Software for Managing Income Risk Through Marketing

by

Rich Alderfer, Steve Harsh, and Jim Hilker

SOFTWARE FOR MANAGING INCOME RISK THROUGH MARKETING

by Rich Alderfer, Steve Harsh, Jim Hilker[1]

Alderfer et. al. developed a set of Decision Support System (DSS) components to assist grain producers in commodity marketing decisions when prices and yields are uncertain. These DSS components, called Farm Income Risk Management (FIRM), incorporated an expert system to measure producer risk attitudes as well as tools for finding optimal pre-harvest marketing portfolios consistent with these preferences. Marketing portfolios for a particular commodity could be composed of futures and options hedging, cash forward contracting, basis contracting and spot sales.

The purpose of this paper is to present field test results using FIRM with commercial grain producers. Summarized data and findings will include risk aversion measures, tests of their functional forms, farm characteristics and the marketing portfolios recommended to the participating producers.

Risk aversion/preferences have been measured before (see Young for a review) with most efforts involving experimental or direct elicitation procedures. Efforts such as these have required an expert in risk and survey methods to be present at the time of elicitation. The expert system in FIRM elicits preferences for the producer's specific marketing problem. This reduces context biases (see Cochran et al.) which may have plagued previous elicitation efforts. In addition, the use of an expert system should provide a more consistent risk analysis than a human expert.

A BRIEF OVERVIEW OF FIRM

Input to the FIRM model includes distributions for yield, futures and basis, as well as static marketing data. Options premiums for soybeans form an implied volatility which is converted to the ending period CDF for futures. FIRM begins by simulating ending period stochastic cash sales in order to establish the income risk the producer faces. The mean and standard deviation of this income distribution are important input values that seed risk attitude elicitation. The values of mean and standard deviation are neither assumptions that gross margins are normal, nor that producers only consider the first two moments. Instead, they are starting values that ensure the utility curve elicited is in the neighborhood of the income distribution.

ELRISK elicits risk attitudes. It is a rule-based expert system based on "equally likely risky outcomes." Discrete utility curves are established in the neighborhood of the marketing problem based on user's responses to ELRISK.

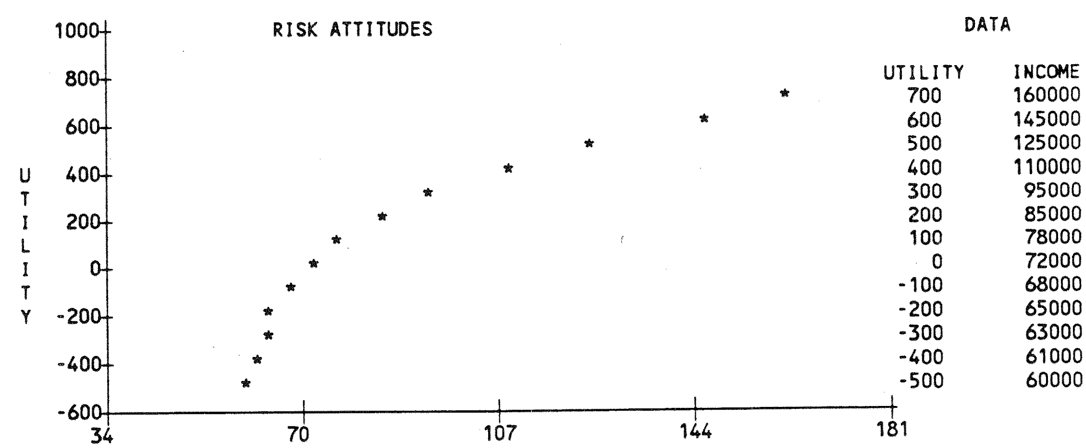
A non-linear optimization routine (MKT-OPT) searches for portfolios of pricing alternatives that maximize expected utility. When MKT-OPT converges, it lists the best 15 portfolios it finds. The user is allowed to enter other portfolios to compare to the best 15, for post-optimal analysis.

---

[1] The authors are research assistant and professors respectively, in Agricultural Economics at Michigan State University. Funding for the AIMS project is by Michigan State University Cooperative Extension Service, Agricultural Experiment Station and department of Agricultural Economics.

