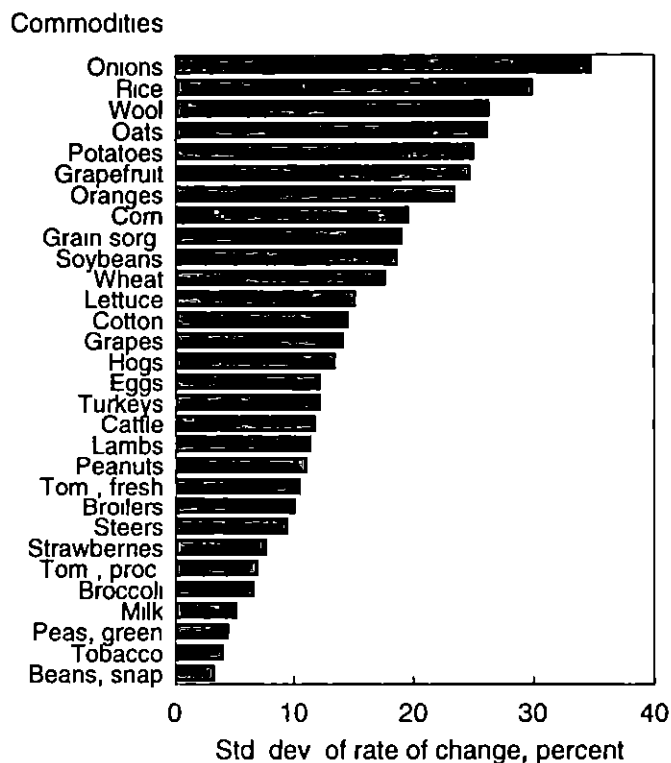
commodities because the commodity prices included in each index are not perfectly correlated

Stationarity in Prices and Price Changes

We turn now to the question of whether the historical patterns of drift and variability of price changes are likely to continue To forecast a stochastic process one must determine that it is stationary, or transform it to a stationary process, and quantify the probability distribution that the stationary process follows Stationarity in the prices and price differences was tested by applying the Dickey-Fuller t test for unit roots to the longest series available for each commodity ⁷ This

⁷A unit root is present if the first order autocorrelation coefficient for a series is 1, which is the condition for a random walk In such cases, the coefficient of the regression of the first difference in the series on the lagged value of the series is zero The essence of the Dickey-Fuller test is to test this regression coefficient for difference from zero using special tables that they provide

Figure 1
Price variability by commodity, 1977-93



is a test of whether a series tends to converge toward its mean or trend level. The augmented test was used, which in this application involves regressing the first difference of the series being tested on the lagged value of the series plus a constant, a trend, and two lagged first differences.⁸ The tests were applied to the original price series, the logarithms of deflated prices, and the first differences of the logarithms of deflated prices.

Unit roots in the nominal prices could be rejected at the 10 percent or higher level for only 3 of the 30 commodities (table 5). When the series were deflated and converted to logarithms, unit roots were rejected at the 10 percent or higher level for 15 commodities. Unit roots in the first differences of logarithms were rejected for all 30 commodities and all 4 price indexes at the 1 percent level. These results show that the rates of change series are more certain to have bounded variances than the undifferenced series and support the use of rates of change (first differences of logarithms) in our analyses.

⁸The unit root, normality, and homoscedasticity tests were calculated using MicroTSP, Version 7.0, written by David M. Lilien and distributed by Quantitative Micro Software of Irvin, CA.

Normality of Price Changes

In addition to stationarity, normality is required to test hypotheses about means and variances. Deviations from normality in the price changes were evaluated by calculating skewness, kurtosis, and the Jarque-Bera statistic using 1949-1993 observations for each series (table 6). The Jarque-Bera test is significant at the 20 percent level, indicating non-normality for 13 commodities: wheat, rice, oats, cotton, grapes, onions, snap beans, green peas, processing tomatoes, milk, broilers, turkeys, eggs, and all of the price indexes. The sample distributions for all of these series exhibit thick tails as evidenced by kurtosis exceeding 3, its value under normality. Inspection of the data suggests that 1 to 3 outlying observations for each commodity account for most of the kurtosis. When these outliers are dropped from the sample, normality is no longer rejected for 11 of the 13 commodities and for all 4 indexes (table 7). Outliers are not removed for oats and cotton because they cannot be clearly distinguished.

