

**Soybean Hedge Ratios for Eastern South Dakota
Producers Facing Production and Price Uncertainty**

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Karen Brovold and Bashir A. Qasmi

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Karen Brovold and Bashir A. Qasmi¹
South Dakota State University

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¹ The authors are respectively, graduate student and assistant professor of economics, South Dakota State University, Brookings, SD 57007.

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ABSTRACT

Optimal hedges with production and price uncertainty for Eastern South Dakota soybean producers are investigated. Assuming a constant absolute risk aversion utility function and jointly normally distributed futures prices, cash prices, and yields, optimal pre-planting hedges are estimated with county level yield data and varying degrees of risk aversion.

Soybean Hedge Ratios for Eastern South Dakota Producers Facing Production and Price Uncertainty

In the past, few agricultural producers have made use of the futures market to manage their risk exposure. With the passage of the Freedom to Farm Act more producers will be looking for alternatives in their marketing practices to protect themselves against an expected increase in price variability. The percentage of expected production that should be hedged, the hedge ratio, has been investigated by many researchers (McKinnon 1967, Heifner 1972, Peck 1975, Grant 1989). It has been shown that the typical negative correlation between price and yield creates a 'natural hedge' which allows a producer to manage risk without hedging 100% of expected production (McKinnon 1967 and Grant 1989).

At pre-planting time, soybean producers face uncertainty in the harvest cash price as well as in the final quantity of production. Accordingly, pre-planting optimal hedge ratios are to be computed by taking into consideration the variances in the yield, harvest futures price, and harvest cash price as well as the correlations among these factors. The objective of this paper is to determine optimal hedge ratios for soybean producers facing production uncertainty in Eastern South Dakota.

The greater yield variability is relative to price variability, the smaller the optimal forward sale will be. Also, the more effective the natural hedge, the smaller the forward sale will be. The more important demand fluctuations are relative to supply variations in determining local price, the smaller will be the effect of the natural hedge and the larger will be the optimal forward sale (McKinnon, 1967, pp 851-52).

Lapan and Moschini (1994) proposed a general framework which allows for optimal hedge ratio determination under varying conditions. Following their approach, we consider a competitive producer with a constant absolute risk aversion (CARA) utility function facing both production and price risk. It is assumed that the futures settlement price is correlated with, but not the same as the cash price. Futures prices, cash prices, and yields are assumed to be jointly normally distributed.

RISK AVERSION

An individual's attitude towards risk is affected by several factors, including current wealth, investment diversity and personality factors. A commonly used measure of risk aversion is a coefficient of relative risk aversion which represents a measure of the elasticity of marginal utility. The greater the risk aversion of an individual, the more curved is his/her utility function implying that the individual receives less utility from increased wealth with risk (Newberry and Stiglitz, 1981).

The risk aversion coefficient can be expressed as a relative risk premium. The relative risk premium is approximately equal to one-half the square of the coefficient of variation of income times the coefficient of relative risk aversion (Newberry and Stiglitz, 1981, p 73).

METHODOLOGY

The general hedge ratio suggested by Lapan and Moschini (1994) is composed of speculative and pure hedge components. The speculative component reflects the individual's estimation of bias in the futures price. When the futures market is unbiased,

the speculative component of the hedge ratio drops out. We assume the futures market is unbiased and focus only on the pure hedge component. In the remainder of this paper, the terms 'optimal hedge' and 'optimal hedge ratio' will be used to refer to the pure hedge component of the optimal hedge ratio. The derivation of generalized hedge ratios by Lapan and Moschini (1994) is quite complex and is shown in detail in their article. In this paper we will outline the basic steps involved in the computation of the optimal hedge assuming an unbiased futures market.

