INSTABILITY IN U. S. FEED GRAINS SUPPLY AND UTILIZATION

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Two basic economic problems that plague commercial agriculture are (1) a chronic cost-price squeeze brought about by input price inflation and other causes and (2) instability in economic outcomes brought about mainly by unpredictable weather which influences yields and production at home and abroad. The objective of this article is to estimate the sources of instability in U. S. feed grains supply and utilization.[1] Because of the inelastic demand for feed grains, changes in the quantities produced, stored, and utilized, both domestically and abroad, are influential in determining price and income. Identifying past sources of instability provides background for possible future policy considerations to reduce price and income variation. The latter step is not considered here, although commodity stock levels necessary to offset variation in domestic production and export demand are estimated.

PREVIOUS RESEARCH

A large number of statistical studies have measured instability in the farming economy. Examples are analysis of the distribution of futures prices [2] and of variation in seasonal average commodity prices [4], of sources of commodity market instability [1], and tests for yield cycles [3]. The authors are unaware of any previous study systematically estimating instability in components of feed grains supply and utilization. One study [5] estimates components of variation in wheat markets but, unlike this study, does not relate variation in production and export demand to appropriate commodity stock levels.

MEASURES OF DISPERSION FOR 10 TIME PERIODS

Two statistics, the standard deviation and the coefficient of variation, are used to measure instability in Table 1. In both the 1967-1971 period and the 1972-1976 period, the standard deviation of production of feed grains is 18.4 million tons. If the same average level of production continued in the future as in the 1972-1976 period (197.2 million tons), total feed grains production would be expected to be within an interval of 178.8 to 215.6 million tons in two-thirds of the years. The variation in production as measured by the standard deviation has tended to increase since 1927. Departures from the trend are notable for the depression and war years when the standard deviation is above the overall trend. These departures can be explained by unstable weather in the 1932-1936 period and increased output in response to war needs in the 1942-1946 period.

The standard deviation for domestic utilization has been fairly erratic since 1927, but is greater for the 1972-1976 period than for any previous period. The variation in domestic utilization has tended to be smaller than the variation in production. Possibly some of the variability in domestic utilization was in response to variability in production in the absence of adequate stocks. In general, exports and stocks have been a modest source of instability.

The coefficient of variation is the standard deviation expressed as a percentage of the average, hence it is a measure of the relative variation in the feed grains market. If stock changes are exempted, exports generally have

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[1]For purposes of this article, instability is defined as the unpredictable variance in components of feed grain supplies and utilization in the United States. Feed grains include corn, grain sorghum, barley, and oats. Because long-term trends that can be predicted with reasonable accuracy are not regarded as instability in this article, the variances are computed for intervals of five or fewer years.

been the greatest source of relative variation in the feed grains market, although since the war years the coefficient of variation for feed grains shows a definite downward trend.

CORRELATION BETWEEN VARIABLES

Many variables contribute to the variation within each of the classifications defined heretofore. These variables include weather, changes in the price of other feedstuffs, and the value of the dollar. For the most part these variables are uncontrollable; however, variations in quantities supplied and consumed can be controlled to a degree by manipulating stocks. Stocks cushion the disturbances in supply and demand and thus have a stabilizing effect on price. The correlation coefficient provides insight into how variation in production or exports is being buffered by changes in stocks or domestic utilization.

Supply, in this analysis, is defined as production plus the net release of feed grains from stocks. Utilization is defined herein as domestic use plus exports. Negative correlations of net release feed grains from stocks with production and positive correlations with utilization indicate commodity stocks are helping to stabilize the feed grains market. The magnitude of the coefficient shows the relative strength with which stocks are doing their job. Between 1942 and 1972 the correlation coefficient between production and stocks is negative (Table 2). For the 1967-1971 period it is −.848 but becomes positive, .199, for the 1972-1976 period which could indicate that commodity stocks have not been a stabilizing device or that stocks were buffering changes in utilization rather than supply. The high positive coefficient of correlation between domestic utilization and stocks for the 1972-1976 period suggests that stocks have helped to buffer domestic demand. The presence of incorrect signs on correlation coefficients between stocks on one side and production and exports

TABLE 2. SIMPLE CORRELATION BETWEEN SELECTED VARIABLES IN THE FEED GRAINS MARKET, 1927-1976, UNITED STATES.[a]