The results suggest that annual price changes are approximately normally distributed for most agricultural commodities. However, more than a third of the commodities exhibited extreme price movements one or more times during the 45-year sample period. Many of the outliers were for the years 1973 and 1974 when the first large grain sales were made to the Soviet Union following the United States' abandonment of gold convertibility. To avoid undue influence from extreme observations, outliers were omitted or post-1975 data were used in several of the statistical tests reported below.

Prospects for Continued Declines in Real Price Levels

The historical observations reported in tables 1 and 2 combined with the evidence of stationarity in price changes shown in table 5 suggest that real prices for many agricultural commodities are likely to continue to drift downward. However, the downward drifts in real prices generally are small relative to their standard errors, making it impossible to conclude with a high degree of confidence that real prices for any particular commodity will continue to decline. T ratios to test for zero price drift (table 8) were calculated for each commodity by dividing the mean rate of price change for 1949-93 by its standard error. The t ratio for the all commodity index is large enough in absolute value to reject the hypothesis of zero drift at the 5

Table 4—Standard deviations of rates of change in real prices by decade, 1901-10 to 1971-80 and for 1981-93, percent

Commodity	01-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-93
Wheat	16 10	16 90	22 41	34 54	12 71	4 36	14 10	30 94	17 80
Rice	—	35 92	16 04	28 25	19 71	9 70	4 73	31 57	32 27
Corn	27 36	54 28	28 88	41 69	24 02	5 93	9 22	24 02	21 82
Oats	23 70	23 77	20 01	45 08	22 28	9 65	5 79	22 59	27 46
Sorghum	—	—	—	49 58	24 73	16 69	8 35	21 26	20 72
Soybeans	—	—	—	46 28	22 93	6 54	8 23	22 14	20 29
Cotton	20 69	41 94	34 67	28 06	19 62	6 47	13 89	19 25	14 76
Tobacco	8 61	31 31	19 84	27 05	18 30	3 77	5 63	6 36	4 27
Peanuts	—	28 57	21 26	32 46	11 97	7 05	3 10	6 04	11 95
Oranges ¹	—	—	—	37 30	35 77	21 17	31 73	19 29	21 93
Grapefruit ¹	—	—	—	37 32	52 64	17 88	37 70	13 92	27 47
Grapes	—	—	—	27 39	47 23	23 62	18 47	19 94	14 99
Strawb	—	—	—	—	27 40	11 83	6 64	6 78	7 32
Broccoli	—	—	—	—	22 94	5 77	4 53	5 48	7 28
Lettuce	—	—	—	—	23 62	9 3	13 97	19 57	12 76
Onions	—	—	—	—	52 24	51 27	28 79	47 34	26 55
Tom fresh	—	—	—	—	18 57	10 12	7 92	9 16	10 79
Potatoes	33 48	44 99	55 29	56 72	25 16	45 93	30 62	31 15	23 33
Bean, snap	—	—	—	—	15 69	5 31	3 33	13 69	3 58
Peas, green	—	—	—	—	12 55	3 43	4 91	15 65	4 67
Tom proc	—	—	—	—	15 88	8 45	12 89	15 37	6 26
Cattle	—	—	—	16 68	9 79	18 29	6 50	18 19	7 21
Steers	—	—	—	—	10 16	14 35	7 26	13 62	6 67
Hogs	—	—	—	31 78	20 52	20 01	14 52	24 24	13 36
Lambs	—	—	—	14 80	7 11	12 93	8 60	8 42	11 76
Milk	—	7 50	9 44	10 43	10 75	6 80	3 70	5 09	5 27
Wool	16 57	21 99	37 32	40 17	12 55	29 07	13 13	44 24	30 08
Broilers	—	—	—	—	13 07	10 51	9 58	18 73	11 36
Turkeys	—	—	—	17 42	17 82	8 54	12 46	23 05	12 51
Eggs	—	9 21	12 71	14 20	16 74	16 59	10 55	19 76	13 32
Crops	—	—	—	—	12 70	5 46	3 77	15 40	8 92
Livestock	—	—	—	—	9 91	9 37	5 80	13 01	4 75
All commod	—	9 74	13 91	15 36	10 62	6 89	3 25	11 98	5 32
Prices paid	—	2 73	5 41	2 45	5 84	2 70	0 99	2 96	1 69

—Data not available

¹Last year is 1992

percent level, but only a few of the t ratios for individual commodities are so large.⁹

No clear pattern of rising or falling rates of price change is evident in the data. Twenty-seven of the 30 commodities exhibited real price declines from 1949 to 1972, all 30 exhibited declines from 1973 to 1993, and 17 exhibited larger rates of decline during the latter period. To test whether the rates of price change are rising or falling over time, each series of price changes was regressed on time. The regression coefficients are negative for all crops that have been under Government support programs and mixed for other commodities, but none of the coefficients differ from zero at the 10 percent level of statistical significance (column 3 of table 8).