The first step is the specification of conditional mean equations for harvest futures price, harvest cash price, and yield. The producer's expectations are conditioned with respect to information available at the time the hedging decision is made. Each of the three equations has an intercept, an autoregressive term and a term containing the futures contract price at pre-planting time.

$$P_{1,t} = \alpha_{11} + \alpha_{1f}P_{1,t-g} + \alpha_{1L}P_{1,t-1} + \epsilon_{1,t} \quad (1)$$

$$P_{2,t} = \alpha_{21} + \alpha_{2f}P_{1,t-g} + \alpha_{2L}P_{2,t-1} + \epsilon_{2,t} \quad (2)$$

$$Y_t = \alpha_{31} + \alpha_{3f}P_{1,t-g} + \alpha_{3L}Y_{t-1} + \epsilon_{3,t} \quad (3)$$

Where:

- $p_{1,t}$ = the futures price quoted at harvest time (week-3 in October) for the November contract of year t,
- $p_{1,t-g}$ = the futures price quoted at pre-planting time (week-1 in April) for the November contract of the year t, with g indicating the fraction of the year from pre-planting time to harvest time,

$p_{2,t}$	=	the cash price at harvest in year t,
y_t	=	the yield in year t,
α_{ij}	=	parameters of the conditional means,
$p_{i,t-1}$	=	$p_{i,t}$ lagged one year ($i=1,2$),
y_{t-1}	=	y_t lagged one year, and
$\varepsilon_{i,t}$	=	random error terms ($i=1,2,3$).

The second step involves estimation of equations (1) through (3). Since, by assumption, the three random variables are jointly distributed, the equations are estimated using a seemingly unrelated regression procedure. The residual variance-covariance matrix of the model is defined as:

$$V \equiv \begin{bmatrix} V_1^2 & \rho_{12} V_1 V_2 & \rho_{13} V_1 V_3 \\ \rho_{12} V_1 V_2 & V_2^2 & \rho_{23} V_2 V_3 \\ \rho_{13} V_1 V_2 & \rho_{23} V_2 V_3 & V_3^2 \end{bmatrix} \quad (4)$$

Where V_i denotes the standard deviation of variable i , ρ_{ij} denotes the correlation coefficient between variables i and j ($i,j=1,2,3$). The subscripts 1,2,3 refer to the harvest futures price, harvest cash price, and yield, respectively.

Finally, following Lapan and Moschini (1994), the optimal hedge ratio is:

$$\frac{f}{\bar{y}q} = (\beta_2 + b_3) \left(\frac{1 + \rho R C_2 C_3}{D} \right) - \frac{R}{D} (b_3 C_2^2 + \rho) \quad (5)$$

Where the parameters are defined as follows:

\bar{p}_1	=	average harvest futures price,
\bar{p}_2	=	average harvest cash price,
\bar{y}	=	average yield,
c_2	=	coefficient of variation of harvest cash price,

c_3	=	coefficient of variation of yield,
V_1	=	variance of harvest futures price,
V_2	=	variance of harvest cash price,
V_3	=	variance of yield,
ρ_{12}	=	covariance between futures and cash prices,
ρ_{13}	=	covariance between futures price and yield, and
ρ_{23}	=	covariance between cash price and yield.

Given the parameters from the seemingly unrelated regressions, the remaining elements of the optimal hedge equation (5) can be computed as follows:

$$\rho = \frac{\rho_{23} - \rho_{12}\rho_{13}}{K} \quad (6)$$

$$K = [(1 - \rho_{12}^2) (1 - \rho_{13}^2)]^{1/2} \quad (7)$$

$$\beta_2 = \rho_{12} \frac{V_2}{V_1} \quad (8)$$

$$\beta_3 = \rho_{13} \frac{V_3}{V_1} \quad (9)$$

$$b_3 = \beta_3 \frac{\bar{P}_2}{\bar{Y}} \quad (10)$$

$$D = (1 + \rho R c_2 c_3)^2 - (R c_2 c_3)^2 \quad (11)$$

The term R represents the producer's degree of relative risk aversion. As a producer becomes less risk averse $R \rightarrow 0$. Since risk aversion varies from one individual to another, it cannot be determined on *a priori* basis. However, for optimality of (5) to exist, the parameter R has to be constrained depending upon the elements of (4). For the details involved in determining the limit on R refer to Lapan and Moschini (1994, pp 467-68).