	Production	Stock Change	Domestic Utilization	Exports
Stock Changes				
1927-31	.567	1.00	.734	.580
1932-36	-.565	1.00	-.669	-.553
1937-41	.106	1.00	.577	-.862
1942-46	-.860	1.00	-.047	-.295
1947-51	-.788	1.00	.208	-.368
1952-56	-.310	1.00	-.677	-.301
1957-61	-.043	1.00	.461	.721
1962-66	-.515	1.00	-.187	.525
1967-71	-.848	1.00	-.091	-.747
1972-76	.199	1.00	.851	-.541
Exports				
1927-31	.824	.580	.689	1.00
1932-36	.954	-.553	.970	1.00
1937-41	-.183	.862	-.741	1.00
1942-46	.557	-.295	-.587	1.00
1947-51	.840	-.368	.779	1.00
1952-56	.985	-.307	.884	1.00
1957-61	.150	.721	.836	1.00
1962-66	.449	.525	.623	1.00
1967-71	.877	-.747	.564	1.00
1972-76	.751	.541	-.085	1.00

[a]Because the correlation coefficients are only used to describe the structural association between two variables in each period and each period is the "population" (inferences are not extended to a larger number of years), a test for statistical significance of the correlation coefficient from a null hypothesis of zero or one was judged to be inappropriate. A test of significance could be relevant if the variables contain sizable measurement error. Because measurement error is likely to be comparatively small, a test of significance could entail large Type II error and be misinterpreted.

TABLE 1. VARIABILITY IN FEED GRAINS PRODUCTION, STOCKS, DOMESTIC UTILIZATION, AND EXPORTS, 1927-1976.[a]

Period	Production St. Dev.	Production Mean	Production C. V.	Stock Change St. Dev.	Stock Change Mean	Stock Change C. V.	Domestic Utilization St. Dev.	Domestic Utilization Mean	Domestic Utilization C. V.	Exports St. Dev.	Exports Mean	Exports C. V.
	million tons		%	million tons		%	million tons		%	million tons		%
1927-31	5.89	86.50	6.80	1.38	2.24	61.74	5.27	84.80	6.21	1.13	1.54	73.98
1932-36	23.30	71.50	32.60	2.32	6.36	36.51	15.72	73.60	21.35	.20	.38	53.93
1937-41	3.66	92.18	3.97	6.61	0.06	1141.00	9.55	87.60	10.89	1.64	1.96	83.72
1942-46	4.70	109.10	4.30	1.50	3.74	40.31	4.35	110.00	3.95	2.02	1.76	114.92
1947-51	14.53	108.80	13.36	12.40	-1.22	-1016.50	7.90	103.60	7.60	1.72	4.66	37.09
1952-56	5.32	114.70	4.64	1.40	5.74	24.47	3.78	104.10	3.63	1.79	6.08	29.47
1957-61	8.86	144.20	6.14	11.02	1.56	706.97	8.92	127.10	7.02	2.69	13.04	20.65
1962-66	10.48	148.90	7.04	4.42	8.98	49.23	6.21	134.60	4.61	4.67	21.66	21.56
1967-71	18.39	177.10	10.38	12.14	-1.56	-778.50	9.09	153.00	5.94	3.35	22.18	15.10
1972-76	18.39	197.20	9.33	6.07	9.94	61.14	16.95	155.00	10.93	6.79	47.08	14.42

[a]Data for this and subsequent tables from U. S. Department of Agriculture [6]. For comparison of summary statistics for wheat, see Tweeten and Gerloff [5].

on the other provides some evidence that stocks were inadequate to stabilize the market—a conclusion apparent in the large fluctuations in feed grain prices in the 1972-1976 period.

Exports can stabilize or destabilize markets, depending on how they relate to production and domestic utilization. Positive correlation coefficients apparent between exports and production (except for the small negative correlation in the 1937-1941 period) indicate that exports have tended to be a stabilizing influence on the market. In contrast, the positive correlation coefficients between exports and domestic utilization for the 1947-1971 periods suggest that exports have contributed to market variability by failing to offset changes in domestic utilization. The following analysis explores this issue further.

The components of variation in the feed grains market can be divided into (1) variation in supplies (production plus stocks) and (2) variation in utilization (domestic utilization plus exports).

Variance in Supplies

To observe more precisely the contribution of production and stocks to dampening total variation in supplies, it is convenient to express variation in supply (production plus net reduction in stocks) as *variance,* which is the standard deviation squared. In equation form the relationship can be expressed as

$$S_T^2 = S_p^2 + S_s^2 + 2S_{ps},$$

where

S_T^2 = estimated variance in total supplies
S_p^2 = estimated variance in production
S_s^2 = estimated variance in stock adjustments
S_{ps} = estimated covariance between production and stock adjustments.

The covariance can be calculated as

$$S_{ps} = r_{ps} S_p S_s$$

where

r_{ps} = the correlation coefficient between production and stocks
S_p and S_s = the standard deviations for production and stocks, respectively.