⁹Similar results were obtained when t ratios were calculated separately for the 1949-72 and 1977-93 intervals to eliminate the large price shocks of the mid-seventies.

We conclude that the downward drift in prices is strong and likely to persist for agricultural commodities as a group, but expected rates of change for most individual commodities are subject to much uncertainty. Moreover, the differences in rates of change between commodities generally are not statistically significant.

Changes Over Time in Price Variability

Three tests were performed to determine if prices are becoming significantly more or less variable over time. White tests and ARCH tests were applied to the residuals from the regressions of price changes on time. The White test is a test for relationships between the squared residuals and the independent variables in a regression. The White test on the residuals rejected homoscedasticity at the 10 percent level or higher for rice, corn, oats, soybeans, peanuts, grapefruit, grapes, potatoes, and milk (column 4 in table 7).

Table 5—Dickey-Fuller t-statistics on nominal prices and logarithms and first differences of logarithms of real prices, selected commodities, and designated time intervals

Commodity	Years included	Nominal price	Log real price	First difference log real price
Wheat	1904-93	-2 92	-3 18+	-6 51**
Rice	1907-93	-3 32+	-2 41	-7 80**
Corn	1904-93	-3 20+	-3 71*	-7 34**
Oats	1904-93	-2 92	-3 19+	-6 82**
Grain sorghum	1932-93	-2 98	-3 72*	-6 71**
Soybeans	1927-93	-2 58	-2 47	-7 56**
Cotton	1904-93	-2 33	-3 10	-7 95**
Tobacco	1904-93	-1 50	-2 81	-7 90**
Peanuts	1912-93	-1 17	-2 37	-8 06**
Oranges	1932-92	-2 20	-3 76*	-7 19**
Grapefruit	1932-92	-2 70	-5 16**	-5 65**
Grapes	1927-93	-2 07	-3 55+	-5 87**
Strawberries	1942-93	-1 58	-5 78**	-4 87**
Broccoli	1942-93	-1 67	-3 98*	-4 19**
Lettuce	1942-93	-1 58	-4 10*	-5 89**
Onions	1942-93	-1 56	-3 48+	-8 92**
Tomatoes, fresh	1942-93	0 10	-3 81*	-5 34**
Potatoes	1904-93	-2 31	-4 20**	-8 67**
Beans, snap	1942-93	-2 35	-6 65**	-5 33**
Peas, green	1942-93	-1 59	-3 54*	-5 20**
Tomatoes, proc	1942-93	-1 88	-2 84	-5 34**
Cattle	1927-93	-1 68	-2 74	-6 29**
Steers, Choice	1938-93	-1 80	-2 90	-6 60**
Hogs	1927-93	-2 29	-2 40	-7 50**
Lambs	1927-93	-2 56	-2 71	-5 33**
Milk	1913-93	-1 55	-2 05	-6 50**
Wool	1904-93	-3 54*	-2 78	-6 86**
Broilers	1937-93	-1 32	-1 84	-5 19**
Turkeys	1932-93	-2 01	-2 14	-6 77**
Eggs	1912-93	-2 59	-2 22	-7 67**
Crops	1937-93	-1 96	-2 56	-5 41**
Livestock	1937-93	-1 41	-2 50	-6 41**
All commodities	1914-93	-1 49	-2 55	-6 48**
Prices paid	1914-93	-0 17	-2 98	-5 84**

**,*, and + indicate that unit roots are rejected at the 1, 5, and 10 percent levels of statistical significance, respectively

The ARCH test is a test of whether large residuals follow large residuals and small residuals follow small residuals (See Engle) It involves regressing squared residuals on lagged squared residuals Three lags were used in the test The tests indicate significant serial dependence in variances at the 10 percent level or higher for corn, oats, tobacco, peanuts, grapefruit, hogs, wool, and the index of livestock prices (column 5 of table 8)

