An Analysis of the Yield-Price Risk Associated with Specialty Crops

W. P. Weisensel and R. A. Schoney

Specialty crops have been cited as means to diversify crop portfolios on the prairies. Lentils, a specialty crop, have high variability in yields and prices but are relatively uncorrelated with the yields and prices of other traditional Saskatchewan crops. In addition, yields and prices of lentils may be negatively correlated. These attributes have important but offsetting effects in crop portfolio selection. The objective of this article is to assess the relative profitability and riskiness of wheat and lentil rotations for a representative Saskatchewan farm and to select appropriate farmers who should consider production of lentils. The cumulative density function of net returns are simulated for both rotations assuming stochastic prices and yields. Stochastic dominance with respect to a function is used to identify the corresponding appropriate profile of agricultural producers for each crop rotation. The results indicate that lentils should be considered by a number of, but not all, Saskatchewan farmers.

Key words: dominance, risk preferences, specialty crops, uncertainty.

Farmers are constantly scrutinizing alternative crops for profitability and risk diversification. One popular alternative crop in Saskatchewan is lentils, primarily because it is more profitable than other traditional Western Prairie crops (Schoney 1987). However, production of lentils is riskier and requires more intensive management than traditional wheat production. Like many specialty crops, lentils are subject to greater price and yield variability than wheat. Saskatchewan lentils markets tend to be confined to a small geographic area and tight quality specifications (Boersch). The latter reduces the large carry-overs from year to year in anticipation of price increases. Consequently, it is likely that prices and yields of lentils are negatively correlated in the aggregate market. However, individual producer yields and prices may be inversely correlated even though individual producers are atomistic if individual yields are correlated through the influence of general weather patterns. Thus, when weather patterns faced by an individual are similar to the area weather patterns, good yields are associated with poor prices. This relationship has important implications on crop profitability and risk. As is well known, when the covariance of two variables is nonzero, expected gross return is the product of expected price and expected yield plus the covariance price and yield,

$$E(PY) = E(P)E(Y) + \mathrm{cov}(P,Y), \tag{1}$$

where E is expected value, P is commodity price, and Y is the commodity. Thus, if price and yield are negatively correlated, basing expected gross returns on the simple product of expected yields and prices can seriously overestimate crop profitability, leading to biased crop selection.

Covariances among net returns of different crops also can have important implications in the risk management of the cropping portfolio. When covariances of net returns among crops are negative or low, additional crops will decrease risk. However, when the correlations among cropping returns are highly positive, diversifying the crop portfolio by adding additional crops is ineffective in reducing portfolio risk. For example, let's examine a crop portfolio where each crop is normally distributed with an expected rate of return above variable costs of 20% and a standard deviation of 5%. Also, assume that the correlation in net

The authors, respectively, are a research associate and an associate professor in the Department of Agricultural Economics at the University of Saskatchewan.

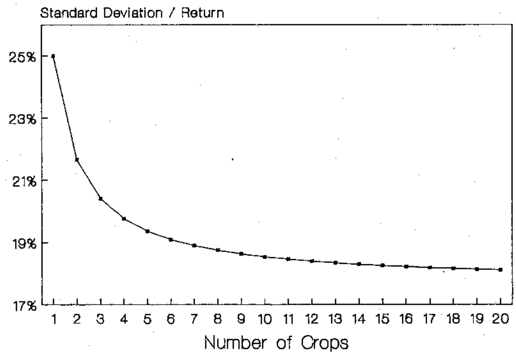

Figure 1. Risk implications of crop portfolio diversification

returns among all crops is .5. The relative riskiness of the portfolio is defined by the coefficient of variation or the standard deviation of the portfolio divided by the mean return. Figure 1 illustrates the effect of diversification as additional crops are added to the crop portfolio, assuming equal proportions of each crop. Note that most of the benefits of diversification are derived from moving from a one-crop to a two-crop portfolio; the relative riskiness of a one-crop portfolio is 25.0% while the relative riskiness of a two-crop portfolio is 21.7%, a difference of 3.3%. However, the relative riskiness of a three-crop portfolio is 20.4%, which is only 1.2% less than the two-crop portfolio. Thus, most of the benefits of diversification occur when the portfolio is small because of the rapidly diminishing benefits of adding more crops.[1]