The design and structure of FIRM is more completely described in Alderfer et al. This paper focuses on the results. Figure 1 is a utility curve constructed by ELRISK, from values entered by a workshop participant.

Figure 1. Sample ELRISK Results



THE WORKSHOPS

An early version of FIRM software has been tested on 29 commercial soybean producers with encouraging results. These Michigan producers were from 7 different counties and represented a spectrum of ages, farm types, education levels and soybean acreages. The 29 farms produced over 10,000 acres of soybeans. The largest soybean acreage was 810 acres and 77 was the smallest.

Extension Agents and District Farm Management Agents were asked to coordinate a local workshop for marketing "new-crop" soybeans. Agents and producers were informed that research was the primary purpose of the gathering, although several evaluation forms indicated that the experience was educational for producers as well. One workshop was held in August 1989 to examine October 1989 sales and the other 3 workshops were held in January and February of 1990 and examined October 1990 pricing alternatives.

Each workshop began with an overview of FIRM, followed by elicitation of probability functions for yields. The yield elicitations were performed using ELICIT (Pease and Black; 1989) with a conviction scores option for evaluation. ELICIT produces an ASCII (text) file with yield intervals, unweighted scores, pdf and CDF values (nonparametric).

The mean and standard deviation for futures prices were solved from option premiums at the previous day's settling price. These distributions were solved for each workshop by the workshop coordinators. Correlations between futures, basis, and yield were very near zero for all data sets. Non-zero correlations can be managed through multivariate methods described by Fackler and King, but to simplify the workshop it was best to assume zero correlations. This allowed the Monte Carlo futures prices and basis to be created the night before the workshop. Monte Carlo basis levels were normally distributed with mean and standard deviation selected by an expert.

For all workshops, the current market data and the ending period probabilities for futures and basis were set to be as unbiased as possible. Thus, the forward contract price (expected cash price) was equal to expected futures price plus expected basis.

Variable costs were entered by the participants. Some variable costs are acreage dependant, such as seed and chemicals. Others vary according to the yield, such as harvesting, drying and trucking. Producers were asked to consider their marketing problem from a gross margin perspective (gross income minus variable costs).

GENRINC is a program that captures independent yields from the ELICIT data files, combines those with acreage, costs, futures price and basis levels, to compute 200 Monte Carlo observations on gross margin. The first gross margin distribution is an all cash marketing plan whose mean and standard deviation are important inputs into the risk elicitation program.

ELRISK was run to solve for utility curves as previously mentioned. These discrete "curves" are used in table lookup functions to convert gross margins after marketing into utility, for all 200 Monte Carlo observations. This process takes place in the objective function of MKT-OPT, with each pricing portfolio being converted into expected utility. When MKT-OPT sufficiently converges, the 15 best marketing plans are printed out (see Table 1).

Table 1. NL-OPT Screen Output

	- - - - - - - - BUSHELS TO-				- - - - - - -			
	Forw.	Futures	Put	Basis	Spec	Expect	Exp.	Risk
Plan	Cont.	Hedge	Hedge	Cont.	Call	SpotBu	Util	Prem
1	22341	7724	216	0	0	4693	256.7	0.0
2	23551	4760	325	0	0	3766	256.6	8.6
3	23043	5858	427	43	0	4111	256.6	10.3
4	21698	7656	307	0	0	5220	256.6	10.7
5	23850	4216	315	0	0	3556	256.4	25.4
6	25611	3868	652	0	0	2500	256.4	27.7
7	21868	7756	429	0	0	5078	256.4	28.4
8	26438	3123	721	0	0	2095	256.3	41.0
9	23371	4605	325	225	0	3734	256.2	45.3
10	25131	2690	302	0	0	2761	256.2	45.6
11	21117	9031	315	0	0	5715	256.2	46.4
12	23987	4062	520	0	0	3461	256.2	47.4
13	21951	5865	366	0	0	5010	256.0	67.9
14	22476	7624	614	166	0	4456	255.9	73.9
15	23136	4744	522	216	0	3911	255.9	73.9
16	22000	5000	0	0	0	4970	254.9	172.9
17	23500	5000	0	0	0	3803	257.0	-37.2
18	0	0	0	0	0	26438	135.4	10189.9

The final phase of FIRM allows producers to enter their own pricing portfolios and compare them to the 15 suggested in non-linear optimization. The bottom of Table 1 shows three such simulations. Plan 18 is an all cash marketing plan. The plan 18 risk premium in shows the approximate benefit of plan 1 (in certain dollars) over plan 18 (no preharvest marketing). Post optimal simulation also helps examine lumpy contract problems.

