MINIMUM RISK PRE-HARVEST
SALES OF SOYBEANS

by

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ABSTRACT

The formula developed by McKinnon for determining minimum risk forward selling levels for crop producers operating under yield risk is modified so that basis risk can also be taken into account. Example results were presented for soybeans for selected Corn Belt counties using both the modified McKinnon method and an alternative method involving the direct minimization of variance of return.

Keywords: Forward selling, basis risk, yield risk, soybeans

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Forward pricing, either via cash contracts or futures contracts, provides farmers an important means to reduce exposure to price risks in growing, as well as storing crops. Indications are that about a fifth of U.S. corn and soybeans are sold by farmers more than 30 days before delivery (Heifner, et. al., 1977 pp. 31-33). But selling before harvest exposes the farmer to the possibility that a yield shortfall may not only reduce the amount he has to sell, but also force him to buy his way out of his sales contract at a loss. Consequently, farmers are typically advised to price only part of their expected output, say one-half, during the growing season and leave the remainder to be sold later. The purpose of this study is to demonstrate how such recommendations can be made more precise. Two methods for determining minimum risk forward selling levels under yield risk are applied, one that I have used previously in analyzing optimal hedging levels, (Heifner, 1973) and a modified version of the method developed by McKinnon. Results for the two methods are compared using soybean data for selected Corn Belt counties. Soybeans were selected for analysis because of their relative freedom from the price fixing effects of government programs in recent decades.

Measuring Profit Expectations and Risks

Like other decisions under risk, decisions about forward pricing involve choosing among alternative probability distributions of prospective returns. These are subjective distributions in that they exist in the minds of decision-makers and are not directly observable. Inferences about these distributions can be drawn from historical time series of prices and yields and from current forward price quotations. But one must keep in mind that historical distributions of prices and yields are of interest only to the degree that they shed light on current distributions. The decision-maker is concerned only about the current distribution of prospective returns, not about the variability of return that might have been obtained in the past.

In this study the forward price at planting for harvesttime delivery is taken as the expected price--mean of the distribution of prospective prices--while a trend value is used as the expected yield. Risk is measured in terms of the historical mean squared deviations of harvesttime prices, yields and returns around their planting time expectations. 2/ This assumes that the variances of these distributions are constant from year to year, but it allows the means of the distributions to change. In contrast, the more common procedure of measuring risk in terms of deviations around historical averages assumes that the mean or expected price as well as the variance is the same each year.

If the producer accepts the planting time forward price as his expected price, and if yield risk and basis risk are absent, then by selling forward he fixes his return at its expected level. He would thereby eliminate risk without affecting his expected return. Under these circumstances the risk averse crop producer would optimize by consistently selling his crop forward at planting time, or earlier when he makes commitments to produce. In the presence of yield risk, however, total return risk can be only partly eliminated by forward selling. And when the forward sale is on the futures market, basis risk--uncertainty about cash-future price relationships--may also be a factor. Both yield risk and basis risk tend to reduce the proportion of the expected output that can be advantageously sold forward. We turn now to the measurement of these effects.

Minimum Risk Forward Selling Levels

The minimum risk forward sale is defined here as that amount of forward selling relative to expected output which minimizes overall risk. 3/ It is expressed as a fraction or percentage of expected output.

Depending upon his forward selling costs and his ability to predict changes in the forward price, the individual producer's optimal forward sale may differ from the minimum risk forward selling levels estimated here. The minimum risk forward sale is optimal for the risk averse producer whose forward trading costs are negligible and who cannot predict price changes on the forward market. Prices on efficient forward markets tend to behave as martingales making price changes difficult to predict. The evidence to date is mixed, but suggests that grain and soybean futures markets are generally efficient in this sense. 4/ Whether or not cash forward markets are similarly efficient is less certain. It depends in part on whether buyers who offer forward contracts apply the same basis early in the growing season as they apply at harvest.