In contrast, specialty crops like lentils have appeal in crop diversification schemes because their gross returns are relatively uncorrelated with other traditional Western Prairie crops (i.e., the correlation among gross returns of lentils and other crops in the portfolio may be substantially less than .5 as used in the example above). In addition, a negative yield-price correlation reduces income variations. The objective of this article is to assess the effect of lentils on the relative risk incurred by representative Saskatchewan grain farms. In addition, a related objective is to determine the profile of farmers who are likely to incorporate lentils in their cropping rotations. Critical in this analysis is the Stochastic Top Management Farm Business Simulator.

[1] This results from the assumption of constant correlation. Thus, as additional crops are added, the number of covariances rises rapidly.

Methodology

The Stochastic Top Management Farm Business Simulator is the stochastic version of the Top Management Forward Planning Model (Schoney 1986). The latter is used in farmer workshops in Saskatchewan and Alberta as well as by university school and undergraduate students. The Top Management Stochastic Farm Business Simulator adds to the deterministic forward planning model a multivariate stochastic process generator (MSPG) developed by Robert P. King at the University of Minnesota. In brief review, the MSPG generates joint distributions of stochastic variables based on individually specified and subsequently modifiable normal and triangular marginal distributions and cross correlations. Currently, up to 250 experiments can be generated. Each experiment simulates farm production, net cash flows, farm income, and net worth growth patterns over a five- to 15-year planning horizon. Risk is summarized by cumulative probability distributions (cdf) of three variables: (*a*) annual farm income available for family living, income taxes, and capital acquisitions; (*b*) total income available for capital acquisition and investment; and (*c*) net worth.

The cdf of farm cash and net worth are simulated for a representative Saskatchewan grain farm for both wheat and lentil rotations. The subsequent cdf are tested for first- and second-degree stochastic dominance (FSD, SSD). Unfortunately, FSD and SSD are often not very successful in filtering out all alternatives but one in the efficient set (Anderson, Dillon, and Hardaker). In order to identify a unique cropping choice, stochastic dominance with respect to a function (SDRF), which incorporates more information as to individual preferences, is used to further discriminate between the two alternatives. SDRF can order choices for decision makers whose absolute risk aversion function lies within specified lower and upper bounds or a risk interval. In this study, SDRF is used as a final filter to determine the appropriate risk intervals of producers who would unambiguously choose the wheat or lentil rotations based on risk-bearing ability.

King and Robison (1981a) have shown that individuals can be grouped according to specific intervals of the Arrow-Pratt measure. The interval is estimated by asking decision makers to choose between pairs of carefully selected discrete probability density functions. Each pair of distributions is defined over a relatively narrow range of income so that the absolute risk aversion space is divided into two regions, one distribution consistent with the risk interval and one not consistent (King and Robison 1981b).[2] By confronting the decision maker with a series of choices between selected pairs of distributions, the risk aversion interval for the decision maker's preferences can be established. The search routine is based on the original program developed by King and Robison (1981b).

Representative Farm Data and Expectations

A representative commercial grain farm from the dark brown soil zone of Saskatchewan is based on the 1988 Top Management Workshops.[3] Total crop acreage for the representative farm is 1,518 acres, and land is valued at \$350/acre. Two rotations are selected as representing the choice set of farmers. The first rotation—WWWF—features wheat on fallow, followed by two years of wheat on stubble, and finally summerfallow. The second rotation—WLWF—is identical to the first except that lentils are seeded after wheat on fallow. Production costs are constructed for both rotations based on truncated mean costs (Schoney, Thorson, and Weisensel). Total debt is approximately \$90,000 (\$15,000 in medium term and 75,000 in long term). Family living withdrawals are \$20,000.