An F test for differences in variance between 1977-1993 and 1949-1972 was applied to each series The larger of the two variances was used in the numerator for each test Significantly larger variances were found during 1977-93 than during 1949-72 for all the grains, soybeans, peanuts, and the crop price index, while grapes, potatoes, processing tomatoes, and hogs exhibited significantly lower variances during the later period (last column of table 8) These test results suggest that price variabilities have changed for enough commodities that the 1977-93 variability estimates are

to be preferred over the 1949-93 estimates for making projections

Differences Among Commodities in Price Variability

Many of the differences in price variability among commodities shown in fig 1 and tables 3 and 6 are larger than would be expected due solely to sampling error and appear to reflect inherent differences among the commodities Differences in price variability between pairs of commodities can be evaluated using the F statistic The 10 percent critical value for F(16, 16), which is applicable to the 1977-1993 interval, is 1 93 Its square root, 1 39, can be used to test for differences in the standard deviations shown in the last column of table 3 The average standard deviation for the 30 commodities during 1977-1993 is 13 55 Thus, we can say with about 90 percent confidence that variabilities exceeding $13 55 \times 1 39 = 18 83$ are

Table 6—Standard deviations, skewness, kurtosis, and tests for normality in rates of change in real prices, selected commodities, 1949-93

Commodity	Standard deviation, percent	Skewness	Kurtosis	Jarque-Bera statistic	Probability
Wheat	18 53	1 49	8 28	68 84	00
Rice	23 21	0 69	4 75	9 28	01
Corn	17 16	0 22	3 13	0 39	82
Oats	18 90	-0 26	4 90	7 29	03
Grain sorghum	17 17	0 11	2 41	0 75	69
Soybeans	15 81	-0 17	3 02	0 22	89
Cotton	15 31	0 43	4 16	3 97	14
Tobacco	5 25	-0 30	3 50	1 15	56
Peanuts	7 80	-0 12	4 02	2 07	36
Oranges ¹	23 29	0 03	2 19	1 22	54
Grapefruit ¹	28 55	0 19	3 43	0 60	74
Grapes	20 64	0 21	4 67	5 55	06
Strawberries	8 03	-0 53	3 15	2 15	34
Broccoli	5 95	-0 18	2 53	0 67	71
Lettuce	14 67	0 08	2 22	1 18	55
Onions	37 83	-0 71	3 94	5 46	07
Tomatoes,	9 38	-0 15	2 73	0 30	86
Potatoes	31 82	0 10	3 13	0 11	95
Beans, snap	7 17	2 99	16 61	414 19	00
Peas, green	8 10	3 36	19 13	572 37	00
Tomatoes,	10 71	1 09	4 59	13 56	00
Cattle	13 07	-0 28	3 86	1 96	38
Steers, Choice	10 78	-0 41	3 85	2 62	27
Hogs	17 54	0 07	2 43	0 62	73
Lambs	10 69	-0 54	2 53	2 60	27
Milk	6 16	-0 40	4 17	3 76	15
Wool	29 77	0 25	3 19	0 52	77
Broilers	12 82	1 14	6 72	35 73	00
Turkeys	14 75	0 50	5 51	13 65	00
Eggs	14 73	0 74	4 44	8 06	02
Crops	9 32	1 52	8 24	68 55	00
Livestock	8 50	70	3 46	4 09	13
All commodities	7 44	1 60	8 35	72 90	00
Prices paid	2 49	1 00	5 31	17 57	00

¹1949-92

Table 7—Standard deviations, skewness, kurtosis, and tests for normality in rates of change in real prices, commodities exhibiting nonnormality in previous table, 1949-93 with outlying observations omitted

Commodity	Years omitted	Standard deviation, percent	Skewness	Kurtosis	Jarque-Bera statistic	Probability
Wheat	73	14 42	0 02	3 47	0 41	81
Rice	73, 86, 87	16 75	05	3 29	17	92
Grapes	50, 51, 73	16 70	19	3 42	57	75
Onions	53	33 24	-15	2 42	78	68
Beans, snap	74	4 47	04	2 67	21	90
Peas, green	74	4 73	03	3 69	89	64
Tomatoes, proc	74	9 21	52	2 70	2 16	34
Milk	49, 91	5 15	42	3 29	1 40	50
Broilers	73	10 29	-26	2 18	1 73	42
Turkeys	73, 74	11 53	-39	3 13	1 11	58
Eggs	73	12 73	02	2 48	50	78
Crops	73, 74	6 70	-31	3 31	87	65
Livestock	73, 74	7 31	47	2 38	2 23	34
All commodities	73, 74	5 79	07	2 60	32	85
Prices paid	73, 74	2 02	27	4 28	3 43	18