When production uncertainty is absent (i.e. $c_3=0$, $\beta_3=0$, and $D=1$), (5) reduces to β_2 , the coefficient of the theoretical regression of cash prices on futures prices, the usual case of a storage hedge. When $R=0$, (5) simplifies to (β_2+b_3) , the standard mean-variance hedge. The term (β_2+b_3) is comprised of the segment of revenue that is linear in the futures price. The term b_3 is the coefficient of a suitably standardized regression of yield on futures price. As long as $b_3 \leq 0$ (i.e. price and yield are inversely correlated) the standard mean-variance hedge will be lower than the storage hedge (Lapan and Moschini, 1994, p 470).

In case of production uncertainty with no risk in basis (i.e. $c_2=0$ and thus $D=1$), (5) reduces to $(\beta_2+b_3)-R(\beta_2 c_3^2)$. This shows that even when the production and price risks are independent (i.e. $b_3=0$), the optimal hedge is reduced by production risk. It also shows that as an individual becomes more risk averse, the optimal hedge decreases (Lapan and Moschini, 1994, pp 470-71).

In case of both basis and production uncertainty, an increased pure basis risk will increase the optimal hedge as long as $b_3 \leq 0$. An increase in pure production risk has an

indeterminate impact, but usually reduces the optimal hedge (Lapan and Moschini, 1994, p 476).

The coefficient ρ represents the correlation between the variations in cash price and yield which are orthogonal to the variation in the futures settlement price. As cash price and yield variations (c_2 and c_3) decrease, the optimal hedge will tend to increase.

THE SCOPE OF THE STUDY AND THE DATA

This study covers three Eastern Crop Reporting Districts of South Dakota, namely Northeast SD, East Central SD, and Southeast SD. These three regions account for approximately 88% of South Dakota soybean production.

Weekly quotes for Chicago Board of Trade November soybean futures contracts, weekly quotes for local cash prices, and average county yield data were used in the analysis. Futures contract closing prices, and cash prices for Thursday were used to represent the weeks' prices. If the market was closed or data was not available for Thursday, the week was represented by the nearest available preceding market day prices. The pre-planting and harvest times were represented by the first week of April and the third week of October, respectively.

Since cash prices were not available for each county, one location per region was chosen to represent the cash price for all counties in the region. The cash price data for Codington (in Northeast SD) and Hutchinson (in Southeast SD) counties were obtained

from the respective local newspapers. The cash price data for Lake county (in East Central SD), were extracted from records of a local grain elevator.

The average county yield data were obtained from the South Dakota Agriculture Statistics Service. The analysis is based on the time period 1979-94 except for the East Central region. Due to lack of availability of cash price data for prior years, the analysis for East Central region is limited to 1982-94. For some counties additional one or two observations were missing due to lack of availability of yield data.

RESULTS AND DISCUSSION

The estimates for correlation between the futures prices and South Dakota cash prices are similar to those reported by Lapan and Moschini (1994) for Iowa. The estimates for correlations between futures prices and yields and between cash prices and yields for Iowa are reported to be -0.315 and -0.424, respectively (Lapan and Moschini, 1994). Our estimates of these correlations are generally lower and in many cases positive (Table 1). Consequently, the natural hedge for soybeans in Eastern South Dakota counties is very weak and in many cases non-existent.

Our estimations of yield variations, particularly for the Northeast and East Central regions, are somewhat higher than the yield variations in Iowa. This tends to offset and in many cases dominate the effects of the weak natural hedge.

The limits for R , the implied risk premiums, and the optimal hedge ratios for the values of R ranging from 0 to the limit were calculated. The implied risk premium is positively related to the coefficient of variation for the revenue (computed with yield and

local cash price). Since the revenue variance varies by county, the implied risk premiums for a given level of R also varies by county (Table 2). Given the risk premiums in Table 2, we feel that, for practical purposes, the relevant range of R for most Eastern SD counties appears to be from 0 to 5. In some cases (Day county for example) the risk premiums are so high that even $R > 3$ does not seem to be relevant.