Plan 17 had higher utility and a negative risk premium. This indicates the producer found a plan slightly better than plan 1. This occurred because initial convergence parameters were medium in size, and the search domain was very large, allowing a variety of portfolios to appear in the final solution. With the non-linear optimization methods used, it is possible to "tighten" the convergence parameter, and narrow the search area. This results in superior optima (like plan 17), but increases the homogeneity of the 15 best marketing plans.

WORKSHOP RESULTS

Table 2. Producer Data.

Code	Age	Yrs farm	Soy Acres	Soys as % Inc.	Cost/ acre	Cost/ bush	Mean G.M.	StDev G.M.	E(Yld)	StDev Yld
FRA1	47	21	810	40	93.14	0.18	99589	37178	41.0	7.92
FRA2	40	22	420	30	79.21	0.19	65342	24514	44.6	10.10
FRA3	45	45	85		74.30	0.11	10632	4723	37.3	9.95
FRA4	46	26	77	10	86.00	0.12	10035	4096	40.7	9.69
FRA5	50	31	300	30	75.00	0.10	41729	17012	40.0	10.07
FRA6	52	30	350	20	57.00	0.10	57698	24999	41.8	12.93
FRA7	40	18	420	30	79.00	0.19	62226	21402	42.5	8.86
FRA8	49	27	700	33	90.00	0.18	88000	38240	41.0	9.76
CAL2	34	17	320		75.00	0.23	46180	15451	37.2	6.29
CAL3	25	6	250	40	57.00	0.30	38122	11280	36.8	6.85
CAL4	44	22	160	45	84.00	0.20	27337	8550	43.3	6.90
MON1	40	18	400	20	136.00	0.32	32086	28949	37.7	10.61
MON2	38	18	480	25	66.00	0.48	75532	25943	40.6	7.85
MON3	38	19	605	29	89.00	0.43	81269	31319	39.9	9.11
MON4	29	20	350	20	100.00	0.40	52708	18256	45.0	7.59
MON5	37	10	98	20	53.00	0.45	20146	4280	45.9	5.80
MON6	50	30	500	50	168.00	0.36	44997	27767	44.8	7.80
MON7	36	18	630	35	96.00	0.44	72383	26095	37.5	6.01
MON8	37	19	300	5	114.00	0.48	44054	1345	47.7	6.21
MON9	50	34	575	30	77.00	0.37	107202	36709	44.7	7.71
MON11	49	30	120	18	73.00	0.40	19394	5563	38.9	7.48
MON12	42	20	225		91.30	0.40	38934	9737	46.6	4.71
MON13	32	20	500	50	66.00	0.47	81756	25653	40.1	7.43
MON14	26	5	347	45	84.38	0.50	47551	18888	40.0	8.59
SHI1	35	17	629	55	75.00	0.10	76354	30307	35.3	7.14
SHI2	46	28	187	38	68.06	0.18	23666	7486	35.6	6.24
SHI3	65	40	162	30	73.50	0.10	18638	6966	33.5	5.50
SHI6	63	45	190	40	71.85	0.06	22113	8063	33.6	5.41
SHI7	80+		200		95.00	0.10	22140	8004	36.6	4.59

Table 2 contains basic descriptive data of the producers involved. Not shown is the fact that two of the producers were actually teams, with two and three family members participating. One wife and husband team chose to make their analyses separately.

Acreage, costs, and percent of income from soybeans varied substantially among the attendees, as did gross margin and yield distributions.