In this study two methods are employed to estimate minimum risk forward selling levels that take into account both yield risk and basis risk. The first method involves application of the formula I used previously in analyzing optimal hedging levels (Heifner, 1973) using the estimated variances and covariances of returns on the crop growing activity and the futures trading activity. The second method will be designated the modified McKinnon method. It combines the McKinnon formula with the formula I previously applied using as data the means, variances, and covariances of cash prices, futures prices and yields.

To show how the minimum risk forward sale can be determined, we define four random variables; y = yield per acre; e = futures price at planting time; f = futures price change from planting to harvest and p = cash price at harvest. Let these variables have means μ_y, μ_e, μ_f, μ_p and variances σ_y^2, σ_e^2, σ_f^2, σ_p^2 respectively and let the covariances and correlations among them be designated as σ_{ij} and ρ_{ij}, i,j = y,e,f and p. Let x be the amount sold forward, which is to be determined, and let b = E(e + f - p) be the average harvesttime basis. We assume that the futures price is unbiased, E(f) = 0. Total return per acre is,

(1) $r = yp - xf$

Expected price at planting time is taken to equal the futures price minus the average harvesttime basis, E(p) = e-b. Expected return at planting time is then;

(2) $E(r) = E(yp - xf) = \mu_y(e-b) + \sigma_{yp}$

Let d be the deviation in return from its expected value

(3) $d = r - E(r) = yp - xf - \mu_y e + \mu_y b - \sigma_{yp}$

Noting that the last two terms in (3) are constants the variance of d is shown to be,

$$(4)\ V(d) = V(yp) + x^2\sigma_f^2 + \mu_y^2\sigma_e^2 - 2xC(yp,f) - 2\mu_y C(yp,e) + 2x\mu_y\sigma_{ef}$$

where V anc C indicate variances and covariances of the variables in parentheses. In an efficient market, one which follows the martingale hypothesis, price changes are uncorrelated with previous prices; hence σ_{ef} would be zero. To minimize V(d) with respect to x we take,

$$(5)\ \frac{dV(d)}{dx} = 2x\sigma_f^2 - 2C(yp,f) = 0$$

Noting that the second derivative is positive we solve for x,

$$(6)\quad x = C(yp,f)/\sigma_f^2 = \rho_{yp,f}\ \sigma_{yp}/\sigma_f$$

Equation (6) provides a direct estimate of the minimum variance forward sale if estimates of the variance of the futures price change and the covariance of cash returns and the futures price change are available.

Alternatively, if y, p and f follow the bivariate normal distribution we can express the minimum risk level of x in terms of the variances and correlations among prices and yield. Bohrnstedt and Goldberger (p. 1440) show that under bivariate normality,

$$(7)\quad C(yp,f) = \mu_y\sigma_{pf} + \mu_p\sigma_{yf}$$

Substituting (7) into (6) and dividing by μ_y we obtain

$$(8a)\ \frac{x}{\mu_y} = \frac{\sigma_{pf}}{\sigma_f^2} + \frac{\mu_p\sigma_{yf}}{\mu_y\sigma_f^2}$$

$$(8b)\ \frac{x}{\mu_y} = \rho_{pf}\frac{\sigma_p}{\sigma_f} + \rho_{yf}\frac{\sigma_y/\mu_y}{\sigma_f/\mu_p}$$

Equation (8b) will be called the modified McKinnon formula. The difference between the first term in (8) and unity represents the effect of basis risk. The second term represents the effect of yield risk. In McKinnon's formula (p. 848) the basis risk is disregarded and the first term is one. In the Heifner formula (1973, p. 39) output risk is disregarded so the second term disappears. 5/ Thus, equation (8) integrates the McKinnon and Heifner formulas allowing us to determine the effects of basis risk and yield risk separately and the two combined. It facilitates combining information from different sources or different time periods about yield and price variation.

Empirical Results

Application of these formulas to obtain estimates of minimum risk forward selling levels useful to farmers encounters several practical difficulties. In many recent years price movements have been constrained by government withdrawal of supplies from the market or by the releasing of government stocks as part of the farm program. To reduce this source of bias, only those years when movement into or out of government ownership was less than 1 percent of total production were used in estimating price and profit variances and covariances. The resulting sample included 10 years, 1963-66 and 1971-76.

