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THE UNIVERSITY OF ALBERTA

RISK AND RETURNS ON ALBERTA GRAIN FARMS

by

© ANNABELLE C. BOYDA

A THESIS

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Date April 20, 1988

Dedication

To Jerry, With Love

Abstract

Mean-variance models following in Markowitz tradition have seen application in business and agriculture. These models are generalizations to a world of uncertainty of the work of Irving Fisher. This thesis used the Fisher framework of the single-period investment model to examine risk-related farmer choice of multiple crop rather than single crop. The causal influence of risk reduction is analyzed. Choice is based on present cost commitment at the time of decision and future anticipated revenue resulting from harvest. Value conversion between present and future is accomplished by a risk-sensitive discount rate. Risk is ascribed to anticipated crop receipts. Measurement of risk is based on dispersion of actual revenue around the predicted values, a mean square error estimate. The relative measurement is the coefficient of variation.

Revenue is derived from three components; yield, price and grade factor. Actual yield estimates for wheat, barley and canola were obtained from Alberta Wheat Pool by grain elevator point for the period 1974 through 1986. Variability in yield may be attributed to agronomic relationships and statistical relationships. This thesis concentrates on statistical characteristics. Predicted yield is based on local historical experience and province-wide deviation attributed to fertilizer use. Predicted and actual prices are based on Canadian Wheat Board payments and futures contracts for each crop. Grade factors were determined from discount associated with quality. Predicted revenue is composed of predicted yield times predicted price times mean grade factor. Differences between actual revenue and predicted revenue estimates provide the relevant variability for analysis.

In the market there is a trade-off between risk and return. Managers select portfolios which have the least risk for a given expected revenue or the maximum revenue for a given risk class. Markowitz diversification is used to reduce risk by combining less than perfectly correlated investments. Covariance and correlation matrices provide the interdependence relationships between the investments. This thesis examined the risk reduction effects of diversification on crop combinations, as well as other risk responses. The other risk responses considered were crop insurance and a hypothetical price insurance.

Tests of the hypothesis that risk reduction through crop diversification provides significant economic benefit were not rejected, however the additional risk reduction associated with diversifying from two crops to three was minor. Alternative risk responses such as the use of price and crop insurance provided more economic benefit than diversification of uninsured crops.

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I. INTRODUCTION

In capital investment theory, the basic investment decision is often described under conditions of certainty, where a choice exists between a quantity of certain, present wealth and another quantity of certain, future wealth. As one moves closer to a discription of reality, the decision is more likely to be represented as a choice between certain, present wealth and future, risky wealth. In this second representation a known quantity of future wealth is replaced by a probability distribution of future wealth prospects. The wealth prospects are usually denominated in money, and the distribution is characterized by at least two parameters, expected money receipt and variance around this expectation.

This thesis uses historical data to study revenues prospects arising from producing crops. It characterizes the farm crop decision as a single-period investment, with an exchange of present cash commitment to farming costs for future cash from the crop sale. The cash commitment is presumed to be known with certainty and includes such input costs as land rent, labour, fertilizer, seed, and pesticide.

Risk is associated with the variability of anticipated future crop revenue. The revenue from crops derive from price, quantity and quality of product. These revenues can be characterized by a two-parameter probability distribution.

This thesis concentrates on forecasting the more difficult parameter used to describe revenue distributions; variability of expected receipts. Historical variability experience will be used in the estimation. Variability will be determined by the dispersion of actual revenue around the expected receipts. In the multiple crop solution, possible effects of diversification need to be considered. Examination of statistical characteristics of crop production that affect the relationship between single crop and multiple crop variability will be required.

A. Objectives and Hypothesis

The central theme of this study is to investigate the risk-related rationale for farmer choice of multiple crop combinations of wheat, barley and canola rather than single crop. The choice of mono-culture or more diversified cropping patterns may be attributed to a number of causes--risk reduction, disease control, pest control, soil structure maintenance to suggest a few. However, it is the causal influence of risk reduction that will be isolated and analyzed.

Other issues to be examined in this study include:

1. the absolute and relative amount of variability of revenues associated with wheat, barley and canola crops,
2. the stability of risk patterns over time,
3. the significance of risk differences between crops,
4. the effect of insurance on crop risk, and
5. the independence, or lack thereof, between risk exposure on crops planted in different years.

Comparisons of crop diversification strategies and the level of income between and within farming areas will involve the testing of the following hypothesis:

Risk reduction through crop diversification under Alberta conditions is significant at the 95% confidence level.

Rejection of this hypothesis will support the contention that the risk-control motive for crop diversification is minor. If the hypothesis is not rejected, risk-control will be assumed to be a motive of crop diversification.

B. Research Approach

Investigation of the dispersion parameter in crop investment is complex, because of its additivity properties. Changing from a single-crop situation to a multiple crop will generate a risk exposure which depends not only on the dispersion parameter of each crop's revenue distribution but also on statistical interaction between those distributions in the form of covariance or correlation. Therefore, data from various crops must be analyzed not only for dispersion, but for covariance as well.

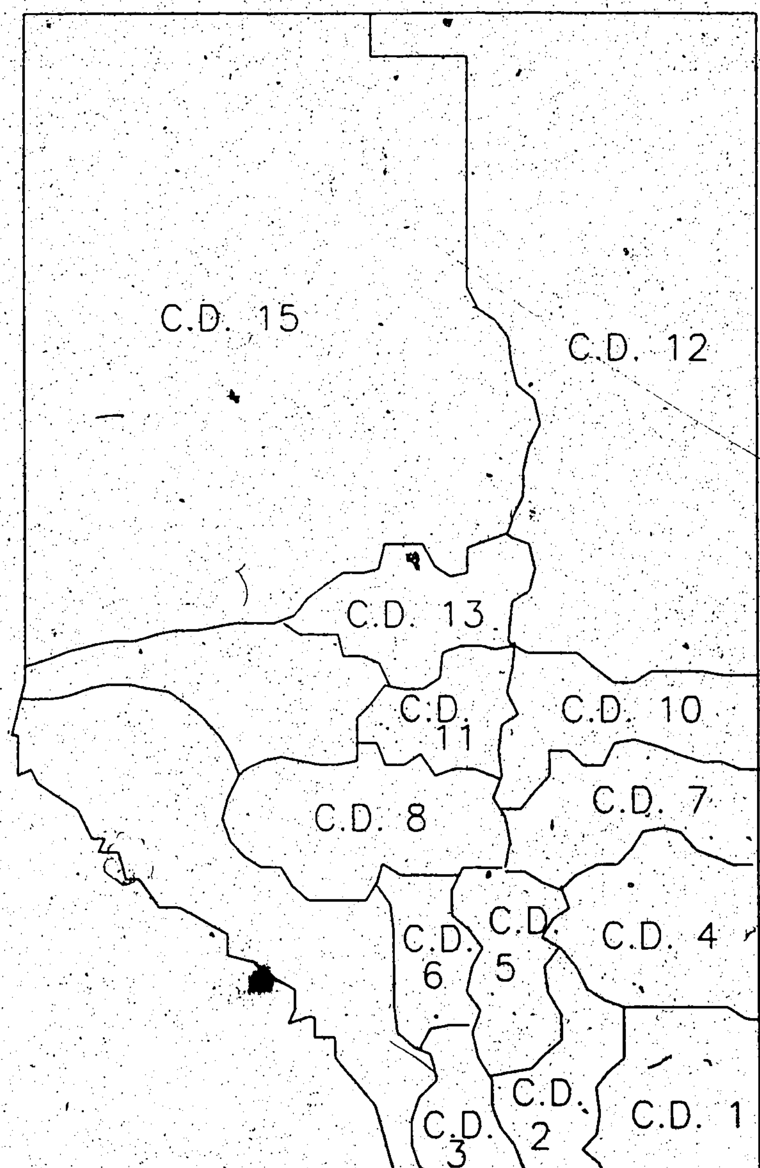
The basis for historical identification of the dispersion parameter will be errors from posited ex ante predictions. For each year in the study, an appropriate prediction for end-of-year price, yield and grade will be formulated, based on information available at the beginning of that period. Actual end-of-period results will then be compared with forecasted results for each crop, for each year. The differences between predicted and actual prices, yields, and grades for each crop are the errors which are investigated. The pattern of errors for each crop, and their interaction between crops, will form the basis for forecasting the dispersion parameter confronting farmers who will be making cropping decisions in the future.

Historical yield and grade data necessary for forecast error estimates will be obtained from the Alberta Wheat Pool estimates of yield at country grain elevator points. Properties of this data source will be discussed in a later chapter. Price data were obtained from Alberta Agriculture Statistical Yearbooks, Chicago Board of Trade Statistical Annual and the Winnipeg Commodity Exchange Statistical Annuals for the period under study. The results are indicated on a regional basis. Regions were set in accordance with census divisions used by Statistics Canada and are represented in the following figure 1.1.

C. Study Outline

Following this introduction the second chapter will present some theoretical background for cropping decisions. Chapter three examines the determinants of revenue. Each component will be examined separately. This section also describes the type of data that will be used in the analysis and the modification necessary to account for insurance effects. The results and analysis are presented in the fourth chapter. The results report the relative risk between crops and the risk reduction resulting from crop combinations. The final chapter summarizes the risk reduction attributed to crop diversification and provides recommendations for further research.

Figure 1.1: AGRICULTURAL REPORTING REGIONS



II. RISK MODELS AND RISK MEASUREMENT

Financial theory deals with rational choices of individuals and firms. This chapter presents models for investment selection which are consistent with rational behavior in a competitive equilibrium market. The models are constructed on the concept that the best representation is that of the simplest which captures the essence of reality. The immediately following sections will report how decision relating to risk has been theoretically represented in literature. The second portion of the chapter will deal with refinement of the concept of variance for purposed of measurement.

A. Risk:Return Trade-offs

There are two well established theoretical representations of decisions relating to risk and both use variance as the fundamental quantitative definiuon of risk. The first view is that minimizing risk is an independent goal competing with the goal of maximium profit. The analysis of behavior under risk by considering variance and expected returns has a history of usage; e.g. Markowitz (1952) and Lintner (1965). The criterion identifies investments with minimum variance (maximum expected return) given levels of expected returns(variance) which are used to find utility maximizing solutions (Robison and Brake, 1979). The difficulty in this approach lies in the limitations of the use of a quadratic utility function (Tobin, 1969) or that investment plans be normally distributed (Borch, 1969; Feldstein, 1969; and Samuelson, 1970). Levy and Markowitz (1979) and Kroll, Levy and Markowitz (19[illegible]) found the quadratic approximation to be quite robust. Tsiang (1972;1974) justified the use of such analysis provided the risk taken is small relative to total wealth.

The expected return-variance (EV) approach has been applied often in agriculture. Heady(1952) was one of the first researchers to examine mean-variance relationships in agriculture. Fruend(1956), Klubeinstein and Scott(1975) used quadratic programming to determine the EV (earnings/variance) efficient set. Other programs that emerged were Hazell's(1971) minimization of absolute deviations (MOTAD) and Chen and Baker's two-stage marginal risk constraint program. Scott and Baker (1972) added the safety-first criterion to the portfolio theory to find efficient plans for corn and soybean farmers in Illinois. Robison and Barry (1980) modified the EV analysis to account for effects of asset indivisibility.

Several studies attempt to specify utility functions based on the premise that the expected utility hypothesis underlies decision making (Halter and Dean, 1971; Lin, Dean and Moor, 1974; and Zuhair, Taylor and Kramer, 1987). These studies are in agreement that the utility functions should possess the properties of continuity and decreasing absolute risk aversion.

More recently, Young and Barry (1987) explore the possibilities of reducing risk by including financial assets in grain farm portfolios. Correlation coefficients between farm and financial assets were generated. Quadratic programming was used to identify efficient combinations.

Risk analysis in public programs and policy is receiving more consideration. Robison and Barry (1987) indicate that government policies of supply control, price stabilization with minimum prices tend to reduce participation of farmers in privately supplied risk-reducing measures as hedging and diversification. Secondary impacts of public credit programs are rising input prices. Scandizzo, Hazell and Anderson (1984) recommend supply functions be specified in terms of anticipated returns rather than anticipated prices and such supply functions be used in determining welfare consequences. This premise is based on producers confronting risk rather than merely instability. These authors also imply that shadow prices used for project appraisal should consider the joint role of price and yield.

B. The Capital Asset Pricing Model

The second theoretical view is that of the Capital Asset Pricing Model (CAPM) which stipulates that risk has a market price and can be directly compared to other economic values through this means. CAPM is a representation of the behavior of financial markets and rests on the assumptions that security markets are competitive and efficient and that these markets are dominated by rational, risk-averse investors who demand a premium in the form of higher expected return for risk.