Table 3. Function evaluation in CARA order

	NEGATIVE EXPONENT	LINEAR	QUAD	SEMILOG	CARA, r(x)
MON13	NA	1.000	1.000	.931758	0
FRA8	.972151	.980680	.991503	.456601	0.000002
FRA6	.981886	.980501	.982205	.756708	0.000003
MON12	.987494	.987507	.987890	.977658	0.000009
MON3	.989913	.915625	.979585	.995698	0.000017
FRA1	.996183	.865203	.980685	.985124	0.000018
MON1	.961897	.930499	.956556	.974156	0.000024
FRA2	.996954	.908581	.991213	.989488	0.000024
MON4	.993433	.935317	.985698	.997972	0.000024
SHI1	.988731	.868287	.966161	.970580	0.000028
MON2	.981150	.863456	.962666	.950985	0.000031
MON14	.989108	.936740	.982139	.992106	0.000031
MON9	.983787	.871433	.959733	.935131	0.000035
CAL3	.994405	.932073	.988513	.990281	0.000042
MON6	.967589	.840537	.930279	.946161	0.000042
FRA5	.974626	.840972	.942543	.965365	0.000048
MON8	.994565	.900257	.981346	.970757	0.000053
MON7	.976526	.777136	.931139	.885739	0.000057
FRA7	.962971	.810394	.922116	.896759	0.000064
CAL2	.952248	.873173	.932353	.920276	0.000071
CAL4	.989818	.904731	.977411	.977964	0.000071
MON11	.965596	.940867	.958683	.965567	0.000087
SHI6	.973757	.920799	.962540	.970512	0.000095
SHI3	.974707	.922686	.965213	.971865	0.000115
SHI2	.869241	.802432	.854719	.844191	0.000119
MON5	.956746	.922310	.949118	.947446	0.000128
SHI7	.912430	.786505	.910180	.886192	0.000146
FRA4	.983675	.857501	.954866	.953484	0.000267
FRA3	.985868	.703571	.882362	.883265	0.000352

Data from the 29 utility curves elicited are summarized in Table 3, in order of risk attitude, from risk neutral at the top, to most risk averse at the bottom. Data from each individual was fitted to four different functional forms of utility. Linear utility is simply $U(x) = a + b(x)$, where x is income, a and b are intercept and slope and U(x) is the Utility (the dependant variable). The linear form was tested, not because it was expected to be common, but to give perspective when comparing the other three functional forms. Table 3 lists the R squared for each regression, as well as the constant absolute risk aversion coefficient (CARA). The far right column of Table 3 (CARA, r(x)) was found in non-linear regression, when solving the negative exponential utility function. The negative exponential function is $U(x) = k + a*(EXP(-b*x))$ where x = income and a, b, k are constants of regression. The quadratic function is $U(x) = k + a*x + b*x*x$ and the semi-log is $U(x) = k + a*LN(x)$, where x must be > 0.

The negative exponential function was fitted using a non-linear optimization routine (NL-OPT) with an objective function to minimize the sum of squared error between the fitted and the research data. The negative exponential function is used in much empirical work as well as theory. One measure of risk is the absolute risk aversion r(x) where r(x) = -U''(x)/U'(x). For the negative exponential function this value is constant and equal to b in the equation shown in the previous paragraph.

One producer exhibited perfect risk neutral behavior, while two other producers were very nearly risk neutral. The classification of neutral is based on the observation that linear R squared's were quite high for the top three producers in Table 2. The fourth individual (MON3) showed higher R squared's in the other functions, than in the linear function. The remaining soybean producers show various degrees of risk aversion. They are listed in order of least risk averse (small r(x)) to most risk averse.