Price Expectations

Price expectations displayed in table 1 are based on the 1988 Top Management Workshop participants' 1988–89 commodity price expectations.[4] Farmers were asked to specify a percentile-based Beta distribution using a "lowest value" (which will be exceeded 19 out of 20 years), a "most likely value," and a "highest value" (which will be exceeded only 1 year out of 20).[5] Unfortunately, none of the farmers in the group surveyed grew lentils. As a result, the distribution for lentils is estimated based on historical relationships. The correlation between wheat and lentil prices is based on 1960–86 prices inflated to 1986 using the Consumer Price Index and indexed for a 2% productivity index (table 1). Prices of lentils are not highly correlated with wheat—.20. Thus, lentils may be used to diversify price risk, but before an assessment of their economic value can be made, yield-yield and yield-price relationships first must be considered.

Yield Expectations

Wheat yield expectations also are based on the 1988 Top Management Workshops (table 1). Note that wheat yields are reasonably symmetrically distributed and that the modes are very close to the means. In addition, the standard deviation is similar between wheat on fallow and wheat on stubble—approximately 6.8 bu./acre. Again, none of the surveyed participants reported lentil yields; the distribution of expected lentil yields is based on crop insurance time-series data and discussions with crop production specialists. Lentil yields on stubble are much more variable than either wheat on fallow or wheat on stubble yields, reflecting greater sensitivity to drought, frost, and moisture damage at harvest.

Cross correlations are based on 1970–80, District 6, Saskatchewan Crop Insurance yields. As can be expected, wheat-on-fallow and wheat-on-stubble yields are highly correlated—.91. In contrast, wheat and lentil yields are relatively uncorrelated, having cross correlations of .26 and .27, respectively, for wheat on fallow and wheat on stubble, suggesting that lentils may be a good candidate for crop diversification. In this analysis, wheat yields and prices are assumed to be independent, but lentil yields and prices are inversely correlated with a correlation coefficient of −.30.

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[2] The narrow range of distributions is also necessary so that constant absolute risk aversion over that range of income can be assumed.

[3] Farm sample costs are truncated to include the mean, ± one standard deviation.

[4] Net price includes quality or grade adjustments. Consequently, individual farm prices will always be more variable than statistical price series.

[5] The percentile-based Beta distribution approach is similar to the triangular distribution approach of eliciting producer-subjective probability distributions. The advantage of the percentile-based Beta approach is that it helps resolve the problem of ambiguous endpoint interpretation of triangular distributions. For more information about the percentile-based Beta approach, readers are referred to Young.

Table 1. Top Management Workshop Price and Yield Expectations, Dark Brown Soils, 1988

Statistic	Prices		Yields		
			Wheat		Lentils
	Wheat	Lentils	Fallow	Stubble	Stubble
	($/bu.)		(bu./acre)		
Mode	3.57	7.50	29.80	24.40	16.90
Low	2.34	0.50	19.85	13.90	0.00
High	5.33	16.00	41.42	35.80	34.00
Mean	3.66	7.75	30.08	24.55	16.93
Std. Deviation	0.94	4.86	6.76	6.87	10.66
Cross Correlations					
Price-Price:					
Wheat	1.00	0.20			
Lentils		1:00			
Yield-Yield:					
Wheat Fallow			1.00	0.91	0.26
Wheat Stubble				1.00	0.27
Lentils Stubble					1.00
Yield-Price:					
Wheat Yield	0.00	0.00			
Lentil Yield	0.00	−0.30			

Sources: Price and Yield Expectations, 1988 Top Management Workshops; Cross correlations, Price: *Agricultural Statistics,* Saskatchewan Agriculture, Yield: Saskatchewan Crop Insurance Yields, District 6, 1970–80, unpublished data.

Risk Preferences

Risk aversion coefficients were elicited using the risk interval approach from 41 of the Top Management Workshop Participants during January to March of 1988 (Schoney, Thorson, and Weisensel).[6] The proportions of farmers by risk interval are presented in table 2. As can be expected, risk attitudes vary widely, even within a producer group which is on the average well educated and innovative. It should not be too surprising that many of the participants are reasonably risk neutral.[7] However, what is surprising is the number of mildly risk-loving individuals. Approximately 34% to 42% of the farmers are classified as risk loving. Accordingly, many of the Top Management Workshop producers would be expected to be good candidates for a relatively high-risk crop such as lentils.