The CAPM is an extension of the Markowitz approach to conditions of capital market equilibrium. Tobin (1958) developed the 'separation theorem' which showed that the Markowitz model implied a process of investment choice that could be broken into two parts; one was the choice of a unique optimum combination of risky assets, and the other was a separate choice of allocation of funds between risky and a single riskless asset. Sharpe's(1964) representation of the capital market in equilibrium allows the investor to attain a point along a capital market line. Higher return can be obtained only by incurring additional risk. The market presents a price of time and a price of risk. The price of risk is the slope of the capital market line, the price of time is the pure interest rate. Sharpe (1964) and Lintner (1965) developed the theory that relates the risk premium for an individual security 'x' $(E(R_x)-R_f)$ to the risk premium of the market, $(E(R_m)-R_f)$. $E(R_x-R_f)=\beta_x[E(R_m)-R_f]$ where: R_x is the return of the individual asset 'x', R_m is return on the market, R_f is the riskless rate of return and β_x is a measure of systematic risk for the individual security. β_x can be determined as $Cov(R_m,R_x)/\delta_m$; resulting from the correlation with the market, ρ_{xm}, its own standard deviation, σ_x, and the market standard deviation, σ_m; equalling $\rho_{xm}(\sigma_x/\sigma_m)$.

Roll (1977) tested the hypothesis that the market portfolio is mean-variance efficient using efficient set mathematics. Roll concluded that little external information is available on the true market portfolio's exact composition and that even a small mis-specification can lead to wrong conclusions. Some previous studies which rejected the Sharpe-Lintner model, such as Fama and MacBeth, 1973 and Black, Jensen and Scholes, 1972 and Blume and Friend, 1973, are shown to have arrived at the wrong conclusions due to specification error in measurement of the market portfolio.

The CAPM approach is useful for investment decision analysis. Stapleton (1971) used the relation between rate of return on a stock and the rate of interest as developed by Sharpe and Lintner, to derive stock value and apply capital budgeting decision rules.

There has been limited application of the CAPM in agriculture. Barry(1980) used CAPM to examine risk-return contributions of holding farm land in market portfolios. He concluded that such diversification could reduce risk. Turvey and Driver(1985) generate beta-risk coefficients for agricultural commodities using gross revenues rather than rates of return.

Collins and Barry (1986) used the Sharpe Single Index approach to examine systematic vs non-systematic risk for crops in the Imperial Valley of California. The index approach does vary from CAPM in that CAPM explains the equilibrium rate of return on assets whereas the index approach is a simplified version of the Markowitz model. Additional work on risk and price-hedging will be cited in Chaper four.

C. Variance Measurement

Variance underlies major theoretical models, which focus directly on mean-variance trade-off, or presume that an asset's risk is described by its contribution to variance of all assets (in CAPM, the market portfolio). In the first case, asset variance enters the model directly; in the second asset variance is of importance, but only as weighted by correlation of the asset's variance with that of the market portfolio. For either purpose, when variance is measured, its measurement should be consistent with its use as a measure of risk. In this context, a distinction between naive variance and a more refined version is of importance.

Naive variance is found through direct historic observation of variability of revenue or of a revenue component. For example, yield variance of a crop would be found by taking the variance of historical yield data. If this variance were used as the measure of risk, prediction of risk exposure based on this measurement would imply that a single-period decisionmake would be, in simplified effect, drawing a number from an urn containing all past yields. Naive variance may exaggerate risk, since some variation may be predictable. For extreme example, suppose that yield variability were fully explained by summer rainfall, and suppose that precisely accurate summer rainfall forecasts were obtainable prior to cropping decisions. Yield would vary historically, but this variability would conceal a situation where single-period decisions were riskless. In the case of crop data, there is no presumption of accurate weather forecasts, but some other information may be know to farmers at the time of the cropping decision which narrows the risk dimension below that implied by naive historical variance.

To determine the risk in anticipated revenues, measures of dispersion of the distribution of revenue estimates about the predicted value, such as the mean square error (MSE) estimate, are required. Whereas, variance measures dispersion around the mean, mean square error measures dispersion around the estimate(γ).[1]

Mean Square Error $= E[\hat{\gamma} - \gamma]^2$

Variance $= E[\hat{\gamma} - E(\hat{\gamma})]^2$

where: γ is the parameter to be estimates. Only if the mean and estimated value of the parameter coincide, are variance and mean square error identical. This study is interested in modeling the predictive process by incorporating some exogenous factors which reduce some of the variation which may be predictable. The variability remaining is the relevant variability to be analyzed.

Comparisons of variability between crop revenue series may require adjustment for unit of measurement and differences in means. The unit of measurement which compensates for these differences is the coefficient of variation (C.V.). The C.V. for revenue series is calculated as the root mean square error (RMSE or $\sqrt{MSE}$) divided by the mean of actual income.

Evaluation of the risk in anticipated revenues in the single-period model of crops in isolation involve the examination of the components of revenue; price, yield and grade. The distribution of revenue, a product of price (p) and non-price (y) components(non-price is built up from yield and grade (Y·G)), is not the same as the random variables y and p themselves. Following an approach for determining variance of a product by Bohrnstedt and Goldberger (1969) under the assumption of normal distribution of revenues, the mean and variance may be computed as:

$E(R) = E(p)E(y) + Cov(p,y)$

[1]Kmenta, Jan. *Elements of Econometrics. 2nd ed.* 1971. MacMillan Publishing Company, New York.

$V(R) = V(p)V(y) + E^2(p)V(y) + E^2(y)V(p) + \rho[\rho V(p)V(y) + 2E(p)E(y)\sigma_p\sigma_y]$.

where: $E(R)$ = expected revenue; $V(R)$ = variance in revenue; $Cov(p,y)$ = covariance between p and y; and ρ = the coefficient of correlation between p and y.

The variance expression illustrates the importance of the correlation coefficient and its impact on variability. It may also serve as a measure of interdependence between the components. Interdependence increases as the absolute value of ρ approaches 1. The partial differentials of the variance of this joint product illustrate the incremental effect of price and non-price components on total revenue variability. Such analysis is helpful in examining the effects of insurance on risk reduction. Insurance can take the form of a yield or crop insurance, or a price insurance such as hedging.

To reiterate, risk, calculated from the mean square error of anticipated revenue, enters the single-period model through the sensitivity of the discount rate to revenue variability. Financial markets manifest an aversion to risk which is reflected in less favorable pricing of risky investments. Lower present values thus result in higher discount rates, where $r = (C_t/C_{t-1}) - 1$ is the exchange ratio between present and future cash flows. The general functional relationship between risk and discount rate may be denoted as $r = r_{i(MSE)}$. The net present value of single-period revenue may be described as $C_i(1 + r_{i(MSEi)})^{-1}$.

D. Multi-Crop Single-Period Model With Uncertainty

Diversification through multi-crop choices may be used to reduce risk. Reduction of risk is accomplished by combining investments which are less than perfectly correlated. Reduction in the multi-crop expected revenue does not necessary result from the risk reduction.

The mean square error around the expected revenue per unit of land at time 1 for three crop possibilities may be calculated as follows:

$$MSE = a_1^2MSE_1 + a_2^2MSE_2 + a_3^2MSE_3 + 2a_1a_2Cov_{12} + 2a_1a_3Cov_{13} + 2a_2a_3Cov_{23}$$

where:

a_i = proportion of expected receipts from the i^{th} crop, so that $\sum_{i=1}^{n} a_i = 1$. Note that the formulation may include the single crop situation where $a_1=1$, $a_2=0$, and $a_3=0$.

Cov_{ij}=covariance between revenue error terms; $\rho_{ij}\epsilon_i\epsilon_j$, and ϵ_i is the sample error in revenue of crop i.

Covariance and correlation matrices between revenue error series are of interest. Examination of such matrices lend to knowledge of how combinations of crops may reduce risk. Confidence intervals constructed around the correlation coefficients provide insight for such analysis.

E. Multi-Asset Single-Period Model With Uncertainty

Although this thesis will deal primarily with identification of error in expected crop revenues, a theoretical understanding of diversification of crop investment with other investments is important to the concepts of portfolio theory. It is conceivable that investments from different and unrelated industries may appear attractive to the farm decision-maker, especially if their returns have low are correlation with that of crop revenues. The previous section introduced the concepts of portfolio theory and demonstrated how Markowitz diversification was beneficial in investment choices. Provided efficient portfolios based on the dominance principle can be selected, efficient frontiers can be constructed in the expected return/risk space. Such analysis should include all cost information to establish rates of returns.

$$MSE_p = C_i^2 MSE_i + C_m^2 MSE_m + 2C_iC_m Cov_{im}$$

$$\partial MSE_p / \partial C_i = 2C_i MSE_i + 2\, C_m Cov_{im}$$

This indicates that the risk effect of adding to the farm asset is conditional upon its relationship with the non-farm asset. One can also observe that where the crop asset is small relative to the other asset ($C_i \rightarrow 0$), the importance of the covariance term is overwhelming.

From standard statistical usage, $Cov_{im} = RMSE_i\, RMSE_m\, Cov_{im}$, one can observe that where the crop investment is a small part of a large investment portfolio, the crops MSE (or RMSE) is only of importance when weighted by the crop's correlation with the other assets.

The variability added to the multi-asset portfolio by the incremental crop investment is the economically relevant variability in the crop choice decision. The equation is applicable to the crop-investment-only situation where C_f, $C_m=0$, $\Delta MSE_p = MSE_i$. This theoretical relationship is important in evaluating the economic significance of adding incremental crop investments to the total portfolio containing non-farm investments, however, it will not be addressed in this thesis.

Mathematical Portfolio Analysis

If cost data were available, mathematical portfolio analysis could be used to develop E,V frontiers. The following mathematical demonstration is purely illustrative. Mathematically, the problem may be approached as one of risk minimization given the constraints of income and resource use. A Lagrangian objective function (z) for risk minimization may be represented as:

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \sigma_{ij} + \lambda_1 \left(\sum_{i=1}^{n} w_i E_i - E^* \right) + \lambda_2 \left(\sum_{i=1}^{n} E w_i - 1 \right)$$

where: w_i = weight of each crop

E = expected income

λ_1 = income constraint

λ_2 = resource constraint

The first order conditions will be:

$$\partial Z/\partial w1 = 2w_1\sigma_{11} + 2w_2\sigma_{12} + 2w_3\sigma_{13} + \lambda_1 E_1 + \lambda_2 = 0$$

$$\partial Z/\partial w2 = 2w_1\sigma_{21} + 2w_2\sigma_{22} + 2w_3\sigma_{23} + \lambda_1 E_2 + \lambda_2 = 0$$

$$\partial Z/\partial w3 = 2w_1\sigma_{31} + 2w_2\sigma_{32} + 2w_3\sigma_{33} + \lambda_1 E_3 + \lambda_2 = 0$$

$$\partial Z/\partial \lambda_2 = w_1 + w_2 + w_3 \; 1 = 0$$

$$\partial Z/\partial \lambda_1 = w_1 E_1 + w_2 E_2 + w_3 E_3 - E^* = 0$$

The efficient frontier may be generated by inverting the matrix C representation and altering E^*. Note this analysis assumes full knowledge of costs, but has been included to illustrate the technical approach . Such a demonstration appears in the appendix.

III. DETERMINANTS OF VARIABILITY

This chapter specifies the historical data used in revenue variability calculations and the approach used to model the decision-making process. The first section of describes the mean square error approach to dispersion measurement. Then the components of revenue are examined separately. Finally, the modification required for insurance is presented.

A. Deviations From Prediction

Variability in this study is determined by the mean square error of revenue, determined from the difference between actual and expected revenue. Sampling error or standard error of the estimate is simply the difference between the value of the estimator (expected revenue) and the actual revenue to be estimated. Recall that

Error $= \hat{\gamma} - \gamma$, and

Mean Square Error $=$ MSE $= E[\hat{\gamma} - \gamma]^2$

The parameter that is to be estimated is expected revenue. In determining the variability associated with expected revenue, consider the actual revenue at time 1, C_{i1} and the predicted revenue, $\hat{C}_{i1}$. Estimation error is $C_{i1} - \hat{C}_{i1}$. Subsequent subscripts used in this thesis shall refer to the following:

1. 'j' denotes elevator point or district,
2. 'i' denotes crop, and
3. 't' denotes year or time.

MSE adjusted for sample size is estimated as:

$M.S.E. = \sum_{j=1}^{n} (C_{ij} - \hat{C}_{ij})^2 / n-1$, where i denotes the crop at elevator point and n is the sample size.