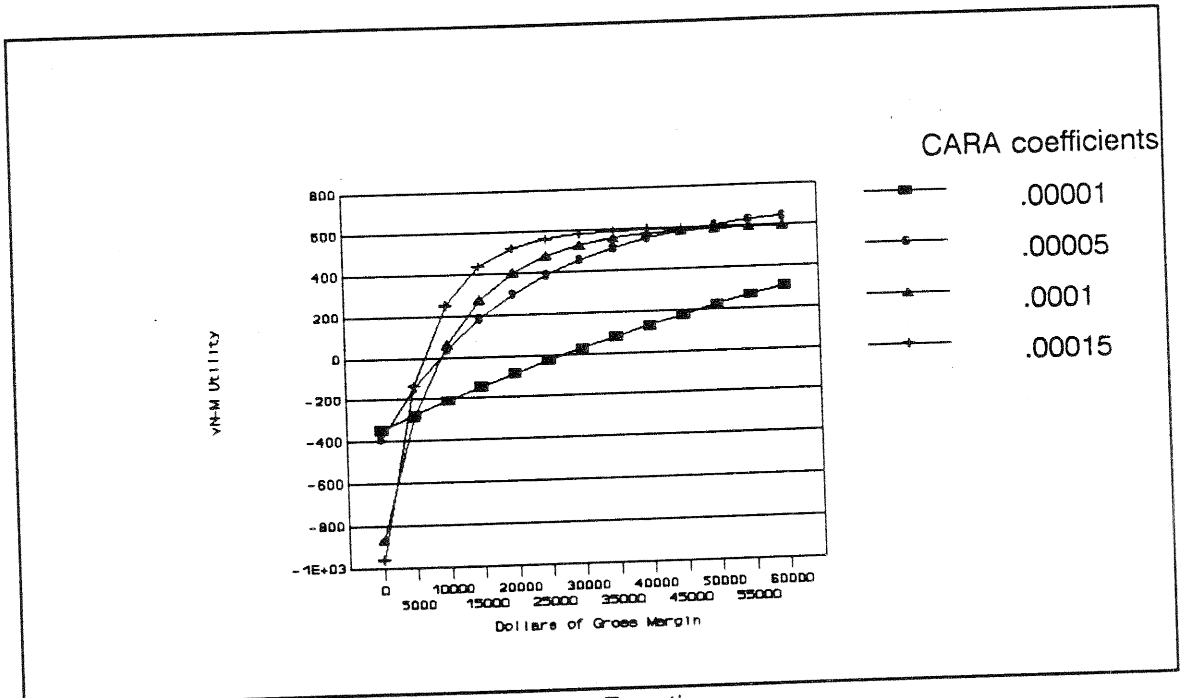


Figure 2. Four Negative Exponential Utility Functions

It is possible to compare the CARA coefficients in this research to those in other risk elicitation studies. This should be done with some care, however. Studies using the interval approach to elicitation usually categorize risk neutral as having a CARA of -.0001 to .0001. These include Thomas, Wilson and Eidman, Tauer, King and Robison and others. Using this range, all but six producers in this study would be risk neutral. Rister et al. catagorized -.00001 to .00001 as risk neutral when analyzing annual grain storage. These later figures more closely match those in this study. Ramaratnam et al. also found the negative exponential function to be superior in their sample of 23 farmers. In their study, the CARA values ranged from .0000026 to .0000135. Because Rister et al. and Ramaratnam et al. were dealing with different crops and income measures this limits the degree to which they should be compared. Their measures were less risk averse (more linear) than most producers in this research.

Raskin and Cochran point out that because the CARA values are small, their differences seem small. As they demonstrated, this is not the case. The most risk averse producer in this study was r(x) = .000352, compared to a moderately averse measure of

.0000709 (moderately averse for this group). These numbers mean that the most risk averse producer's marginal utility is declining by .035% from each additional dollar of income. The difference in these preferences for an added dollar at $10,000 is a factor of 82. At the average gross margin for the group ($22,000) the difference in preference for an additional dollar between these two individuals was a factor of 2408.

The final conclusion from Table 3 is that the negative exponential function is the best of the functional forms tested for the 29 producers. Even risk neutral functions that approached linearity had good R squared values when fitted to the negative exponential function. The only exception is when the utility function is strictly linear. Asymptotically, the negative exponential utility function can approach linearity but cannot become strictly linear. For this reason, the strictly linear case was not fitted to the negative exponential function.

Figure 2 shows four negative exponential curves across the same gross margin range. All four have closely related cases within the data. They are included to give perspective of the curvatures of these small numbers.