The optimal soybean hedge ratios for Eastern South Dakota for varying degrees of R along with the storage hedges are presented in Table 3. The storage hedge for Iowa is reported to be 92% (Lapan and Moschini, 1994). Our estimates for the storage hedge are 74%, 102%, and 80% for Northeast SD, East Central SD, and Southeast SD, respectively. The mean-variance hedge ratio for Iowa is reported to be 73% (Lapan and Moschini, 1994). Our estimates for mean-variance hedge ranged from 24% to 159% for counties in Northeast SD, 5% to 154% for counties in East Central SD, and 14% to 81% for counties in Southeast SD. For most counties in Northeast and East Central SD, the estimates for mean-variance hedge are higher than the respective estimates for storage hedges as the yield and prices in these counties did not exhibit an inverse correlation.

The optimal hedge for Iowa ranges from about 73% for $R=0$ to about 55% for $R=20$ (Lapan and Moschini, 1994). As expected, the optimal hedge ratios for Eastern South Dakota also decrease with an increase in R . The optimal hedge ratios in Eastern South Dakota have a much wider range of -71% (for Hanson county when $R=10$) to 159% (for Day county when $R=0$) and vary considerably by county (for example 100% to 159% for Day county and -59% to 14% for Douglas county).

CONCLUDING REMARKS

Empirical optimal pre-planting soybean hedge estimates for Eastern South Dakota producers, based on county level data for 1979-94, confirm the importance of accounting for yield risk in determining the optimal hedge and the sensitivity of optimal hedges to producers' risk attitudes. A wide range of estimates for the optimal hedges underscores the importance of marketing research into local yield and price conditions in devising effective hedge strategies.

REFERENCES

- Farmer's Cooperative Elevator, Unpublished tabulation from the manager's records, Madison, SD:Farmer's Cooperative Elevator, 1995
- Freeman Courier. *Freeman Courier: a Hutchinson County Newspaper*. Freeman, SD: 1979-94 (various issues).
- Grant, D. *Optimal futures positions for Corn and Soybean Growers Facing Price and Yield Risk*. Washington DC: U.S Department of Agriculture, ERS Technical Bulletin No. 1751, March 1989.
- Heifner, R. "Optimal Hedging Levels and Hedging Effectiveness in Cattle Feeding." *Agr. Econ. Res.* 25 (1972):25-36.
- Lapan, H., and G. Moschini. "Futures Hedging Under Price, Basis and Production Risk." *Amer. J. Agr. Econ.* 76 (August 1994): 465-77.
- McKinnon, R. "Futures Markets, Buffer Stocks, and Income Stability for Primary Producers." *J. Polit. Econ.* 75(December 1967):844-61.
- Newberry, D., and J. Stiglitz. *The Theory of Commodity Price Stabilization*. Oxford: Clarendon Press, 1981.
- Peck, A. "Hedging and Income Stability: Concepts, Implications, and an Example." *Amer. J. Agr. Econ.* 75(August 1975):410-19.
- SAS Institute Inc. *SAS Companion for the Microsoft Windows Environment, Version 6, First Edition*. Cary, NC:SAS Institute Inc., 1993.
- South Dakota Agricultural Statistics Service. *South Dakota Agricultural Statistics*. Sioux Falls, SD:South Dakota Department of Agriculture, 1980-95 (various issues).
- Watertown Public Opinion. *Public Opinion: a Codington County Newspaper*. Watertown, SD: 1979-94 (various issues).
State University in 1994.

Table 1. Estimates of selected parameters of conditional joint distribution of prices and yields.