A desirable property of a statistic is accuracy or consistency. A consistent estimator is one which converges stochastically to the true value. Consistency in probability may be measured by the MSE. The mean square error (MSE) measures dispersion of the distribution about a true parameter, in this case anticipated revenue. This term is composed of two portions, variance and a squared bias, which results from the squaring of the standard error

(RMSE).[2]

Lack of bias is a desirable attribute in estimation, and leads to accuracy. Bias refers to the degree to which the mean of estimated values of a parameter diverges from the mean of actual values. If the estimating procedure is unbiased, these means will converge with large numbers of estimations. If comparing two unbiased estimators, the one that has the smaller mean square error is more efficient. The minimum MSE is of use when something is known of the relation between the parameters of the distribution from which the sampling is done.

If estimates are consistent but biased, removal of bias is performed by evaluating the expected value of the predicted value and applying a correction to obtain an unbiased estimate. Removal of bias would therefore involve the incorporation of some multiple that adjusts the sample mean to estimate population means with minimum MSE. Incorporating these factors minimizes error associated with the predicted revenue estimate, ie. $E(a\bar{x}) = a\mu$

$Var(a\bar{x}) = a^2\sigma^2/n$

where: a is an adjustment multiple, σ^2 is the population variance and n is the sample size. As n approaches infinity, 'a' approaches 1.

Some variables in crop production are under farmer control, such as fertilizer, seed quantity, crop variety, herbicides and insecticides. More information about controlled variables could provide closer estimates, but would not necessarily decrease bias. To accommodate for influences from exogenous information and bias adjustment, the underlying components of crop revenue (yield, price and grade factor) will be considered separately. Consistent estimators which are both unbiased and have minimum variance may be determined simultaneously.

[2]$MSE = Var + (bias)^2$

Proof: if $\mu = E(\hat{\theta})$.

$$E(\hat{\theta}-\theta)^2 = E[(\hat{\theta}-\mu)+(\mu-\theta)]^2$$
$$= E(\hat{\theta}-\mu)^2 + 2(\mu-\theta)E(\hat{\theta}-\mu) + (\mu-\theta)^2$$
$$= Var\hat{\theta} + (\mu-\theta)^2$$

Yield

Equations in the form of production functions have been developed for yield prediction purposes. Common variables considered in yield estimation include weather, herbicides, other technology, nitrogen level and soil type. Several Western Canadian studies have developed detailed fertilizer response equations which are crop specific and account for soil moisture and growing season precipitation. Heapy et.al. (1976) developed equations relating yield of barley to nitrogen and phosphorus fertilizer and to soil nitrogen and extractable phosphorus for central Alberta. Robertson (1974) determined the response of wheat to weather patterns at Swift Current, Saskatchewan. Bole and Pittman (1980) developed equations of yield response of Galt barley on Dark Brown soil to spring soil water, precipitation and nitrogen fertilizer. The effect of crop rotation and fertilization on spring wheat yield and moisture use in Southwestern Saskatchewan was examined by Campbell, Zentner and Johnson (1988) using data from 1967 to 1984. The 18 year average grain yields were greatest for wheat grown on summerfallow that received phosphorus or nitrogen and phosphorus. The lowest yields and greatest variability were reported for continuous wheat receiving no nitrogen. Variability was attributed to growing season precipitation and average spring soil moisture.

Yield responds both to decision variables such as fertilizer, crop variety and herbicide, and to predetermined variables such as soil fertility and moisture. Uncontrolled variables such as weather interact with the decision variables. Since yield depends in part on variables which are known or controllable, estimation errors will be reduced if effects on yield from these known input:output relations can be isolated.

For this study, sufficient input data were only available for nitrogen fertilizer; an adequately defined functional relationship to work with nitrogen fertilizer was provided by Alberta Agriculture. [3] The aggregate nitrogen data are only a primitive proxy for adjustment on nitrogen by elevator point, however its relationship to yield does reduce error in yield

[3]Equations were developed by Len Kryzanowski, Alberta Soil and Animal Nutrition Laboratory, O.S.Longman Bldg. Edmonton. Coefficients are based on provincial soil test area for spring wheat, malt barley and canola.

prediction, and it allows development of a model which is adaptable to input data. The equations were of the following general form:

$$y=\beta_1 N_s/(\beta_0+\beta_2 N_s - \beta_3 N_s W + \beta_4 N_s W^2)$$

where: N_s = nitrogen supply = soil nitrogen + fertilizer

W = moisture = growing season precipitation + soil moisture

The following equations were used to estimate yield associated with to fertilizer application;[1].

1. Barley bu./acre= $\frac{1000Ns}{9.31 + .382N_s - .0014N_s W + .0000024N_s W^2}$
2. Wheat bu./acre= $\frac{1000Ns}{14.88 + .442N_s - .0014N_s W + .0000025N_s W^2}$
3. Canola bu./acre= $\frac{1000Ns}{25.63 + 1.76N_s - .0083N_s W + .0000122N_s W^2}$

The moisture value used in the above equations was set at the mean provincial historic value of 368.46 mm, based on mean soil moisture of 36 mm and mean precipitation. Substituting the constant 'w' into the equations results in yield equations as a function of nitrogen supply:

1. Barley yield= $\frac{1000Ns}{9.31 + .382N_s - .516N_s + .3258N_s}$
2. Wheat yield= $\frac{1000Ns}{14.88 + .442N_s - .516N_s + .3394N_s}$
3. Canola yield= $\frac{1000Ns}{25.63 + 1.76N_s - 3.058N_s + 1.656N_s}$

[1]Equations vary with soil type and crop variety. Medium-fine soil texture and medium spring soil moisture was used. Phosphorus and potassium levels are assumed adequate. Most efficient form of application has been used. Growing season precipitation was obtained from *Probability of Precipitation in Alberta,* Alberta Agriculture, Conservation and Development Branch. Mean soil nitrogen levels were used over a 23 year period.

During the period under study, nitrogen fertilizer was presumed to be used at most country elevator points. Under usual economic assumptions, nitrogen use would vary over time in response to grain price and nitrogen price. Since these prices are likely to be approximately homogeneous across all elevator points, they would exercise a homogenous influence on fertilizer decisions across these elevator points. Using this heroic rationale, which was necessary because only province-wide data on fertilizer use was available, the assumption was made that fertilizer use varied homogenously across elevator points over time. The application rate of nitrogen was based on provincial data for nitrogen use obtained from the Alberta Statistics yearbook[5]. Observed yield is treated as a function of nitrogen and yield unexplained by exogenous influences. Estimates of yield increases from fertilizer use were then based on differences in expected yield from the historic means due to fertilizer application. These changes were added to the mean of the area or elevator point with the following procedure:

1. Calculate yield, y_{fi}, each year, based on the given production functions and each year's fertilizer use.
2. Calculate annual yield variation, $\Delta\hat{y}_i$, due to fertilizer use by subtraction from mean calculated yield;

   $\Delta\hat{y}_i = y_{fi} - \bar{y}_{fi}$, where y_{fi} = predicted yield based on fertilizer application and $\bar{y}_{fi}$ = mean estimated yield from fertilizer application.
3. At each elevator point, form a total yield estimate, $\hat{y}_i$ for each year from historic mean yield plus the province-wide annual yield increment attributable to fertilizer;

   $\hat{y} = \bar{y}_i + \Delta\hat{y}_i$.

Predicted yield ($\hat{y}$) is therefore equal to the mean elevator point yield for each crop plus a province-wide annual adjustment of yield based on changes attributed to fertilizer use.

[5]Reported fertilizer sales in tonnes divided by intended seeded acreage obtained from Agriculture Statistics Yearbook, Agdex 853-10.

Aggregation

Several studies have demonstrated that aggregated data, unless perfectly correlated between farms, are less variable than individual farm data (Carter and Dean, 1960; Eisgruber and Schuman, 1963; and Siegfried and Hall, 1987). This aggregation problem is particularily characteristic of yields. Farm-level data are scarce, and prairie-wide or province-wide data results in an 'averaging-out' of local crop yield disturbances. Yield variability increases with disaggregation, seemingly due to independent local weather effects. For this study, yield estimates for wheat, barley and canola were obtained from Alberta Wheat Pool(AWP) crop reports as estimated by elevator managers. The AWP data are aggregated across farms within the elevator point area, but this level of aggregation may be representative of conditions that a large scale farmer may experience. If data had been obtained at the quarter-section level, reaggregation might be required to reflect variability of larger farmers whose farming system include considerable spatial diversification.

Yield Data

In any one year of the 13 year period, the greatest number of reporting elevator points for wheat and barley was 293, therefore there were 3809 possible data points for each crop. Approximately 9% non-response occurred in the wheat reporting and 9.5% in barley. In canola, the greatest amount of reporting elevator points were 262. Of a possible 3406 data set, 8.9% non-response resulted. A portion of the non-response may be attributed to shut-down of elevator points, however a proportion results from non-reporting on the part of the managers.

Variability in yield may be attributed to two sources; physical agronomic relationships and statistical relationships. This study will concentrate on the statistical characteristics of the data and use them to measure risk. Agronomic factors such as disease control resulting from crop rotation may have an impact on variability; however data do not allow for this type of analysis.

Error in yield estimate is determined as $(Y_{i1}-\hat{Y}_{i1})$ where $\hat{Y}_i$ is the predicted yield estimate. This yield estimate is unbiased because of the use of province-wide deviation from mean yield attributed to fertilizer differences, where $\hat{y}=\bar{y}_i+\Delta\hat{y}_i$ and $\Sigma\hat{y}=\sum_{j=1}^{n}\bar{y}_{ji}$ since $\sum_{j=1}^{n}\Delta\hat{y}_{ji}=0$. Variability in yield is estimated as $\sum_{j=1}^{n}(Y_{ji}-\hat{Y}_{ji})^2/n$.

Price

In an efficient market, the best available predictor of price for a crop is the price for future delivery at the time the cropping decision is being made. An efficient market is one in which prices reflect available information and provide accurate signals for resource allocation.[6]

Variability in expected prices is represented by the difference between realized prices of the crop and prices predicted by futures prices, $MSE_p=\Sigma(P_{i.5}-\hat{P}_{i1})^2/n$. In this MSE estimate for prices, $\hat{P}_{i1}$ represents the predicted price for one period in advance, made at the time of the cropping decision; ie: a March price of a contract for delivery next spring. To make a production decision in April, the producer must form some notion of expected price. $P_{i.5}$ is the actual price for the product that may be locked in at one half year from the decision. The subscripts on price designate the crop i and the time value (.5 or 1). In the case of a spring contract, once the quantity is known with certainty in the fall, a guaranteed price may be locked in via the futures market. The crucial variance remaining is that which surround the accuracy of forecast, the MSE of the forecast.

Predicted prices are based on the best available forecast of price. Wheat is usually marketed through the Canadian Wheat Board (CWB). A price prediction based on this market channel will be the initial price announcement. Adjustment for historical bias is possible with a factor of (Σrealized price/Σinitial price), making the predictor unbiased. Predicted price $\hat{p}$ is set at initial price announcements times (Σrealized price/Σinitial price). It is plausible that political distortions of the market signals may be introduced in the price announcements, therefore an alternative marketing channel was also tested. The alternative source of price

[6]In accordance with Fama, Eugene. *Efficient Capital Markets: A Review of Theory and Empirical Work.* Journal of Finance, 1970.

information lies in the exchange adjusted Chicago Board of Trade [7] which provides prices for milling grades of wheat. The March price of a December contract served as the predicted price.

Similarily, predicted prices for barley were based on two different marketing channels. The initial Canadian Wheat Board price announcement adjusted for historical bias was used as one source. The alternative price source of information on barley prices was the Winnipeg futures market [8]. As with wheat, December barley contracts priced in March provided the price prediction. The March Winnipeg futures price for a January contract deliverable at Vancouver was used for canola.

Rather than address the issue of whether CWB initial prices or futures market prices are superior estimators of realizable prices a half-year in the future, price estimates based on both methods will be presented in subsequent material.

Futures and the cash price would be expected to differ in delivery month by the physical costs of the delivery (transportation costs, storage costs, and quality adjustments). This price difference is the *basis*[9]. Basis is considered to be more stable than the price level itself and therefore predictable. For the purposes of this study, basis has been implicitly treated as an input cost and therefore not variable.

Actual prices for board marketings of wheat and barley were determined as the realized prices, the sum of all payments regardless of timing. In the alternative futures markets, the November price of December contracts served as the actual price. The actual price for canola was set at the November price of the January contract.

The following table summarizes the price series used in determining the error of prediction for the price component of revenue.

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[7] Prices were obtained from the *Chicago Board of Trade(CBT) Statistical Annual, Grains--Options on Agriculture Futures* 74/75-86/87.