Table 2. Distribution of Absolute Risk Aversion Coefficients by Income Level, Top Management Participants[a]

Risk Interval Mid Point	Income Level[b]		
	Low	Middle	High
	(%)		
−0.00500	10.5	7.9	5.3
−0.00025	31.6	34.2	18.4
0.00000	13.2	10.5	36.8
0.00015	18.4	0.0	23.7
0.00035	18.4	7.9	7.9
0.00065	2.6	26.3	0.0
0.00280	2.6	7.9	5.3
0.00500	2.6	5.3	2.6
	100.0	100.0	100.0
Mean	−.00017	.00008	.00010
Std. Dev.	.00167	.00217	.00159

[a] A single risk aversion coefficient was calculated for each participant by taking the average of the two endpoints of the risk interval.
[b] The income levels are −$4,600 to $3,600, $14,700 to $26,800, $35,800 to $65,000, respectively, for the low-, middle- and high-income classes.

[6] The Top Management Program is operated by the Department of Agricultural Economics at the University of Saskatchewan. For more information regarding the program, readers are referred to Schoney (1987, 1986).

[7] The risk intervals are broadly defined leading to potentially overlapping classifications. Therefore, there are a number of classifications which are essentially risk neutral. Empirically, this is not a serious problem for the first two levels of income, but it could be a problem for the high-income interval. Since the Arrow-Pratt coefficient of absolute risk aversion is not a scale-free measure (Raskin and Cochrane), the maintenance of the same risk interval for the high-income interval could explain the clustering of people around the risk-neutral level. Fortunately, this limitation does not influence the rest of the analysis since the stochastic dominance used in the analysis is far more sensitive to changes in risk aversion at the low- and middle-income intervals than the high-income interval. We would like to thank an anonymous reviewer for bringing this to our attention.

Table 3. Simulated Distributions of Farm Cash by Crop Rotation

Statistic	Rotation	
	W-W-W-F	W-L-W-F
	($)	
Mean	25,112	28,473
Std. Dev.	26,712	33,064
Minimum	−26,885	−36,795
Maximum	98,520	138,913
CV	1.06	1.16

Results

Each of the two alternative rotations is simulated 250 times over a one-year planning horizon. The distribution of farm cash available for family living withdrawals, income taxes, and capital expenditures is presented in figure 2 for the first year, and the summary statistics are provided in table 3. The relative mean and standard deviation values are as expected—the lentil rotation is more profitable but generates greater income variability. Neither distribution is first- or second-degree stochastic dominant. This can be verified by figure 2—the lentil crop rotation generates less farm cash until the fortieth percentile, but after the fortieth percentile it generates considerably greater farm cash. While the stochastic dominance tests are inconclusive, additional information as to decision makers' risk preferences may allow further discrimination between the rotations.

Stochastic dominance with respect to a function is used to define a profile of agricultural producers who would select wheat, wheat and lentils, and lentils by parameterically searching risk-attitude intervals until one rotation prevails (table 4). In other words, by trial and error we used stochastic dominance with respect to a function to determine the risk interval ranges for which a single alternative (WWWF or WLWF) is in the risk-efficient set.[8] Since the same income intervals as the Top Management survey have been maintained, these results are directly comparable to the distributions in table 2.[9]

[8] In essence, we are determining the conditions necessary to be able to discriminate between two alternatives based on the level of risk aversion.

[9] The SDWF program developed by King and Robison requires absolute risk aversion intervals for a number of different income intervals. This is reasonable since it is unlikely that an individual's level of risk aversion would remain constant over all levels of income (King and Robison 1981b).