Region/ County	No. of Obs.	Futures Price Var 2/ Var	Cash Price Var	Yield Var	Futures Cash Cor 3/ Cor	Futures Yield Cor	Cash Yield Cor	Cash Price C.V. 4/ C.V.	Yield C.V.
Northeast SD:									
Clark	15	0.928	0.726	5.126	0.950	0.151	0.220	0.130	0.225
Codington 1/	15	0.928	0.726	5.565	0.950	0.195	0.152	0.130	0.231
Day	13	0.964	0.700	6.733	0.944	0.564	0.547	0.130	0.286
Deuel	15	0.928	0.726	6.661	0.950	-0.026	-0.113	0.130	0.261
Grant	15	0.928	0.726	5.797	0.950	0.177	0.226	0.130	0.224
Hamlin	15	0.928	0.726	5.571	0.950	0.228	0.165	0.130	0.209
Marshall	13	0.964	0.700	5.474	0.944	0.121	0.248	0.130	0.230
Roberts	15	0.928	0.726	5.721	0.950	-0.368	-0.249	0.130	0.226
East Central SD:									
Brookings	13	0.489	0.523	5.725	0.961	0.028	-0.162	0.097	0.207
Davison	11	0.394	0.380	6.361	0.976	-0.085	-0.114	0.072	0.245
Hanson	13	0.489	0.523	6.778	0.961	-0.344	-0.420	0.097	0.258
Kingsbury	13	0.489	0.523	5.629	0.961	0.078	-0.024	0.097	0.211
Lake 1/	13	0.489	0.523	6.181	0.961	0.000	-0.113	0.097	0.211
McCook	13	0.489	0.523	5.465	0.961	-0.019	-0.117	0.097	0.197
Miner	12	0.447	0.405	5.498	0.907	0.141	0.080	0.074	0.219
Minnehaha	13	0.489	0.523	4.710	0.961	0.002	-0.123	0.097	0.153
Moody	13	0.489	0.523	6.569	0.961	0.031	-0.130	0.097	0.205
Sanborn	11	0.394	0.380	3.856	0.976	0.262	0.180	0.072	0.172
Southeast SD:									
Bon Homme	15	0.928	0.844	6.526	0.885	-0.394	-0.338	0.152	0.256
Charles Mix	15	0.928	0.844	6.450	0.885	-0.313	-0.269	0.152	0.239
Clay	15	0.928	0.844	4.855	0.885	-0.415	-0.613	0.152	0.156
Douglas	15	0.928	0.844	7.451	0.885	-0.372	-0.350	0.152	0.300
Hutchinson 1/	15	0.928	0.844	6.823	0.885	-0.257	-0.277	0.152	0.261
Lincoln	15	0.928	0.844	4.332	0.885	0.010	-0.303	0.152	0.136
Turner	15	0.928	0.844	4.351	0.885	-0.024	-0.282	0.152	0.149
Union	15	0.928	0.844	5.594	0.885	-0.564	-0.758	0.152	0.163
Yankton	15	0.928	0.844	5.543	0.885	-0.473	-0.566	0.152	0.199

1/ Cash price source for the region.

2/ Variance.

3/ Covariance.

4/ Coefficient of variation.

Table 2. Risk premium as a percentage of revenue for varying degrees of risk aversion for S.D. soybean producers.

Region/ County	No. of Obs.	Revenue C.V. 2/	Risk Aversion Coefficient						
			0	1	2	3	4	5	10
... All values displayed as percentages...									
Northeast SD:									
Clark	15	22.46	0.00	2.52	5.04	7.57	10.09	12.61	25.22
Codington 1/ Day	15	24.91	0.00	3.10	6.20	9.30	12.41	15.51	31.01
Deuel	13	45.31	0.00	10.27	20.53	30.80	41.06	51.33	102.60
Grant	15	25.62	0.00	3.28	6.57	9.85	13.13	16.41	32.83
Hamlin	15	24.69	0.00	3.05	6.10	9.14	12.19	15.24	30.48
Marshall	15	23.47	0.00	2.75	5.51	8.26	11.02	13.77	27.54
Roberts	13	35.71	0.00	6.38	12.75	19.13	25.51	31.88	63.77
	15	17.03	0.00	1.45	2.90	4.35	5.80	7.25	14.49
East Central SD:									
Brookings	13	22.44	0.00	2.52	5.04	7.56	10.07	12.59	25.19
Davison	11	25.45	0.00	3.24	6.48	9.72	12.96	16.20	32.39
Hanson	13	22.62	0.00	2.56	5.12	7.68	10.24	12.79	25.59
Kingsbury	13	22.52	0.00	2.54	5.07	7.61	10.14	12.68	25.36
Lake 1/ McCook	13	26.05	0.00	3.39	6.79	10.18	13.57	16.97	33.94
Miner	13	24.11	0.00	2.91	5.81	8.72	11.62	14.53	29.05
Minnehaha	12	19.12	0.00	1.83	3.66	5.49	7.31	9.14	18.29
Moody	13	17.62	0.00	1.56	3.12	4.68	6.25	7.81	15.61
Sanborn	13	22.98	0.00	2.64	5.28	7.92	10.56	13.21	26.41
	11	20.77	0.00	2.16	4.31	6.47	8.63	10.78	21.57
Southeast SD:									
Bon Homme	15	24.10	0.00	2.91	5.81	8.72	11.62	14.53	29.05
Charles Mix	15	22.90	0.00	2.62	5.24	7.86	10.48	13.11	26.21
Clay	15	14.73	0.00	1.09	2.17	3.26	4.34	5.43	10.85
Douglas	15	26.41	0.00	3.49	6.97	10.46	13.95	17.43	34.86
Hutchinson 1/ Lincoln	15	23.68	0.00	2.80	5.61	8.41	11.21	14.02	28.03
Turner	15	17.73	0.00	1.57	3.14	4.71	6.28	7.85	15.71
Union	15	18.81	0.00	1.77	3.54	5.31	7.08	8.84	17.69
Yankton	15	11.83	0.00	0.70	1.40	2.10	2.80	3.50	6.99
	15	16.28	0.00	1.33	2.65	3.98	5.30	6.63	13.25