[8] Prices were obtained from *The Winnipeg commodity Exchange(WCE) Statistical Annuals*

[9] Basis is defined as the difference between the futures and spot price in the delivery period.

Table 3.1: PRICE SERIES AND SOURCES

Crop	Predicted Price	Actual Price
Wheat	CWB adj. initial	CWB realized
Wheat (alt.)*	CBT Dec. in Mar.	CBT Dec. in Nov.
Barley	CWB adj. initial	CWB realized
Barley(alt.)	WCE Dec. in Mar.	WCE Dec. in Nov.
Canola	WCE Jan. in Mar.	WCE Jan. in Nov.

(alt.)* = alternative market channel

Grade

Quality adjustment is accomplished through a grade factor. This factor accounts for grade loss due to such causes as excess heat, frost and fall weather conditions during harvest. The factor is both quantity and price related. Calculation is determined by:

$$g_{ji} = \sum_{j=1}^{n} W_{jig} (P_{ig} / P_i)$$

where: W_{jig} is the proportion of crop i at each grade in each census division as reported by the Alberta Wheat Pool.[10] The proportion of crop by grade is then multiplied by a price factor which adjusts a discount associated with lower grades. P_{ig}/P_i values are available from relationships between annual CWB payouts on wheat and barley[11]. For canola, the grade discount factors used were obtained from Alberta Hail and Crop Insurance Corporation (AHCIC) records[12].

Predictions on grade are based on experience within the census division, therefore the historic mean grade factor was used as the grade factor estimate;

$M.S.E._g = \sum_{j=1}^{n} (g_{ji} - \bar{g}_{ji})^2/n$. Bias was not evident in the error term, therefore no adjustment

[10] Alberta Wheat Pool, *Series C Crop Report Estimate of Quality by District.* 1974-1986.

[11] All grades relative to total payments from Wheat Board Payments for #1 CWRS wheat and No.1 Feed barley as reported in *Alberta Agricultural Statistics Yearbook*, Agdex 853-10 and *Canadian Grains Industry Statistical Handbook*, Canadian Grains Council.

[12] Yearly rapeseed grade factors from AHCIC based on #1 Canada rapeseed.

was required.

Revenue

Historical data were used to approximate revenue possibilities in an ex ante distribution. Error in revenue estimation may be determined as $C_{it} - \hat{C}_{it}$, where $C_{it} = y_{it} p_{it} g_{it}$ and $\hat{C}_{it} = \hat{y}_{it} \hat{p}_{it} g_{it}$. The MSE of the revenue forecasts provides the measure of revenue risk. Variability in each of the components was determined separately. Prediction of each of the components involved some bias adjustment.

B. Insurance Modification

Natural uncertainties in weather, including frost, hail, flood and drought, cause yearly fluctuations in crop yields. Farmers, in an attempt to contain the impact of such fluctuations may use crop insurance. Government crop insurance offers farmers compensation for shortfall from an insured yield and allows farmers to engage in an activity that they may not otherwise engage in. Payment for the shortfall is based on a preset price. Yield has been grade-corrected (though this policy will change for the 1988/89 crop year). The amount of insured yield is determined from historical yield in the locality, or, at the option of the insured, from historical yield on the individual farm. This insured level represents a percentage of annual yield average over an historical time period.

In Alberta, crop insurance is heavily subsidized. The actuarial premium is the fee per acre which is needed to sustain the insurance program. It is equal to expected average annual loss. One half of the total actuarial premium is subsidized by government, as well as all the administrative costs. Alberta crop insurance operates within a non-profit context. Insurance coverage is offered at either 60% or 70% of historical yield averages for all soil classes and at two price options. For the purpose of this study, a coverage level of 60% of a grade-adjusted elevator point yield average was selected. Such a procedure for determining the amount of payout is consistent with current AHCIC program practices to encourage individual coverage. This type of coverage is determined by the farmer's past yield averages. The top price option

Table 3.2: DATA SOURCE LIST[13]

Crop	Yield	Grade Dist'n	Price	Grade Discount
ACTUAL REVENUE:				
Wheat	AWP by elev. pt.	AWP by C.D.	CWB realized	CWB
Wheat (alt.)	AWP by elev. pt.	AWP by C.D.	CBT Dec.inNov.	CWB
Barley	AWP by elev. pt.	AWP by C.D.	CWB realized	CWB
Barley(alt.)	AWP by elev. pt.	AWP by C.D.	WCE Dec.inNov.	CWB
Canola	AWP by elev. pt.	AWP by C.D.	WCE Jan.inNov.	AHCIC
PRED. REVENUE:				
Wheat	Soil lab equation	mean AWP	CWB initial	CWB by C.D.
Wheat (alt.)	Soil lab equation	mean AWP	CBT Dec.in Mar.	mean CWB
Barley	Soil lab equation	mean AWP	CWB intial	mean CWB
Barley (alt.)	Soil lab equation	mean AWP	WCE Dec.inMar.	mean CWB
Canola	Soil lab equation	mean AWP	WCE Jan.inMar.	mean AHCIC

[13] Futures prices are based on futures contracts for wheat, [illegible]ley and canola deliverable at Chicago, Winnipeg and Vancouver, respectively. Delivera[illegible]des for Barley are No.1 Feed or No.2Feed at discount, for Wheat are No.[illegible] Winter, No.2 Hard Red Winter, No.2 Dark Spring, No.1 Northern [illegible] for canola are [illegible] Canad[illegible] No.2 Canada at discount.

available is approximately expected market price, so for this analysis the price option is set a $\hat{p}$, the beginning-of-year expected price used in determining expected crop receipts.

The application of 60% insurance on an individual farm basis results in modification of actual crop revenue to:

if $y_{it}g_{it} < .6\bar{y}$,

$C^*_{it} = (.6(\bar{y}_i) - y_{it}g_{it})\ \hat{p}_{it} + y_{it}p_{it}g_{it}$.

if $y_{it}g_{it} \geq .6\bar{y}$,

$C^*_{it} = C_{it}$.

Predicted revenues are also modified by crop insurance. Privately offered insurance contracts must set premiums to cover expected losses. Since government crop insurance is heavily subsidized, expectations of revenues should be increased as a result of taking insurance. Given that the government pays approximately half the expected payouts, the expectation of increased revenues was set at twice the farmer premium. Provincial yearly premiums were obtained from AHCIC. By this rationale expected revenues would be modified to:

$\hat{C}^*_{it} = \hat{C}_{it} + 2(prem_{it})$.

Although generally expected payouts plus administration costs should equal premium, bias may be introduced from the above procedure. This results because crop shortfalls on individual farms are the basis for premium setting, but this study is based on data aggregated at country elevator point. Therefore calculated payouts in this study, analogous to those on farms with considerable spatial diversification, would be less than the payouts on which actual premiums are based. A farmer may rationally base an adjustment of expected income on local historical payout experience. An adjustment factor will consist of (Σactual regional insured revenue/Σactual regional uninsured revenue), which adjusts revenue expectations in accordance with regional historical payouts. Local adjustment compensates for areas with historically higher payout experience. The new expected revenue will be:

$\hat{C}^{**}_{it} = \hat{C}_{it}$ (Σinsured regional C^*_i/Σuninsured regional C_i).

The revenue variability as a result of these modifications will in turn be compared to revenue variability without insurance to determine the risk reduction effect of insurance. The impact on smaller farms without geographical diversity would be greater than at the country elevator point.

IV. RESULTS

In this chapter the first section presents the results of how well the yield and price data conform to normality. The aggregate form of the yield data is also compared to other data sources (national and provincial).

In the second section of this chapter, the approach to risk analysis depicts the decision problem in terms of moments. Results of the analysis of the single period decision model are portrayed for each crop in isolation.

The third section examines the components of revenue variation and their interaction. Effects of insurance on price and yield error can be determined from the relationship. Tests for the presence of serial correlation in the components of revenue error were conducted to determine existance of bias in the forecasts.

Diversification effects resulting from crop combinations are examined in the final sections. Comparisons of diversification effects between uninsured, crop insured, price insured, and price and crop insured revenues are based on minimum relative variability.

A. Examination of Data

Tests for Normality

The understanding of stochastic properties of crop yields is important in risk analysis. Such an approach is usually based on the assumption of normal distributions. This theoretical distribution is popular due to its familiarity and extensive empirical support. Justification for the wide use is based on the Central Limit Theorem. In accordance with this theorem, if x has any distribution with mean μ and variance σ^2, the distribution of $(\bar{x}-\mu)/\sigma_{\bar{x}}$ approaches the standard normal distribution as the sample size increases. Therefore, the distribution of $\bar{x}$ in large samples is approximately normal with mean μ and variance σ^2/n.

Distributions are characterized by their moments. In normal distributions, the relevant moments are those describing symmetry (μ_3) and peakedness (μ_4). Symmetry or skewness and kurtosis or peakedness may be measured as follows:

$\sqrt{\beta_1}=\mu_3/\mu_2^{3/2}$ and $\beta_2=\mu_4/\mu_2^2$

Normal distributions have $\beta_1 = 0$ and $\beta_2 = 3$. Another statistic which has been often used to test for normality, and has a chi-square distribution (X^2) with two degrees of freedom is:

$$\eta^*[\beta_1/6 + (\beta_2 - 3)/24]^2 = X^2_2$$

Table 4.1: TESTS FOR NORMALITY IN AGGREGATE YIELD DATA

CROP	β_1	β_2	X^2_2
Wheat	.9793	1.632	.0641**
Barley	[illegible]	3.201	.1588*
Canola	.56[illegible]	2.957	.1212*

In Table 4.1, tests for normality in the aggregate data provide X^2_2 distributions which suggest that the distributions approach normality. Wheat is normally distributed at the 95 % confidence level, whereas barley and canola approach normality at the 90% confidence level. Slight positive skewness is evident in these yield data, however not significant enough to warrant a characterization by a different distribution. The histograms in Appendix A also demonstrate how nearly the yield distributions approach normality. If the parent distribution is symmetric or is close to being symmetric, the normal approximation will work well even for relatively small sample sizes.

To determine whether the characteristics of normality persist at the micro-level, one elevator point was selected per census division and tested for normality in yield distribution over time. The following table reports the X^2_2 statistics, ** indicates significance at the 5 % level and * at the 10% level.

Table 4.2: CHI-SQUARED STATISTICS FOR NORMALITY TESTS OF YIELD DATA BY REGION

REGION	Wheat	Barley	Canola
1	.1833**	.1155*	.0386**
2	.0265**	.0113**	.0148**
3	.00001**	.0113**	.017**
4	.0555**	.0221**	.0134**
5	.0819**	.0141**	.0814**
6	.0423**	.1364*	.0701**
7	.0258**	.1758*	.0388**
8	7.282	.5300	.0218**
10	.0059**	.0434**	.011**
11	.9263	.0032**	.6213
12	.60611	.0344**	.0841**
13	.1904*	.003**	.0268**
15	.1175*	.680	.0383**

Most elevator points illustrated a normal distribution. In the wheat yield, elevator points in Regions 8 and 11 demonstrated a positive skewness, and the elevator point in Region 12 was leptokurtic. Leptokurtic refers to distributions which are more sharply peaked than normal distributions. Elevator points in Regions 8 and 15 also showed positive skewness in barley. Only the elevator point in Region 11 did not prove to have a normal distribution for Canola yields. Both positive skewness and leptokurtic properties were evident. Although these results are based on a small sample, the trend toward normality is evident.

Table 4.3: TESTS FOR NORMALITY IN AGGREGATE PRICE DATA

CROP	β_1	β_2	X^2_3
Wheat	.000058	.0028	.2038*
Barley	.00023	.7134	.2029*
Canola	.000216	.00451	.2026*
CWB WHEAT	.00071	0	.2032*
CWB BARLEY	.000989	.00603	.2028*

Table 4.3 reports the *Beta* coefficients and chi-squared statistic for aggregate price data. β_1 does approach zero, however β_2 is not near 3. The chi-square statistic suggests that the price series may be characterized as normally distributed at the 90 % confidence interval. These price series did demonstrate some platykurtic or flatter curved characteristics however the distributions are symmetric.

Comparison With Estimates From Other Sources

To compare how well these data correspond to available aggregate form data such as that of reported by the Alberta Statistics Yearbooks, the Alberta Wheat Pool data were aggregated across elevator points. Such a comparison examines the reliability of the data. The following graph illustrates the similarities between the two data sources.