A second problem relates to the level of aggregation. In principle, individual farm data should be used since part of the variation is averaged out when using aggregated data. But broadly representative individual farm data are not easily obtained. In this study, county data were used as being the most disaggregated level of observation where the needed yield series are readily available. The counties were selected to provide broad geographic representation of major Corn Belt soybean producing areas. 6/ County yields were obtained from the reports of the Federal-State statistical reporting offices for the States included. In calculating variances and correlations, yields were measured as deviations from linear trends for the 20 year period 1957-1976.

The forward prices used in the analysis are closing futures quotations at the Chicago Board of Trade for Thursdays nearest May 16 and October 16 each year. Corresponding cash prices for October were obtained from USDA's Grain Market News reports for Chicago and Toledo and from newspapers for the Des Moines, Indianapolis, Lincoln and Sioux City areas. 7/ Single day prices were used to avoid averaging out day-to-day price variation. When price ranges were reported the midpoint of the range was used. All prices were deflated by the index of prices paid by farmers.

Estimated price-yield correlations, cash return-futures price change correlations and minimum risk hedging levels differ substantially among counties in the same general area. Most of these observed differences among such counties appear due to sampling or measurement errors rather than to differences in the underlying parameters. Consequently, the county estimates were averaged and reported by State.

Statistics on the distributions of returns per acre, the correlations between cash returns and futures price changes and the estimated minimum risk forward selling levels calculated using equation (6) are shown in table 1. The estimated minimum risk hedging levels are markedly higher for Iowa than for Illinois and Indiana. The Illinois and Indiana results were strongly affected by very low yields in 1974, a year of extremely high harvesttime prices.

Statistics on the distribution of prices and estimates of basis risk effects are presented in table 2. Price changes were skewed to

Table 1.--Distribution of differences in returns per acre from planting time expectations and estimated minimum risk forward selling levels, averages for selected counties, Iowa, Illinois, and Indiana 1/

	10 Iowa counties priced at Des Moines	10 Illinois counties priced at Chicago	10 Indiana counties priced at Indianapolis	U.S. priced at Chicago
Mean return, $/acre	92.87	98.71	84.90	83.69
Difference between actual return and return expected in May				
Std. dev. $/acre	12.37	8.19	10.29	7.60
Skewness	.28	.19	.30	1.12
Kurtosis	2.42	2.78	2.21	3.42
Coef. var.	.13	.08	.12	.09
Correl. with futures	.71	.40	.33	.93
Min. risk forward sale, %	57	23	22	52

1/ Based on data for 1963-76. See text footnote 6 for county names.

the right and leptokurtic for the 10 years in the sample, but the sample is too small to draw conclusions about the general distribution of such price movements. The correlations between cash price deviations from expectations and futures price movements were near 1. However, price changes from expectations tended to be slightly less variable in the producing area markets than for the futures market reducing the minimum risk forward sale by 6 to 17 percent for these areas. 8/ These results support the notion that basis risk depresses optimal hedging levels, but they do not enable us to say that the basis risk effect is statistically significant.

Statistics on yield distributions and the effects of yield uncertainty on minimum risk forward selling levels are shown in table 3. Again, we see the yield risk effect much greater for the Illinois and

Table 2.--Distribution of harvesttime price differences from planting time expectations and effects of basis risk on optimal forward selling levels, selected markets 1/

	Chicago terminal market	Toledo terminal market	Indian-napolis area	Des Moines area	Sioux City area	Lincoln Nebraska area	Futures
Mean mid-Oct. price $/bu.	3.03	2.98	2.81	2.84	2.93	2.79	3.04
Difference between Oct. price and price expected in May							
Std. dev., $/bu.	.48	.50	.48	.45	.50	.51	.54
Skewness	2.07	1.93	2.04	1.90	1.95	2.12	1.80
Kurtosis	5.97	5.56	5.93	5.43	5.56	6.15	5.15
Coef. var.	.16	.17	.17	.16	.17	.18	.18
Correl. with futures	1.00	.99	.98	.99	.99	.98	---
Basis risk effect, %	-11	-6	-13	-17	-8	-8	---

1/ Based on data for 1963-66, 71-76.