Table 8—Statistics for testing drift and variability of price changes, 1949-93

Commodity	t ratio, test for zero drift	Regression of rates of change on time			F for variance ratio, 1977-93 vs 1949-72 ¹
		Regression coefficient	F for White test	F for ARCH test	
Wheat	-1 09	- 028	1 22	03	2 60*
Rice	- 79	- 044	2 60+	1 24	9 38**
Corn	- 98	- 030	2 93+	2 35+	2 51*
Oats	- 92	- 045	3 51*	3 07*	8 25**
Sorghum	-1 04	- 019	1 00	1 29	2 00+
Soybeans	- 74	- 063	4 60*	1 86	3 43**
Cotton	-1 22	- 078	64	13	1 21
Tobacco	-1 55	- 073	55	2 84+	1 48
Peanuts	-1 51	- 026	6 28**	3 11*	4 61**
Oranges ¹	- 48	- 213	48	55	1 16
Grapefruit ¹	- 09	- 238	3 39**	2 30+	1 76
Grapes ¹	13	- 097	3 19+	92	3 13*
Strawberries	-1 81+	049	88	79	1 30
Broccoli	-2 06*	046	1 65	15	1 37
Lettuce	- 47	044	21	1 40	1 10
Onions ¹	- 02	047	1 26	41	1 30
Tom fresh	- 30	- 062	2 35	96	1 32
Potatoes	- 44	077	2 48+	15	2 15+
Beans snap	-3 03*	0	61	12	1 84
Peas green	-1 49	- 031	64	06	1 12
Tom proc	-1 49	- 095	76	11	2 19+
Cattle	- 73	044	1 07	38	1 24
Steers	-1 27	051	1 48	54	-1 39
Hogs	- 99	017	1 07	2 61+	1 94+
Lambs	-1 10	0	1 95	1 28	1 12
Milk	-2 10*	0	5 29**	28	1 48
Wool	- 91	- 168	21	2 99*	1 05
Broilers	-2 20*	181	42	01	1 08
Turkeys	-1 04	111	80	1 21	1 24
Eggs	-1 57	017	08	37	1 29
Crops	-1 76+	- 023	69	63	2 61*
Livestock	-1 63	037	72	2 72+	1 29
All commod	-2 03*	011	21	07	1 05
Prices paid	-1 14	0	10	77	1 36

***,*, and + indicate statistical significance at the 1, 5, and 10 percent levels, respectively

¹Years are 1952-92 for citrus, 1955-93 for grapes, and 1957-93 for onions

greater than average, and variabilities less than 13 55/1 39 = 9 75 are less than average. By this criterion, onions, rice, wool, oats, potatoes, grapefruit, oranges, corn, and gain sorghum exhibit significantly higher than average price variability while snap beans, tobacco, green peas, milk, broccoli, processing tomatoes, strawberries, and Choice steers exhibit significantly lower than average variability.

Conclusion

We have shown that agricultural commodities exhibit important and persistent differences in price variability. Variability has changed over time for certain commodities, most notably for the grains and soybeans, where prices were less variable during the fifties and sixties than in earlier or more recent decades. The persistence of commodity differences suggests that variability depends largely on inherent commodity charac-

teristics, such as the elasticity of supply, production lags, yield variability, foreign production variability, storability, and elasticity of demand. Government policies and programs and other institutions appear to have moderated price variability in some cases. In particular, changes in US and foreign policies on trade and exchange seem to account for some of the historical changes in grain and soybean price variability (See Miller, et al.) Government programs probably have reduced the variability of milk and tobacco prices while industry structure and marketing practices may account for the relatively low variability of processing vegetable prices. Detailed analyses of individual commodities is needed to assess the effects of specific programs and policies on price variability.

Finally, the longterm downward drift in real farm prices, while reflecting major gains to consumers, is grounds for continuing concern for persons and

firms in agriculture The historical prices analyzed here tell us little about how long and at what rate these downward drifts will continue To make such forecasts calls for studying prospective changes in demand, supply, and costs, for individual commodities

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