The evaluation in the workshop extends beyond the producer's responses and into the performance of the model. ELRISK was intended to elicit risk attitudes from the second standard deviation below the mean gross margin to the second standard deviation above the mean (or beyond). The reason for this, is that points on the utility curve are used in a table lookup function to convert from gross margin to utility. Monte Carlo gross margin values beyond those in the utility curve are extrapolated (linearly) from the last two endpoints. For MKT-OPT to function, it is best to get a utility function that covers as much of the gross margin distribution as is practical.

Table 4 demonstrates the degree to which ELRISK extended across the gross margin distribution. The far right two columns are the distance in standard deviations that ELRISK did not reach the target levels. Where a zero appears the levels were exceeded. A value of one indicates the elicitation failed to reach the second deviation by an entire deviation

In examining Table 4 it is easy to see that ELRISK was largely successful at surpassing the second standard deviation above the mean. Only six times were the highest user values below the mean plus two standard deviations. ELRISK did not perform as well on the lower end of the gross margin distribution. Was the expectation unreasonable on the lower end? Are improvements needed in ELRISK or ELRO methods? The methods used have given mixed risk attitudes when examining values in the neighborhood of $0.00 gross margin. Cochran et al. noted that when endpoints reach certain biases, this can effect the elicitation. One other weakness of the elicitation method used, common to many elicitations, is serial dependence. This occurs in the ELRO method when previous answers are used to build new situations. For example, a person may transpose two digits in their response and not realize their mistake. Such a mistake usually affects subsequent elicitations.

CONCLUSIONS

FIRM performed very well in four extension workshops. FIRM helped teach elementary applied probability, risk principles, and marketing. Workshop evaluations were encouraging and supportive. If the producers adopt the marketing plans suggested, substantial risk reduction would occur. The risk premium between doing nothing (marketing fall cash), and following the best pricing portfolio is nearly $1500 per producer and more than $40,000 for the 29 producers. This research was not only an educational program for nearly all who participated, but allowed for computation of its own potential benefits.

The software developed to date, is very suitable for a workshop setting but is not ready for individual producer use. Much database development is needed and empirical

Table 4. ELRISK Range Analysis

Code	Mean G.M.	StDev G.M.	Mean - 2 Stand Dev's	Mean + 2 Stand Dev's	Bottom ELRISK Value	Top ELRISK Value	Amnt ELRISK is Short of Dev's LOWER	UPPER
FRA1	99589	37178	25233	173945	27500	200000	0.061	0
FRA2	65342	24514	16314	114370	25000	123000	0.354	0
FRA3	10632	4723	1186	20078	3400	24500	0.469	0
FRA4	10035	4096	1843	18227	4200	18500	0.575	0
FRA5	41729	17012	7705	75753	13000	100000	0.311	0
FRA6	57698	24999	7700	107696	2000	105000	0	0.108
FRA7	62226	21402	19422	105030	35500	115000	0.751	0
FRA8	88000	38240	11520	164480	50	145000	0	0.509
CAL2	46180	15451	15278	77082	28300	72000	0.843	0.329
CAL3	38122	11280	15562	60682	18000	68000	0.216	0
CAL4	27337	8550	10237	44437	12500	50000	0.265	0
MON1	32086	28949	-25812	89984	17000	100000	1.479	0
MON2	75532	25943	23646	127418	41000	150000	0.669	0
MON3	81269	31319	18631	143907	20000	163000	0.044	0
MON4	52708	18256	16196	89220	15500	105000	0	0
MON5	20146	4280	11586	28706	13900	30200	0.541	0
MON6	44997	27767	-10537	100531	21000	130000	1.136	0
MON7	72383	26095	20193	124573	38000	125000	0.682	0
MON8	44054	1345	41364	46744	22000	74000	0	0
MON9	107202	36709	33784	180620	60000	160000	0.714	0.562
MON11	19394	5563	8268	30520	11000	31000	0.491	0
MON12	38934	9737	19460	58408	19000	58000	0	0.042
MON13	81756	25653	30450	133062	20000	140000	0	0
MON14	47551	18888	9775	85327	14000	79000	0.224	0.335
SHI1	76354	30307	15740	136968	29000	150000	0.438	0
SHI2	23666	7486	8694	38638	16290	42000	1.015	0
SHI3	18638	6966	4706	32570	9700	34500	0.717	0
SHI6	22113	8063	5987	38239	11000	40500	0.622	0
SHI7	22140	8004	6132	38148	12750	47000	0.827	0

work on ending period price distributions.