Figure 4.1: Comparison of Alberta Statistics and Alberta Wheat Pool Yield Data

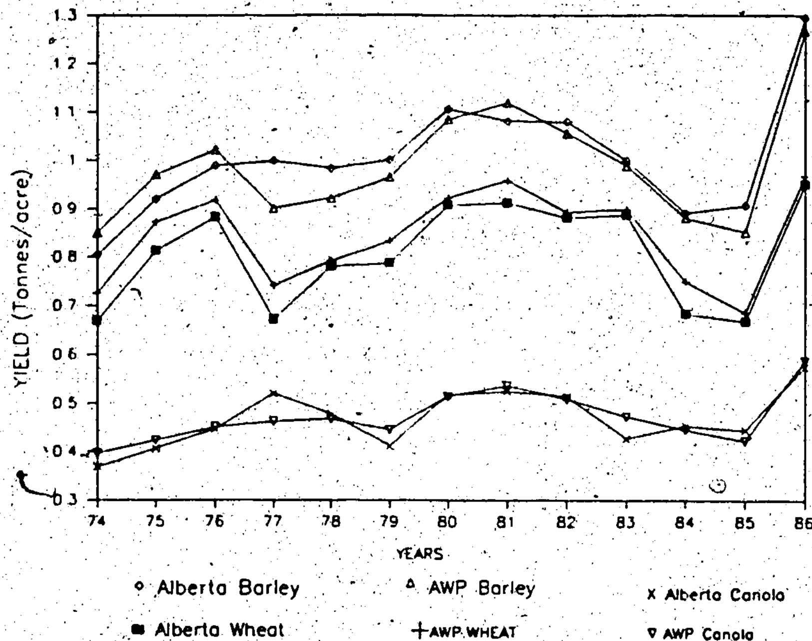


Figure 4.1 illustrates how well the two data sources track one another. As expected, barley has higher yields, followed by wheat and canola. Over the time period, similar turning points were identified with the exception of 1977 for barley and canola. The AWP estimates were slightly lower than those of Alberta Statistics.

Table 4.4: TESTS FOR HOMOGENEITY OF VARIANCE OF YIELD

	S^2	$\log S^2$	$(n-1)\log S^2$	Q/l#
Alta Wheat	10136	4.005	48.07	.1315
AWP wheat	8210.6	3.914	46.972	
Alta Brly	13585	4.133	49.597	.0021**
AWP Brly	13227	4.121	49.458	
Alta Can.	3178.1	3.502	42.026	.155
AWP Can.	2528.3	3.403	40.833	

S^2 = variance of yield

$Q = n\log \sum_{i=1}^{n} n_i/n\, \hat{s}_i^2 \sum_{i=1}^{n} s_i^2 - \sum_{i=1}^{n} n_i \log \hat{s}_i^2$ and $l = 1 + 1/3(p-1) \sum_{i=1}^{n} (i/n_i - 1/n)$

Q/l = Barttlett's test for homogeniety of variances. Q/l statistic is distributed as X^2.

The results show that the Alberta Statistics data contains more variability than the AWP data in all three crops, however barley variance was homogeneous at the 95 % confidence interval. Wheat and canola variances were homogeneous at the 73 and 71 per cent confidence interval, respectively. While AWP results manifest moderate differences from those of Alberta Statistics, there are two reasons to regard AWP data as superior:

1. AWP are based on a larger sample size.
2. Estimates in the AWP data are based on direct access to production quantity information. In some cases a farmer may deliver a field's crop and calculate actual yield at the elevator.

B. Variability of Crops in Isolation

Crop revenue is composed of price, quantity and grade factor components. The variability in revenue results from variability in each of the components. The yield component includes deviations from predicted yield estimates. Predicted yield ($\hat{y}$) is developed based on elevator point historical yield data plus an estimate of yield deviation attributed to yearly changes in nitrogen use. The measure for deviation from yield predictions may be represented as $\sqrt{\sum_{j=1}^{n} (y_{ji}-\hat{y}_{ji})^2/n}$. This measure is the RMSE, or alternatively, the standard error of the yield estimate.

Similarly, deviations from price prediction are used to determine the standard error associated in the price expectation process. Predicted prices are set at prices for future delivery which are futures contract prices or initial prices for board marketings. Actual prices are determined from the futures price of the same contract once quantity is known, or the realized price for board marketings. RMSE in prices is $\sqrt{\sum_{j=1}^{n} (p_{ji}-\hat{p}_{ji})^2/n}$. Grade variability results from deviations from mean grade factor calculations. The mean grade factor is developed from historical data on the portion of crop at each grade by census division multiplied by a discount associated with pricing: $g_{ji} = \sum_{j=1}^{n} w_{ji}(P_{ig}/\hat{P}_i)$.

$\text{R.M.S.E.}_g = \sqrt{\sum_{j=1}^{n} (g_{ji}-\bar{g}_{ji})^2/n}$.

Revenue is determined as price times grade factor times yield. RMSE associated with anticipated revenue estimates results from deviations from the expected revenue and can be calculated as $\sqrt{\sum_{j=1}^{n} (C_{ji} - C_{jf})^2 / n}$.

The analysis used in this study is based not just on historical deviation, but on the relevant variability of crop revenues from forecasts. Measurement of this variability is presented in terms of RMSE, or the standard error of the prediction. Tables 4.5 through 4.9 report the actual and expected revenues, as well as the MSE, the RMSE and the 95% confidence interval around the RMSE for each crop revenue series by region. The reported MSE and RMSE statistics are district-wide or province-wide means of MSEs or RMSEs calculated at individual country elevator points. The reported confidence intervals are the respective means of the individual elevator point confidence intervals.

Provincially, the lowest MSE and RMSE were calculated for CWB Barley revenue, $1223.2 and $34.975 per acre , respectively. The RMSE measurement of risk varied from a low of $20.65/acre in Region 12 to a high of $54.86/acre in Region 5. The provincial RMSE for Chicago wheat revenue was $35.40/acre, followed by $38.328/acre in Winnipeg barley revenue, $43.09/acre in CWB wheat revenue and finally $48.86/acre for canola.

Chicago futures prices on wheat were used as an alternative market channel to CWB initial prices. The futures prices were more accurate as predictive prices as is evident by the lower RMSE associated with Chicago revenue. On the other hand, CWB initial prices were better predictors in barley than Winnipeg futures market prices, again illustrated by the absolute risk measure.

The coefficient of relative deviation or variation (C.V.) is a relative measure of variation. This statistic enables comparison of risk in crop revenues between crops since it is independent of a unit of measurement. It expresses risk relative to gross sales and is calculated as the absolute measure of risk (RMSE) divided by the average actual crop revenue ($\bar{C}$), RMSE/$\bar{C}$.

Adjustment of C.V. calculations potentially enables direct comparison to security market data. Published security market variability is in the form of standard deviations. Standard deviations in security markets is equal to (RMSE of end-of-period cash flows)/(beginning-of-period investment cost). The C.V.s in this study are calculated as RMSE/revenue. Therefore, a conversion of C.V. to the equivalent of a security market standard deviation would, if cost data were available, be accomplished by

St.dev. =C.V.[mean expected crop receipts.c/mean expected crop costs].

The coefficients of variation suggest the ordering of variability is wheat revenue (.2955), CWB barley (.3064), canola (.3228), CWB wheat (.3319) and barley (.3379). Confidence levels around the C.V.s were constructed from the upper and lower bounds for RMSE significance levels. Winnipeg barley and CWB barley contained large confidence limits ranging from .3079 to .3683 on Winnipeg barley and .2757 to .3371 on CWB barley.

Regions 2, 3 and 15 show significantly higher risk in wheat revenue error estimates than that of the provincial average of .30. Regions 2 and 3 also reported the higher absolute risk levels while Region 5 reported lower income. Regions 4-10 and 12 reported significantly lower risk than average. Barley revenue risk was significantly higher in Regions 1 and 3. The C.V.s for canola revenue were significantly higher in Regions 1-6 and 15. RMSEs for canola revenue were significantly higher than the provincial average in Regions 1,2,3,5,6 and 8. Although Region 8 reported higher absolute risk, average actual income was high as well. Results using the CWB wheat revenue were more variable than that of Chicago wheat revenue calculations, with Regions 2,3,4 and 15 as the regions with highest variation. Regions 2 and 3 likewise reported high absolute risk. Regions 4 and 15 resulted in lower income, likely attributable to lower grade of yield. The CWB barley revenue however was less variable than that of the Winnipeg revenue calculations. The differences were not significant. Again, Regions 1, 3 and 5 indicated the greatest variation. Regions 3 and 5 had higher RMSE, and Region 1 reported lower actual income. Although generally, the southern regions demonstrated greater relative variability, it should be kept in mind that these regions may experience more spot growth. Consideration must also be given to the fact that no distinction between crops grown on stubble or fallow, or to cropping rotation have been incorporated in the analysis. Bar graphs of the relative variation for each crop follow. Differences are apparent by region and by crop.

Table 4.5: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN UNINSURED CHICAGO WHEAT REVENUE

Reg.	Unins. Inc.*	Exp. Inc.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	109.39	110.61	1045.0	32.326	34.858	29.795	0.2954	0.3186	0.2723
2	137.05	123.18	2302.6	47.986	51.172	44.799	0.3501	0.3733	0.3268
3	117.80	118.21	2276.6	47.714	53.319	42.109	0.4050	0.4526	0.3574
4	95.210	95.967	611.33	24.725	26.967	22.483	0.2596	0.2832	0.2361
5	121.51	120.60	1122.1	33.497	35.376	31.619	0.2756	0.2911	0.2602
6	127.61	128.81	1278.9	35.763	39.655	31.870	0.2802	0.3107	0.2497
7	115.81	117.13	1090.2	33.018	35.337	30.700	0.2851	0.3051	0.2650
8	132.47	132.57	1269.4	35.629	38.810	32.448	0.2689	0.2929	0.2449
10	116.70	117.77	909.92	30.165	31.837	28.492	0.2584	0.2727	0.2441
11	130.67	139.47	1459.2	38.200	41.410	34.989	0.2923	0.3169	0.2677
12	110.27	111.49	711.50	26.674	29.747	23.600	0.2418	0.2697	0.2140
13	124.20	125.44	1328.1	36.443	39.884	33.002	0.2934	0.3211	0.2657
15	108.69	110.50	1224.8	34.997	37.338	32.656	0.3219	0.3434	0.3004
Prov.	119.80	119.57	1253.3	35.403	36.165	34.640	0.2955	0.3018	0.2891

Unins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.6: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN UNINSURED CANADIAN WHEAT BOARD WHEAT REVENUE

Reg.	UNINS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	118.39	120.23	1503.4	38.774	35.307	42.241	0.3275	0.2982	0.3567
2	148.92	133.76	3379.6	58.134	54.463	61.805	0.3903	0.3657	0.4150
3	127.22	129.08	3588.2	59.902	53.260	66.543	0.4708	0.4186	0.5230
4	102.76	104.60	1238.6	35.195	32.330	38.059	0.3424	0.3146	0.3703
5	135.28	138.03	2049.4	45.270	42.837	47.703	0.3346	0.3166	0.3526
6	137.83	140.71	1900.0	43.589	40.216	46.963	0.3162	0.2917	0.3407
7	125.31	127.81	1668.4	40.846	38.263	43.430	0.3259	0.3053	0.3465
8	143.36	145.21	1914.5	43.755	40.034	47.476	0.3051	0.2792	0.3311
10	125.69	129.44	1193.4	34.547	32.778	36.316	0.2748	0.2607	0.2889
11	139.72	153.77	1916.3	43.776	40.195	47.356	0.3133	0.2876	0.3389
12	117.86	123.42	876.08	29.598	26.223	32.973	0.2511	0.2224	0.2797
13	132.71	138.22	1581.3	39.765	36.122	43.409	0.2996	0.2721	0.3270
15	117.60	121.27	1672.3	40.894	38.291	43.497	0.3477	0.3255	0.3698
Prov.	129.83	131.69	1857.0	43.093	42.202	43.984	0.3319	0.3250	0.3387

Unins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.7: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN UNINSURED WINNIPEG BARLEY REVENUE