Indiana counties than for Iowa, largely because of the 1974 experience. When the yield risk effect and the basis risk effect are combined using equation (8) the indicated minimum risk forward selling level is about 50-70 percent of the expected crop.

Conclusions

This pilot study of price-yield relationships for soybeans in the Corn Belt demonstrates that basis risk over the growing season is a relatively minor consideration, but yield risks are a major factor in determining how much to sell forward at planting time. The results provide much less precision than would be desirable, but suggest that when soybean prices are unconstrained by government programs, forward

Table 3.--Yield distributions and effects of yield risk on optimal forward selling levels, averages for selected counties, Iowa, Illinois and Indiana 1/

	Average for 10 Iowa counties	Average for 10 Illinois counties	Average for 10 Indiana counties	U.S.
Mean yield, bu./acre	28.70	30.56	28.03	25.33
Yield trend, bu./acre annually	.45	.35	.32	.21
Yield deviation from trend:				
Std. dev. bu./acre	2.80	2.81	3.61	1.28
Skewness	-.09	-.62	-.24	-.98
Kurtosis	2.72	3.81	2.90	3.40
Coef. var.	.10	.09	.13	.05
Correl. with futures	-.32	-.72	-.55	-.68
Yield risk effect, %	-17	-38	-39	-20

1/ Statistics on yield distributions are based on 1957-76 data, correlations and yield risk effect estimates on 1963-66, 71-76 data. See text footnote 6 for county names.

contracting about half to two-thirds of the crop at planting will tend to minimize risk. The modified McKinnon method generally gave higher and less dispersed estimates of minimum risk forward selling levels than did the direct minimization of the variance of return. Differences between the results from the two methods apparently arise because the joint probability distribution of prices and yields is not strictly bivariate normal.

To improve estimates of minimum risk forward selling levels the most pressing need is for additional years of data, when prices were unconstrained by government programs, to use in measuring price-yield-profit variances and correlations. Also, there are gains to be obtained from using individual farm yield data in lieu of the county data employed here. The analysis needs to be extended to other regions and to additional forward selling dates between planting and harvest. Effects of forward selling costs, commissions etc., and anticipated changes in the forward price on optimal forward sales can also be taken into account. And the possibility of modifying the analysis to incorporate price floors and ceilings imposed by government programs deserves exploration.

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FOOTNOTES

1/ The author is an economist with the Economics, Statistics and Cooperatives Service, USDA. The helpful comments of Kandice Kahl and Allen Paul on an earlier draft of this paper are gratefully acknowledged.

2/ See Peck pp. 410-411 for further discussion of risk measurement for forward selling decisions.

3/ This generalizes the concept of a minimum risk hedge defined by Heifner (1973, pp. 5, 6, 39, and 40) to allow for yield risk and cash forward sales as well as hedging in futures. Correlations with returns on other enterprises are not considered in the formulation presented here, but the methods can be extended to take such correlations into account.

4/ For a review of some recent studies bearing upon this question, see Heifner, 1977.

5/ The covariance and variance in the Heifner formula are for profits, not prices, but the difference is inconsequencial when the units are the same for the cash and futures positions.

6/ Included in the analysis were Allamakee, Carroll, Delaware, Fayette, Hamilton, Hancock, Mitchell, Pocahontas, Shelby and Sioux, Counties, Iowa; Adams, Bond, Cass, Carroll, McHenry, Jersey, Kendall, Lee, Putnam, and Warren counties, Illinois; and Carroll, Elkhart, Fulton, Jasper, LaPorte, Montgomery, Owen, Vigo, Wells and Whitley Counties, Indiana.

7/ Local elevator prices were obtained from back issues of the Des Moines Register, Indianapolis News, Omaha World Herald and Sioux City Journal.

8/ This difference in coefficients of variation persisted when the midpoints of the ranges of reported producing area prices were replaced by the lower ends of the ranges.