Variance in production is greater than variance in supplies in seven of the 10 periods considered in Table 3. In the 1967-1971 period, variance in production is approximately triple

TABLE 3. ESTIMATED VARIANCE IN SUPPLIES AND UTILIZATION OF FEED GRAINS WITH COMPONENTS, 1927-1976 BY 5-YEAR INTERVALS, UNITED STATES

Period (Years)	Total Variance in Supplies and Utilization[a]	Variance in Supplies: Variance in Production	Variance in Supplies: Variance in Stock Change	Variance in Supplies: 2 Times Covariance	Variance in Utilization: Variance in Domestic Utilization	Variance in Utilization: Variance in Exports	Variance in Utilization: 2 Times Covariance
				(million tons)			
1927-31	41.6	34.7	1.9	9.2	27.8	1.3	8.2
1932-36	370.8	543.7	5.4	-61.1	247.4	.04	6.3
1937-41	66.4	13.4	43.7	5.1	91.2	2.6	-23.2
1942-46	12.4	22.1	2.3	-12.1	18.9	4.0	-10.3
1947-51	84.1	211.3	153.7	-283.9	63.0	2.9	21.3
1952-56	27.6	28.3	1.9	-4.6	14.3	3.2	12.0
1957-61	159.3	78.5	121.6	-8.4	79.6	7.2	40.1
1962-66	89.1	109.9	19.5	-47.7	38.6	21.8	36.1
1967-71	117.6	338.3	147.4	-378.6	82.7	11.2	34.3
1972-76	332.4	338.3	36.9	-44.4	287.4	46.1	-19.6
				(percent of total)			
1927-31	100	75.8	4.1	20.0	74.5	3.5	22.0
1932-36	100	111.4	1.1	-12.5	97.5	0.0	2.5
1937-41	100	21.5	70.3	8.2	129.2	3.7	-32.8
1942-46	100	179.7	18.6	-98.4	150.0	31.7	-81.7
1947-51	100	260.5	189.5	-350.1	72.2	3.3	24.4
1952-56	100	110.5	7.5	-18.0	48.5	10.8	40.7
1957-61	100	40.9	63.4	-4.4	62.7	5.7	31.6
1962-66	100	134.5	23.9	-58.4	40.0	22.6	37.4
1967-71	100	315.9	137.6	-353.5	64.5	8.7	26.8
1972-76	100	102.3	11.2	-13.4	91.6	14.7	-6.2

[a]Component variances in supplies and utilization do not exactly sum to total variance because of errors in the data as well as rounding error. Imports are not included in supplies.

that in supplies. Thus, commodity stock adjustments have not dampened overall variation in supplies.

Variance in Utilization

The total variance in utilization can be expressed with a mathematical form similar to that for supplies but with different components. The relationship for domestic utilization is

$$S_T^2 = S_d^2 + S_e^2 + 2S_{de}$$

where d and e represent domestic utilization and exports, respectively. In theory, total variance in utilization is equal to total variance in supplies. Omission of imports and rounding errors in Table 3 distort the equality of supply and utilization variances.

If supply were unstable and the demand curves for domestic utilization and exports were fixed, the demand quantities of the latter would move together. Under this condition, the correlation coefficient and covariance for domestic utilization and exports would be positive. Such is the case between 1947 and 1971 (Table 3). For the 1972-1976 period the signs are negative but magnitudes are not far from zero—the correlation coefficient between domestic utilization and exports is only −.085 (Table 2); the covariance is only −9.8 (Table 3). The finding that variance in domestic utilization is less than the variance in *total* utilization for every period since 1946 suggests that exports have added instability to feed grains demand.

Buffer Stocks

From the foregoing data it is possible to derive a crude estimate of commodity buffer stocks required to stabilize the feed grains market. Given that supply (production P plus stock depletions) is equal to utilization (domestic demand plus Exports E), the variance of stocks S_s^2 can be estimated as

$$S_s^2 = S_e^2 + S_p^2 - 2r_{ep} S_e S_p \quad [2]$$

where terms are as defined before and domestic utilization is considered to be changing in a way that can be predicted with accuracy. For the 1972-1976 period, S_e^2 is 46.10, S_p^2 is 338.2 (Table 3), and r_{ep} is .751 (Table 2). Thus, S_s is 14 million tons. If the structure of markets for the 1972-1976 period continues, a 28 million ton (2 standard deviations) buffer carryover of feed grains would be expected to meet the shortfall of production below utilization in 98 out of 100 years.[3] Adding working (pipeline) stocks of 15 million tons gives a total carryover of 43 million tons to meet unpredictable demand in 98 out of 100 years with minimal price adjustments.