1/ Cash price source for the region.

2/ Coefficient of variation.

Table 3. Estimated planting time optimal hedge ratios for S.D. soybean producers.

Region/ County	No. of Obs.	Storage Hedge	Risk Aversion Coefficient						
			0	1	2	3	4	5	10
Northeast SD:									
Clark	15	0.743	0.947	0.900	0.856	0.815	0.775	0.737	0.568
Codington 1/ Day	15	0.743	1.013	0.973	0.934	0.895	0.857	0.820	0.635
Deuel	13	0.743	1.589	1.516	1.449	1.385	1.324	1.266	1.005
Grant	15	0.743	0.702	0.659	0.615	0.571	0.525	0.478	0.195
Hamlin	15	0.743	0.981	0.936	0.893	0.852	0.813	0.775	0.605
Marshall	15	0.743	1.030	0.997	0.966	0.935	0.905	0.875	0.729
Roberts	13	0.743	0.842	0.795	0.750	0.709	0.670	0.633	0.475
	15	0.743	0.244	0.212	0.183	0.154	0.127	0.100	-0.023
East Central SD:									
Brookings	13	1.027	1.092	1.062	1.030	0.997	0.963	0.926	0.705
Davison	11	1.027	0.663	0.610	0.556	0.502	0.448	0.393	0.105
Hanson	13	1.027	0.048	-0.012	-0.074	-0.138	-0.206	-0.277	-0.707
Kingsbury	13	1.027	1.208	1.169	1.130	1.090	1.050	1.009	0.788
Lake 1/ McCook	13	1.027	1.028	0.990	0.952	0.913	0.874	0.833	0.607
Miner	13	1.027	0.987	0.954	0.921	0.887	0.853	0.818	0.632
Minnehaha	12	1.027	1.201	1.162	1.123	1.085	1.046	1.008	0.816
Moody	13	1.027	1.031	1.014	0.996	0.979	0.961	0.943	0.850
Sanborn	13	1.027	1.097	1.065	1.032	0.998	0.964	0.927	0.716
	11	1.027	1.543	1.519	1.495	1.471	1.446	1.422	1.299
Southeast SD:									
Bon Homme	15	0.805	0.200	0.161	0.123	0.084	0.046	0.006	-0.216
Charles Mix	15	0.805	0.356	0.321	0.286	0.252	0.218	0.183	0.001
Clay	15	0.805	0.415	0.410	0.405	0.400	0.395	0.390	0.364
Douglas	15	0.805	0.135	0.078	0.020	-0.039	-0.101	-0.165	-0.589
Hutchinson 1/ Lincoln	15	0.805	0.402	0.359	0.315	0.272	0.227	0.181	-0.092
Turner	15	0.805	0.813	0.810	0.806	0.803	0.800	0.797	0.786
Union	15	0.805	0.806	0.800	0.793	0.787	0.781	0.775	0.748
Yankton	15	0.805	0.253	0.248	0.243	0.238	0.233	0.228	0.194
	15	0.805	0.240	0.224	0.207	0.189	0.171	0.152	0.199

1/ Cash price source for the region.