Reg.	UNINS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	103.41	105.4	1625.4	40.317	43.701	36.932	0.3898	0.4226	0.3571
2	148.60	150.99	2265.5	47.597	51.917	43.278	0.3202	0.3493	0.2912
3	112.35	113.85	2692.6	51.890	56.978	46.803	0.4618	0.5071	0.4165
4	84.680	86.17	663.85	25.765	27.851	23.679	0.3042	0.3288	0.2796
5	120.82	129.29	1822.7	42.693	46.540	38.846	0.3533	0.3851	0.3215
6	120.99	123.61	1391.6	37.304	40.358	34.250	0.3083	0.3335	0.2830
7	109.83	111.3	1333.3	36.515	39.788	33.241	0.3324	0.3622	0.3026
8	124.91	126.48	1322.6	36.367	39.698	33.037	0.2911	0.3178	0.2644
10	106.20	107.83	1385.9	37.228	40.477	33.979	0.3505	0.3811	0.3199
11	114.05	117.72	1179.0	34.336	37.399	31.274	0.3010	0.3278	0.2741
12	102.83	105.3	878.12	29.633	32.209	27.057	0.2881	0.3131	0.2631
13	114.84	117.62	1275.3	35.712	38.796	32.627	0.3109	0.3378	0.2841
15	91.981	93.23	1092.8	33.058	35.822	30.293	0.3594	0.3894	0.3293
Prov.	113.41	116.15	1469.0	38.328	41.778	34.878	0.3379	0.3683	0.3075

Unins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.8: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN UNINSURED CANADIAN WHEAT BOARD BARLEY REVENUE

Reg.	UNINS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	104.69	105.40	1416.2	37.633	41.056	34.210	0.3594	0.3921	0.3267
2	150.70	150.99	1608.0	40.100	43.792	36.408	0.2660	0.2905	0.2415
3	113.56	113.84	2468.6	49.685	54.421	44.949	0.4375	0.4792	0.3958
4	84.749	86.173	594.73	24.387	26.500	22.273	0.2877	0.3126	0.2628
5	121.54	129.28	3009.8	54.862	60.585	49.139	0.4513	0.4984	0.4042
6	121.83	123.60	1146.6	33.861	37.041	30.682	0.2779	0.3040	0.2518
7	110.06	111.30	859.83	29.322	31.978	26.667	0.2664	0.2905	0.2422
8	125.97	126.47	744.94	27.293	29.937	24.650	0.2166	0.2376	0.1956
10	106.45	107.83	763.16	27.625	30.187	25.063	0.2594	0.2835	0.2354
11	114.92	117.71	582.71	24.139	26.348	21.930	0.2100	0.2292	0.1908
12	103.20	105.29	426.43	20.650	22.352	18.948	0.2000	0.2165	0.1836
13	115.71	117.62	564.23	23.753	25.875	21.631	0.2052	0.2236	0.1869
15	91.953	93.228	801.35	28.308	30.882	25.733	0.3078	0.3358	0.2798
Prov.	114.13	116.14	1223.2	34.975	38.480	31.469	0.3064	0.3371	0.2757

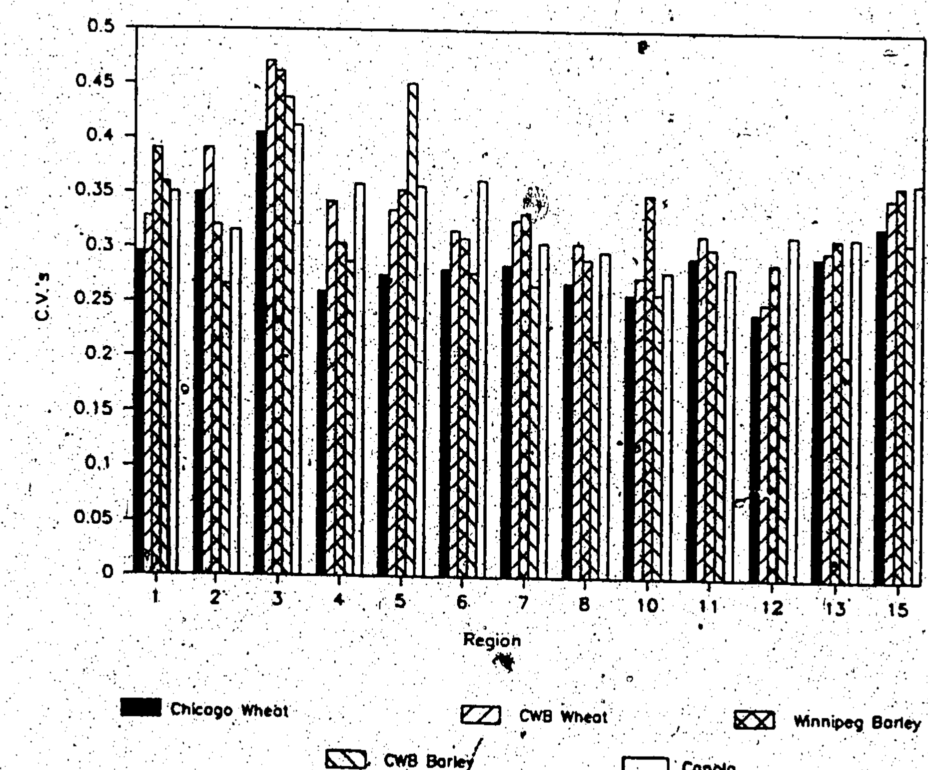
Unins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.9: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN UNINSURED CANOLA REVENUE

Reg.	UNINS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	CL* (2)	CV	CLcv** (1)	CLcv** (2)
1	150.73	108.71	2792.1	52.841	61.461	44.221	0.3505	0.4077	0.2933
2	179.84	166.42	3225.1	56.790	60.761	52.818	0.3157	0.3378	0.2936
3	143.36	134.9	3489.2	59.069	66.146	51.992	0.4120	0.4613	0.3626
4	116.72	99.23	1749.7	41.829	47.190	36.469	0.3583	0.4042	0.3124
5	149.90	134.56	2861.3	53.491	56.844	50.139	0.3568	0.3791	0.3344
6	155.80	145.31	3193.6	56.512	60.991	52.033	0.3627	0.3914	0.3339
7	159.26	149.75	2359.8	48.578	51.749	45.407	0.3050	0.3249	0.2851
8	182.16	170.17	2942.5	54.245	58.868	49.622	0.2977	0.3231	0.2724
10	157.17	149.37	1928.8	43.918	46.337	41.499	0.2794	0.2948	0.2640
11	147.84	143.44	1757.6	41.924	45.497	38.352	0.2835	0.3077	0.2594
12	128.98	124.13	1635.8	40.446	45.533	35.358	0.3135	0.3530	0.2741
13	142.45	126.59	1976.9	44.462	49.004	39.920	0.3121	0.3440	0.2802
15	113.84	108.72	1696.9	41.193	43.900	38.487	0.3618	0.3856	0.3380
Prov.	151.34	138.62	2387.2	48.859	49.965	47.753	0.3228	0.3301	0.3155

Unins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Figure 4.2: Coefficients of Variation by Crop and By Region



Diversification Effects of Revenue Components

The factors which determine the risk of a crop revenue are the price risk, yield risk, grade risk, the standard deviation or variance of these components and the correlation coefficient or covariance between them. Revenue may be represented as the jointly distributed random variables of price (p) and non-price(y) components with the expectations E(p) and E(y) respectively and variance V(p) and V(y) and covariance C(p,y). Following an approach proposed by Bohrnstedt and Goldberger (1969) for determining the variance of a product, the problem of exact variance may be defined as:

$V(py) = E[py-E(py)]^2$

if: $\epsilon_p = p-E(p)$ and $\epsilon_y = y-E(y)$

then, Revenue $= (\epsilon_p + E(p))(\epsilon_y + E(y))$

$= \epsilon_p\epsilon_y + \epsilon_p E(y) + \epsilon_y E(p) + E(p)E(y)$

$E(py) = E[\epsilon_p\epsilon_y] + E(p)E(y)$

$= Cov(p,y) + E(p)E(y)$

revenue-expected revenue $= \epsilon_p\epsilon_y + \epsilon_p E(y) + \epsilon_y E(p) - Cov(p,y)$

since $V(y) = E(\epsilon_y)^2$ and $V(p) = E(\epsilon_p)^2$

therefore: $V(py) = E^2(p)V(y) + E^2(y)V(p) + E[(\epsilon_p)^2(\epsilon_y)^2] + 2E(p)E[(\epsilon_p)(\epsilon_y)^2]$

$+ 2E(y)E[(\epsilon_p)^2(\epsilon_y)] + 2E(p)E(y)Cov(p,y) - Cov^2(p,y)$

If p and y are bivariate normally distributed then the third moments disappear and

$E[(\epsilon_p)^2(\epsilon_y)^2] = V(p)V(y) + 2Cov^2(p,y)$.

The variance equation thus reduces to:

$V(py) = E^2(p)V(y) + E^2(y)V(p) + 2E(p)E(y)Cov(p,y) + V(p)V(y) + Cov^2(p,y)$

$= E^2(p)V(y) + E^2(y)V(p) + V(p)V(y) + \rho[\rho V(p)V(y) + 2E(p)E(y)\epsilon_p\epsilon_y]$

The last portion of the equation shows the importance of the correlation coefficient between p and y. If p and y are stochastically independent then;

$V(py) = E^2(p)V(y) + E^2(y)V(p) + E[(\epsilon_p)^2(\epsilon_y)^2] + 2E(p)E[(\epsilon_p)(\epsilon_y)^2] + 2E(y)E[(\epsilon_p)^2(\epsilon_y)]$.

The correlation coefficient is the covariance standardized by dividing by the product of the standard deviations. It measures the strength of association. As in the case of covariances, two independent variables are uncorrelated but uncorrelated variables need not necessarily be independent. The correlation coefficient is independent of change of origin and scale. It is essentially a coefficient of linear interdependence. As $|\rho|$ increases, the interdependence increases until when $|\rho| = 1$. When linear correlation is small, ρ is near zero. If correlation were positive unity, diversification could do nothing to eliminate risk. Imperfect correlation implies that diversification may reduce risk. The sign of ρ and covariance are the same. The correlation coefficients and the covariances of the price, yield and grade risk components for each crop revenue appear in the appendix.

To establish whether the correlation coefficients are significantly different from zero or one, 95% confidence intervals were established around ρ. This procedure required the transformation:

$Z = .5\ln(1+\rho/1-\rho)$ which is approximately normally distributed.

Confidence limits for Z are set by the standard error Sz. $Sz = \sqrt{(1/n-3)}$.

The conversion of Z to ρ was set by the formula: $\rho = (e^{2Z}-1)/(e^{2Z}+1)$.

To test the null hypothesis that $\rho = 0$, a t-statistic with n-2 degrees of freedom was calculated as:

$t = \rho/\sqrt{(1-\rho^2)/n-2}$.

The following table presents the price/non-price correlation and covariance results on a provincial basis. Those correlations which were significantly different from 0 are indicated by a double asterisk. The numbers in brackets are the covariances of the two components. It may be noted that most non-price components are negatively correlated with price. The exception is that of canola where price and non-price components were uncorrelated and CWB wheat which showed a small positive covariance of .0324. Results by region appear in the appendix.

Table 4.10: PROVINCIAL CROP CORRELATION COEFFICIENTS AND COVARIANCES

	Wheat Pr.	CWBwh Pr.	Brly Pr.	CWBbrly Pr.	Canola Pr.
Wheat non-pr	-.1135**	.0627**			
	(-.0405)	(.0324)			
Brly non-pr			-.1054**	-.150**	
			(-.1023)	(-.1010)	
Can non-pr					.0347
					(.0106)

The change in total revenue variability resulting from a small change in price or non-price error may be calculated by taking the partial derivatives of the variance of the joint product:

$$\frac{\partial V(R)}{\partial \epsilon_y} = 4\epsilon_y V(p) + 2\epsilon_y E^2(p) + r[2r\epsilon_y V(p) + 2E(p)E(y)\epsilon_p]$$

$$\frac{\partial V(R)}{\partial \epsilon_p} = 4\epsilon_p V(y) + 2\epsilon_p E^2(y) + r[2r\epsilon_p V(y) + 2E(p)E(y)\epsilon_y]$$

Note that the correlation coefficients play a pertinent role in the partial differentiation. Likewise, consider the situation where either non-price or price error are eliminated:

if $\epsilon_y = 0$; $V(R) = E^2(y)V(p)$ and

if $\epsilon_p = 0$; $V(R) = E^2(p)V(y)$.

The degree of correlation between price and yield generally act as a natural hedge against revenue risk. Less than perfect correlation between price and yield lowers revenue risk. The lower the correlation coefficient the greater the reduction in risk. Yields and prices will likely not move together since higher yields may be positively related to yields in other areas which could lead to surpluses thus having a negative impact on price. When weakly positive or negative covariances between price and non-price components exist, strategies for price hedging and for crop insurance use are affected.

The regions with higher revenue risk associated with wheat were earlier determined to be Regions 2,3 and 15. Closer examination of the regions shows that in Region 3 and 15, the price/non-price correlations were not different from zero. The covariance in Region 2 was negative, but the significance was lower than average. Similarily, Region 3 price and non-price components were uncorrelated for barley revenue. The riskier regions in Canola all demonstrated strong positive correlations between the grade factor component and price, with little or no negative price-yield correlation. Risk in CWB wheat and CWB barley may again be attributed to positive correlations between price and grade factors. In the case of CWB barley, the negative yield-price correlations were strong.