FIRM adds substantial support for the negative exponential function in empirical and theoretical use. Further tests of the model are needed. Some of these should involve additional workshops and data collection, while the remainder of the work is internal. Other questions also need exploring. Is there some link between the ELRO method and the negative exponential function, that makes it fit so well? Do fitted functions in continuous form give different marketing plans than the linearly extrapolated discrete functions? Is it possible to assume a negative exponential function after the producer answers only 3 or 4 ELRO situations? Why did some persons get utility curves across a great portion of their income range and others did not?

Faster microcomputers, improved computer algorithms and a growing risk literature, have contributed to constructing the FIRM model. With continued research and model changes, other suitable risk management problems may be examined in this way.

References

Alderfer, R., S. Harsh, J. Hilker and J. Black. "Farm Income Risk Management (FIRM): A Decision Support System Approach." NCR-134 Conference, April 1989, Chicago, Ill. (Also available as MSU Ag. Econ Staff Paper 89-51.)

Black, F. "The Pricing of Commodity Contracts." J. of Fin. Econ. 3(1976): 167-179.

Cochran, M., P. Zimmel, N. Stone, T. Toman, G. Helms, "An Expert System to Elicit Risk Preferences: The Futility of Utility Revisited." Forthcoming in the J. of Computers and Electronics in Ag. 1990.

Fackler, P. L., and R. P. King. "Generation of Dependent Random Variates with Given Marginal Distributions and Fractile Correlation Structure." Selected Paper presented at the AAEA meetings, Knoxville, TN, July 31-Aug. 3, 1988.

Halter, A. N., and R. Mason. "Utility Measurement for Those Who Need to Know." West. J. of Agr. Econ. 3(1978): 99-109.

King, R. P. Operational Techniques for Applied Decision Analysis Under Uncertainty. Ph.D. dissertation, Michigan State University, 1979.

King, R. P., and P. L. Fackler. "Probabilistic Price Forecasts Based on Commodity Option Values." Department of Agricultural Economics Staff Paper P85-28, University of Minnesota. August, 1985.

King, Robert P., and Lindon J. Robison. "An Interval Approach to Measuring Decision Maker Preferences." Amer. J. of Ag. Econ. 63(1981). 510-520.

Pease, J., and J. R. Black. "User's Manual for ELICIT." Draft 6:10/28/88, Version 2.3 .

________. 1989. "Estimation of the Probabilities of Alternative Yields using the Conviction Weight Method. Agr. Econ. Staff Paper 89-98, Michigan State University.

Ramaratnam, S. Sri, M. Edward Rister, David A. Bessler, and James Novak. "Risk Attitudes and Farm/Producer Attributes: A Case Study of Texas Coastal Bend Grain Sorghum Producers." So. J. of Ag. Econ. 18(Dec. 1986). 85-95.

Raskin, Rob and Mark J. Cochran. "Interpretations and Transformations of Scale for the Pratt-Arrow Absolute Risk Aversion Coefficient: Implications for Generalized Stochastic Dominance." West. J. of Ag. Econ. 11(Dec. 1986). 204-210.

Rister, M.Edward, Jerry R. Skees, and Roy Black. "Evaluating Use of Outlook Information in Grain Sorgham Storage Decisions." So. J. of Ag. Econ. 16(1984). 151-158.

Tauer, Loren. "Risk Preferences of Dairy Farmers." N. C. J. of Ag. Econ. 8:1(1986) 7-15.

Thomas, Arthur C. "Risk Attitudes Measured by the Interval Approach: A Case Study of Kansas Farmers." Amer. J. of Ag. Econ. 69(1987). 1101-1105.

Wilson, Paul N., and Vernon R. Eidman. "An Emperical Test of the Interval Approach for Estimating Risk Preferences." West. J. of Ag. Econ. 8(Dec.1983). 170-182.

Young, D., "Risk Preferences of Agricultural Producers: Their Use in Extension and Research." Am. J. of Ag. Econ. 61(1979). 1063-70.