The correlation between production and exports shown in Table 2 is erratic. To be very cautious, assume the correlation between exports and production is zero. Then buffer carryover required to fill the shortfall of production below utilization 98 percent of the time is 39 million tons according to the equation for S_s^2. Adding pipeline stocks of 15 million tons to these buffer stocks gives a total carryover of 54 million tons required to meet all but a shortfall that would occur only once in 50 years on the average.

Finally, the estimated variance in exports is unusually large for 1972-1976 and may not characterize the future because of the export agreement with the Soviet Union to purchase a prescribed range of grain tonnage per year. If the production variance is 330.8, the export variance is 21.8 (the second highest export variance, for 1962-1966, shown in Table 3), and the production-export correlation coefficient is .751 as before, then total stocks of 45 million tons (buffer carryover stocks of 30 million tons plus working stocks of 15 million tons) would be expected to meet all shortfalls of supplies except those which occur only once in 50 years.

SUMMARY AND CONCLUSIONS

1. Production has been the principal *absolute* source of variation in the feed grains market.

2. Exports have been the greatest source of *relative* variation in the feed grains market,

[2]Let $s_t = C_t - C_{t-1} = P - F - D$ where C_t is commodity stock at the end of year t, C_{t-1} is stock at beginning of year t, P is production, F is exports, and D is domestic utilization of feed grains in year t. The variance σ_s^2 of s is

$$\sigma_s^2 = E[(P - \mu_p) - (F - \mu_e) - (D - \mu_d)]^2$$

Let $E(P) = \mu_p$, $E(F) = \mu_e$, and $E(D) = \mu_d$; then

$$\sigma_s^2 = E[(P - \upsilon_p) - (F - \sigma_e) - (D - \sigma_d)]^2$$
$$= \sigma_p^2 + \sigma_e^2 + \sigma_d^2 - 2\sigma_{ep} - 2\sigma_{pd} + 2\sigma_{ed}.$$

If P can be predicted without error and taken to be a constant, then

$$P - E(P) = 0, \text{ and } \sigma_s^2 = \sigma_p^2 + \sigma_e^2 - 2\sigma_{ep} = \sigma_p^2 + \sigma_e^2 - 2\Theta\sigma_e\sigma_p$$

or, with estimated values of the parameters,

$$S_s^2 = S_p^2 + S_c^2 - 2r_{ep} S_e S_p.$$

[3]Here only one tail of the assumed normal distribution is of concern.

but a downward trend has been evident since World War II.

3. Correlation coefficients between production and stocks are negative for seven of 10 time periods considered in the analysis. Negative coefficients suggest that commodity stocks were adding stability to the market.

4. The variance in production was greater than the variance in total supplies in seven of 10 time periods studied. Changes in stocks were insufficient in most periods to reduce total variation in supplies below that in production.

5. From 1947 until 1971 the correlation coefficient (and covariance) between domestic utilization and exports is positive and thus indicates that exports were a destabilizing factor in utilization of feed grains. For the 1972-1976 years, the correlation is negative but of very small magnitude ($r = -.085$). However, the generally positive (and high in recent periods) correlation coefficient between exports and production indicates that exports may have dampened the impact of unstable domestic output and reduced the need for stocks.

6. Carryover of 43-54 million tons of feed grains seems adequate to meet unanticipated shortfalls of production below utilization in 98 out of 100 years with minimal impact on price if the 1972-1976 structure of grain production and marketing extends into the future. This calculation is based on the assumption that changes in domestic utilization can be anticipated to allow appropriate adjustments in production.

REFERENCES

[1] Firch, Robert. "Sources of Commodity Market Instability in U.S. Agriculture," *American Journal of Agricultural Economics,* Volume 59, 1977, pp. 164-69.

[2] Heifner, Richard, and Jitendar Mann. "Market Instability: Some Research Approaches," *in* Robert Spitze, ed., *Agricultural and Food Price and Income Policy,* Agricultural Experiment Station Special Publication No. 43. Urbana-Champaign: University of Illinois, 1976, pp. 118-26.

[3] Luttrell, Clifton, and R. Alton Gilbert. "Crop Yields: Random, Cyclical or Bunchy," *American Journal of Agricultural Economics,* Volume 58, 1976, pp. 521-31.

[4] Robinson, K. L. "Unstable Farm Prices," *American Journal of Agricultural Economics,* Volume 57, 1975, pp. 769-77.

[5] Tweeten, Luther, and Delton Gerloff. "Instability in supplies and utilization of U. S. wheat," Oklahoma Current Farm Economics, Volume 50, Number 1, 1972.

[6] U. S. Department of Agriculture. *Feed Statistics.* Washington, D.C.: Economic Research Service, USDA, September 1967 and later issues.