Effects of Insurance on Risk Reduction

Crop Insurance

Insurance is a form of risk pooling. Individuals face different probabilities of loss and share a common pool of risks. Pooled benefits contribute to reduction in variability. Because of this variance reduction effect risk pooling has been suggested to increase resources devoted to risky cultivation. Insurance will be purchased if expected returns with insurance is greater than without. Several authors (Ashan, Ali and Kurian,1982; and Nelson and Loehman,1987) have suggested that insurance creates incentives for the insured to use less 'effort' than is socially optimal. Problems arise because the insurer cannot observe the actions of the insured. Arrow (1971) demonstrates the importance of the concept of moral hazard and suggests rate adjustments to eliminate it. Nelson and Loehman(1987) also suggest some "second-best" solutions which are lower cost than public subsidies.

Tests were conducted to determine if insurance significantly reduced risk on grain farms. Insured revenue error estimates were calculated as described in the previous chapter and new coefficients of variation were determined. Tables 4.11 through 4.15 present the new C.V.s and their confidence intervals.

Table 4.11: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN INSURED CHICAGO WHEAT REVENUE

Reg.	Ins Inc.*	Exp. Inc.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	110.78	112.02	892.89	29.881	32.138	27.624	0.2697	0.2900	0.2493
2	138.87	124.81	2022.1	44.968	47.951	41.984	0.3238	0.3452	0.3023
3	122.80	123.18	1589.0	39.863	44.364	35.361	0.3246	0.3612	0.2879
4	95.734	96.02	563.89	23.746	25.887	21.604	0.2480	0.2704	0.2256
5	122.23	121.31	1045.4	32.334	34.137	30.530	0.2645	0.2792	0.2497
6	128.48	129.69	1171.9	34.233	36.699	31.767	0.2664	0.2856	0.2472
7	116.85	118.18	971.22	31.644	33.307	29.021	0.2666	0.2850	0.2483
8	133.88	133.98	1086.8	32.967	35.858	30.075	0.2462	0.2678	0.2246
10	117.26	118.33	849.79	29.151	30.742	27.560	0.2485	0.2621	0.2350
11	132.11	141.01	1283.2	35.821	38.719	32.924	0.2711	0.2930	0.2492
12	111.38	112.60	612.62	24.751	27.565	21.936	0.2222	0.2474	0.1969
13	125.89	127.15	1134.3	33.679	36.816	30.542	0.2675	0.2924	0.2425
15	110.31	112.16	1062.2	32.592	34.713	30.470	0.2954	0.3146	0.2762
Prov.	121.05	120.80	1110.4	33.323	34.025	32.620	0.2752	0.2810	0.2694

Ins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.12: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN INSURED CANADIAN WHEAT BOARD WHEAT REVENUE

Reg.	INS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	119.82	121.67	1324.9	36.399	34.020	38.778	0.3037	0.2839	0.3236
2	151.05	135.63	2953.1	54.342	50.916	57.769	0.3597	0.3370	0.3824
3	133.41	135.40	2512.0	50.119	47.232	53.007	0.3756	0.3540	0.3973
4	103.41	105.23	1159.8	34.056	32.043	36.070	0.3293	0.3098	0.3487
5	136.4[illegible]	[illegible].27	1876.3	43.316	40.704	45.928	0.3174	0.2983	0.3366
6	138.8[illegible]	[illegible].69	1736.9	41.677	39.128	44.226	0.3001	0.2817	0.3184
7	126.5[illegible]	[illegible]9.08	1520.3	38.991	36.476	41.507	0.3081	0.2883	0.3280
8	144.92	146.80	1703.1	41.269	38.483	44.056	0.2847	0.2655	0.3039
10	126.28	130.09	1125.5	33.549	31.494	35.605	0.2656	0.2493	0.2819
11	141.41	155.61	1680.8	40.998	38.513	43.482	0.2899	0.2723	0.3074
12	118.90	124.53	800.23	28.288	26.542	30.034	0.2379	0.2232	0.2526
13	134.42	140.02	1387.1	37.244	34.801	39.687	0.2770	0.2588	0.2952
15	119.39	123.09	1470.6	38.349	35.972	40.728	0.3211	0.3012	0.3411
Prov.	131.29	133.18	1658.7	40.727	38.133	43.321	0.3101	0.2904	0.3299

Ins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.13: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN INSURED WINNIPEG BARLEY REVENUE

Reg.	INS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	104.90	109.47	1417.8	37.653	43.332	31.975	0.3589	0.4130	0.3048
2	149.47	152.51	2112.4	45.961	50.063	41.859	0.3074	0.3349	0.2800
3	116.69	118.68	1989.7	44.606	48.838	40.373	0.3822	0.4185	0.3459
4	85.042	87.428	622.90	24.958	26.939	22.977	0.2934	0.3167	0.2701
5	122.41	122.27	1697.5	41.201	44.983	37.419	0.3365	0.3674	0.3056
6	121.66	123.95	1299.2	36.045	38.943	33.147	0.2962	0.3200	0.2724
7	110.54	111.92	1237.0	35.172	38.260	32.083	0.3181	0.3461	0.2902
8	125.21	126.44	1259.6	35.491	38.699	32.283	0.2834	0.3090	0.2578
10	106.56	107.68	1341.8	36.631	39.809	33.452	0.3437	0.3735	0.3139
11	114.64	117.54	1110.7	33.327	36.270	30.384	0.2907	0.3163	0.2650
12	103.01	104.45	836.57	28.923	31.425	26.421	0.2807	0.3050	0.2564
13	115.11	117.06	1217.4	34.891	37.867	31.916	0.3030	0.3289	0.2772
15	92.358	93.193	1048.1	32.374	35.053	29.695	0.3505	0.3795	0.3215
Prov.	114.23	115.82	1535.8	37.055	40.611	33.499	0.3243	0.3555	0.2932

Ins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.14: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN INSURED CANADIAN WHEAT BOARD BARLEY REVENUE

Reg.	INS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	(2)	CV	CLcv** (1)	(2)
1	106.16	106.87	1212.6	34.822	37.900	32.790	0.3174	0.3569	0.2990
2	151.46	151.74	1492.3	38.630	42.138	35.122	0.2550	0.2782	0.2318
3	118.15	118.39	1659.7	40.740	44.378	37.101	0.3448	0.3756	0.3140
4	85.126	86.518	552.18	23.498	25.499	21.497	0.2760	0.2995	0.2525
5	127.84	136.01	1724.7	41.530	45.376	37.684	0.3248	0.3549	0.2947
6	122.56	124.34	1032.6	32.134	35.079	29.189	0.2621	0.2862	0.2381
7	110.78	112.07	762.02	27.604	30.001	25.208	0.2491	0.2708	0.2275
8	126.29	126.85	680.59	26.088	28.542	23.633	0.2065	0.2260	0.1871
10	106.81	108.15	723.23	26.892	29.358	24.426	0.2517	0.2748	0.2286
11	115.50	118.30	21.593	22.838	24.857	20.819	0.1977	0.2152	0.1802
12	103.30	105.40	412.45	20.309	21.994	18.623	0.1965	0.2129	0.1802
13	115.79	117.72	550.40	23.460	25.527	21.393	0.2026	0.2204	0.1847
15	92.37[illegible]	93.695	748.56	27.359	29.800	24.919	0.2961	0.3226	0.2697
Prov.	115.56	117.64	973.74	31.204	34.114	28.295	0.2700	0.2952	0.2448

Ins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.
CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.
CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Table 4.15: REGIONAL ANALYSIS OF COEFFICIENTS OF VARIATION IN INSURED CANOLA REVENUE

Region	INS. INC.*	EXP. INC.**	MSE	RMSE	CL* (1)	CL* (2)	CV	CLcv** (1)	CLcv** (2)
1	151.78	115.57	2562.5	50.621	58.428	42.813	0.3335	0.3849	0.2820
2	181.52	167.91	2976.2	54.554	58.386	50.722	0.3005	0.3216	0.2794
3	147.12	138.40	2750.7	52.447	58.515	46.379	0.3564	0.3977	0.3152
4	117.87	100.22	1532.4	39.146	44.066	34.225	0.3320	0.3738	0.2903
5	151.32	135.77	2414.3	51.130	54.329	47.931	0.3378	0.3590	0.3167
6	157.35	146.76	2894.8	53.803	58.032	49.574	0.3419	0.3688	0.3150
7	160.00	150.49	2207.6	46.986	50.022	43.949	0.2936	0.3126	0.2746
8	182.68	170.68	2781.6	52.741	57.231	48.251	0.2886	0.3132	0.2641
10	157.89	150.11	1793.8	42.354	44.657	40.054	0.2682	0.2828	0.2536
11	149.44	145.02	1514.7	38.919	42.155	35.684	0.2604	0.2820	0.2387
12	130.21	125.36	1447.2	38.043	42.775	33.310	0.2921	0.3284	0.2558
13	143.13	127.22	1872.8	43.276	47.767	38.785	0.3023	0.3337	0.2709
15	114.72	109.59	1573.9	39.673	42.253	37.092	0.3458	0.3682	0.3233
Prov.	152.50	140.03	2200.7	46.912	47.963	45.861	0.3076	0.3144	0.3007

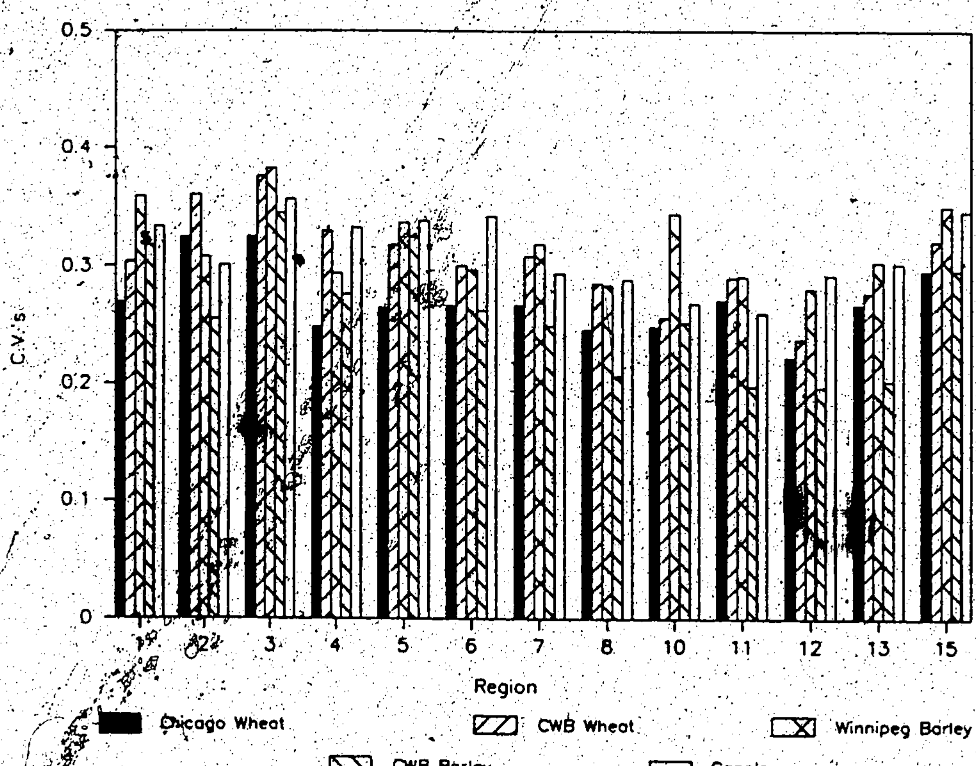
Ins. Inc.* = Uninsured income and Exp. Inc.** = Expected Income.

CL* = 95% confidence level for root mean square error(RMSE). (1) and (2) give upper and lower bounds.

CLcv** = 95% confidence level for coefficent of variation based on upper and lower bounds of root mean square error (RMSE)divided by mean actual revenue.

Province-wide, risk at the elevator points was significantly reduced with the use of crop insurance in all crops except Winnipeg barley. Although the C.V.s were more consistent, the risk reduction was not significant. The regions most significantly affected were Regions 1,2,3 and 15 in Chicago Wheat revenue, Region 3 in Winnipeg barley revenue, Region 3 in Canola revenue, Regions 2, 3 and 15 in CWB wheat revenue and Regions 1, 3 and 5 in CWB barley revenue series. The following graph illustrates the C.V.s by region.