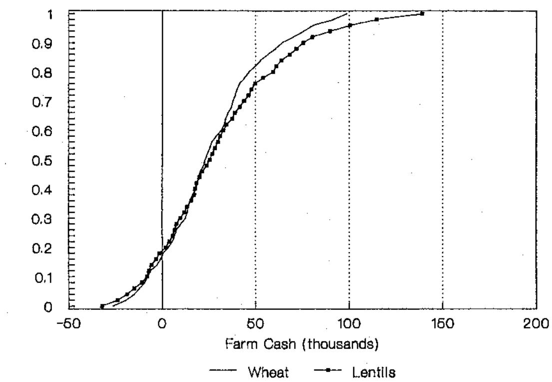

Figure 2. Comparison of the cumulative probability of farm cash for lentils and wheat

From table 4, risk averters, as expected, would prefer wheat, and risk takers would prefer lentils. In fact, based on the low-income interval (−$4,600 to $3,600), a producer must have an absolute risk aversion level greater than .0003 to prefer the wheat rotation to the lentil rotation. In contrast, for the same income interval, an individual who absolutely prefers the lentil rotation must have a level of absolute risk aversion less than −.0004. Using the information found in table 2, only 5% to 10% of farmers will unambiguously prefer the lentil to wheat rotation at low-income levels. However, at the same income level, approximately 18% to 36% of the farmers would unambiguously prefer the wheat rotation, and 59% to 72% of the farmers might include both or are undecided in their preferences.

As can be expected, the upper boundary of risk aversion for the lentil rotation increases at higher income levels. This is explained by the fact that the WLWF rotation dominates the WWWF rotation for farm cash levels greater than $15,000. Note that this coincides with the lower boundary of the middle-income interval of table 2. Consequently, one can be risk averse over higher levels of income and still prefer the lentil rotation. However, none of the farmers in the risk survey currently are growing lentils. It is not known whether they have grown lentils in the past or have ever considered growing lentils.

We emphasize that one should use caution in interpreting table 4. The risk interval approach is designed to be used for small changes in income. However, our experience, which is supported by previous research, suggests that most farmers tend to find small changes in

Table 4. Risk-Aversion Intervals Defining a Risk-Efficient Alternative, Wheat vs. Lentils

Rotation	Risk-Efficient Income Intervals		
	−$4,600 to $3,600	$14,700 to $26,800	$35,800 to $65,000
W-W-W-F	[0.0003, ∞]	[0.0, ∞]	[−0.0001, ∞]
W-L-W-F	[−∞, −.0004]	[−∞, .0001]	[−∞, .0001]

income relatively meaningless (Thomas). In addition, as Fleisher notes, farmers may have individual preferences regarding wheat and lentils which are not linear with respect to income. Finally, the risk aversion coefficients are not directly comparable between income levels.

Implications and Conclusions

Much emphasis by the Economic Council of Canada and others has been placed on crop diversification.[10] While lentil acreage has increased (Young and Malorgio), these increases have not been as large and extensive as some had hoped. Based on the above analysis, many of the better farmers will reject lentils, even when they may appear to be profitable. In addition, there are other factors which may influence crop selection including production and marketing management levels, as well as the possible need for specialized equipment. Boersch notes that inexperienced lentil growers generally depend on marketing organizations to market their product, while those with more experience market their own. Moreover, Boersch points out that more experienced growers tend to get higher and more stable prices for their product. This seems to suggest that extension efforts in the marketing area could result in greater adoption of lentils within farm crop rotations.

Finally, there are also a number of potential artificial barriers raised by Canadian institutions. Until recently, many of the government assistance and stabilization programs discriminated against diversification into specialty crops (Rosaasen and Schoney). Two examples of the bias of government programs are: (*a*) the Canadian special grains program, which omitted payments on specialty crops in 1986–87, and (*b*) the Western Grain Stabilization Program, which refused levy contributions from specialty crop production. Fortunately, both of these programs now have been modified to accommodate specialty crops.

While many farmers would not consider lentils because of their risk attitudes, a number of farmers should carefully consider lentils as a cropping alternative, if profitable. Further extension programs are needed to teach and develop appropriate marketing and production management skills.

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[10] It is interesting to note that the Economic Council Report tends to support the notion of diversification, but at the same time argues that farmers make the correct economic decision in sticking with traditional crops they know best.

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