Figure 4.3: Coefficients of Variation of Crop Insured Revenues by Region



In general, all C.V.s were lower as a consequence of crop insurance use. The lower relative risk may be attributed to either lower absolute risk and/or to higher expected revenues. Based on these findings, it will be assumed that it is advantageous to use insurance as a risk reduction strategy and therefore, the remainder of the analysis will continue based on the assumption that it is economically beneficial to carry crop insurance and farmers will do so in order to maximize wealth.

Price Insurance

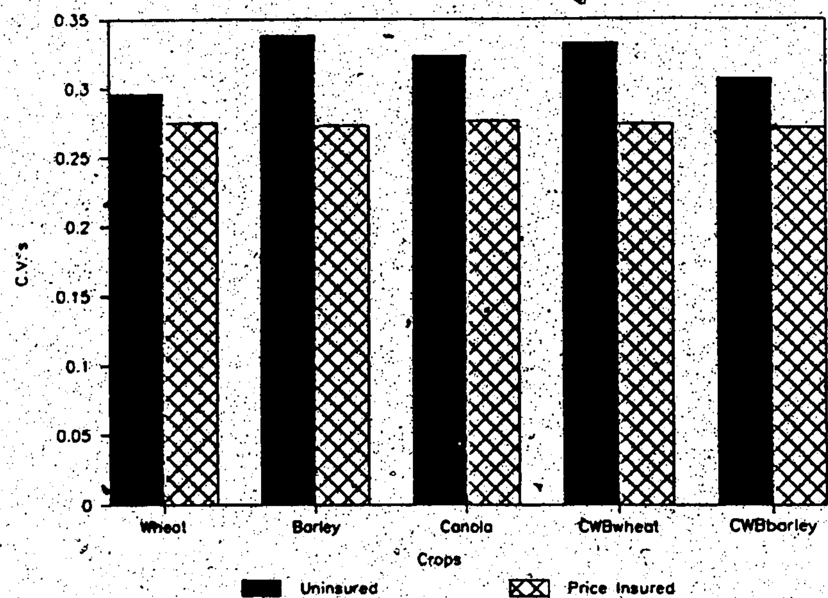
Work by Peck (1977), Rolfo(1980) and Grant (1985) suggest that futures markets may have a useful role in reducing variability of crop revenues. Such studies attempt to determine the optimal hedging strategy using futures. An empirical examination to determine the effects of price insurance was conducted by developing a scenario of perfect price hedging where price risk is eliminated ($\hat{p}=p$).

Although perfect price insurance scenario may not be achieved in the market because one must have prior knowledge of exact quantity, the concept demonstrates maximal effects of price insurance on revenue variation. The pure risk elimination scenario is a hypothetical representation of price insurance based on the effects created by the interaction equation:

$$\frac{\partial V(R)}{\partial \epsilon_p} = 4\epsilon_p V(y) + 2\epsilon_p E^2(y) + r[2r\epsilon_p V(y) + 2E(p)E(y)\epsilon_y]$$

Results from the scenario demonstrating the new coefficients of variation which result appear in the appendix. The following graph illustrates the price insurance effects by crop on a provincial basis.

Figure 4.4: Price Insurance Effects on Coefficients of Variation for Provincial Crop Revenues Without Crop Insurance



The first graph (Figure 4.4) illustrates the effects of price insurance on crop revenues without crop insurance. The first bar in each of the crop series represents the coefficient of variation associated with uninsured crops. Relative variability was significantly reduced by price insurance in all crops. In the Chicago wheat revenue, price insurance has the greatest effect in Regions 7 through 12 and 15 (Appendix D). Only three regions did not report significant results in CWB wheat revenue, Regions 1, 2 and 13. All the regions in the Winnipeg Barley series indicated significantly lower C.V.s as a result of price insurance, likewise all the regions in the canola series did report significant C.V. reduction due to price insurance except Region 2.

Figure 4.5 Price Insurance Effects on Coefficients of Variation for Provincial Crop Revenue With the Inclusion of Crop Insurance

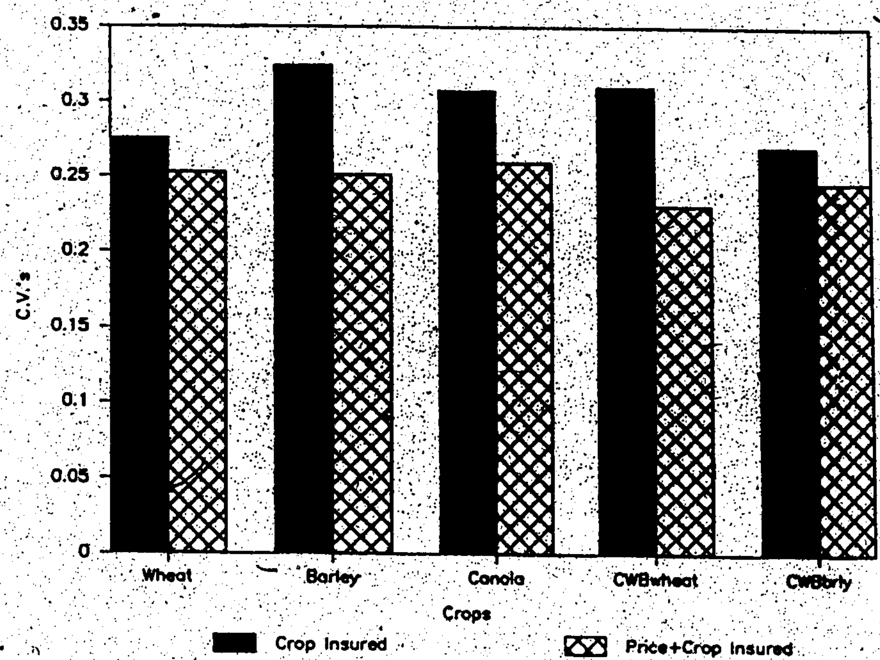


Figure 4.5 illustrates the effects of price insurance on crop insured revenues. The first bar in each crop series represents the coefficient of variation with crop insurance only. For all crops, the perfect price insurance served to significantly reduce risk.

In wheat revenue, price risk elimination combined with crop insurance significantly reduced risk from insured crop revenues in all regions except Region 1 (Appendix D). In CWB wheat revenues, significant risk reductions from price risk elimination were reported for all regions except Regions 10, 12 and 13. Similarily, risk was significantly reduced in Winnipeg barley revenues for all regions except Region 1. Significant risk reduction from price risk elimination was reported in all regions except Regions 1, 2 and 3 in canola.

Serial Correlation

The analysis in this study is limited to single-period analysis, but decision making may involve multiperiod analysis. In such analysis, it is important to determine if serial correlation between revenue deviation occurs. Such correlation would suggest that errors in prediction from one period are carried over into another. Such covariance between time periods may be attributed to two prime sources; yield error and price error. In the yield component, a greater proportion of variability of prediction is due to weather, which *a priori* is assumed to contain no serial correlation. It is highly unpredictable. The divergence of the price component from the assumption of independence of price error terms would be contrary to efficient market theory which is dependent on the assumption that prices reflect all available future information. The efficient market hypothesis implies that past history of price series can not be used to predict future prices.

The assumption of zero covariance or independence of error terms is $cov(\epsilon_i, \epsilon_j)=0$, where 'i' and 'j' indicate different time periods. This assumption implies that the disturbances occurring in one period are not correlated with any other disturbance. In practice the assumption of nonautocorrelation is more occasionally violated in the use of time series rather than cross-sectional analysis. The nature of autocorrelation most prevalent is that of the first order autoregressive scheme where current data is depend on past situations. Errors would be related in the following manner:

$\epsilon_t = \rho\epsilon_{t-1} + \epsilon_t$

ϵ_t is pure white noise and ρ is a parameter which may be calculated as:

$\rho = cov(\epsilon_t, \epsilon_{t-1}) / \sqrt{var\epsilon_t}\sqrt{var\epsilon_{t-1}}$.

To establish the absence of autocorrelation, the hypothesis $H_0: \rho=0$ must be tested. The appropriate alternative hypothesis is $H_A: \rho>0$, since in this economic relationship positive autoregression is plausible. Although the Durbin-Watson test is often used to test such hypotheses, it is not applicable when the explanatory variable is a lagged dependent. Data for one elevator point per region were drawn for each component (revenue error, price error, yield error, and grade error) over the total time period. The one period lagged form variable was thus regressed against itself, therefore, 16 regressions per region were examined. Table 4.16 presents the results of the test for serial correlation in the revenue terms. Results for yield, price and grade factor error autocorrelation appear in the appendix. A t-statistic greater than 2.201 indicates that the ρ parameter is significantly different from zero at the 95%

confidence interval.

The hypothesis of absence of autocorrelation in the revenue series (ie: $H_0': \rho=0$) was not rejected at the 95 % confidence level. The only exception [illegible] in the grade factor for wheat in Regions 1 in which autocorrelation was detected (Appendix E).

Homogeneity of Variances and Correlation

Testing for equality of variances is useful for deciding whether it is legitimate to pool variances. The identification of regional bounds is important for crop insurance purposes. Tests of homogeneity may be used to [illegible]ify the use of risky areas in premium calculations. To test for homogeneity, the null hypothesis that variance of disturbance is constant for all observations is implied. Because the nature of data is microeconomic, the observations should involve differences in magnitude. Thus, *a priori*, the assumption of homoskedascity is not plausible. To test for homogeneity of variances, the Bartlett's test was used. The following table 4.17 indicates the regions which did not refute the null hypothesis. 95 % level of confidence is indicated as **.

Table 4.16: TESTS FOR PRESENCE OF AUTOCORRELATION IN REVENUE ERROR ESTIMATES

		Wheat	Brly	Canola	CWBwh.	CWBbr.
Reg.1	ρ	-.094	-.079	-.337	-.195	-.165
	t-stat.	-.305	.289	-1.137	-.630	-.599
Reg.2	ρ	.140	.077	.429	.344	.102
	t-stat.	.435	.262	1.281	1.144	.321
Reg.3	ρ	.202	.078	.342	.327	.058
	t-stat.	.671	.250	1.119	1.119	.184
Reg.4	ρ	.120	.012	-.068	.323	.063
	t-stat.	.375	.032	-.206	1.065	.197
Reg.5	ρ	.206	-.039	.271	.272	.120
	t-stat.	.887	-.099	.865	1.093	.401
Reg.6	ρ	.515	.522	.199	.545	.256
	t-stat.	1.958	1.268	.608	2.097	.687
Reg.7	ρ	.161	-.060	-.176	.318	.018
	t-stat.	.522	-.177	-.590	1.075	.064
Reg.8	ρ	.061	-.113	-.189	.383	-.404
	t-stat.	.184	-.325	-.613	1.23	-1.384
Reg.10	ρ	-.151	-.340	-.337	.353	-.158
	t-stat.	-.478	-1.250	-1.132	1.190	-.562
Reg.11	ρ	.228	.439	-.153	.368	.131
	t-stat.	.859	1.09	-.478	1.409	.421
Reg.12	ρ	.300	.225	.013	.406	.020
	t-stat.	.922	.690	.043	1.307	.063
Reg.13	ρ	.056	-.009	.088	.134	.014
	t-stat.	.176	-.029	.266	.422	.044
Reg.15	ρ	-.315	-.020	-.185	-.046	-.192
	t-stat.	-1.109	-.068	-.712	-.149	-.632

Table 4.17: TESTS FOR HOMOGENEITY OF VARIANCES BY CROP REVENUE

	Regions	Q/1
Wheat	5,8,13 & 15	.525
Barley	none	
Canola	1 & 5	.0013**
	2,3,6 & 8	.3071**
	4,11,12,13 & 15	.596**
CWB wheat	6 & 10	.0139
	7,11 & 15	.1433
CWB barley	11&13	.0126

95 % level of confidence is indicated as **.

Table 4.18: TESTS FOR HOMOGENEITY OF VARIANCES OF CROP REVENUE BY REGION

Regions	Crops	Q/1
4	Wheat & CWB barley	.00156**
11	Can. & CWB wheat	.00399
15	Wheat & barley	.00387**

95 % level of confidence is indicated as **.

Stability of variability over time may be determined by the use of similar homogeneity tests between years. Such tests demonstrate heteroskedascity in the variability. This heteroskedascity results primarily from the yield component. Variability in weather between years causes the fluctuation in yields. Such variations are random and unpredictable. Analysis of data therefore contains the total period since no trend or pattern could be isolated to suggest subgrouping. Longer term climatic changes could produce climatic regimes which affect yield, however a longer time period would be required to assess such climatic effects.

Homogeneity in the price series over time is more probable. Boyle, Panjer and Sharp (1987) reported standard deviations of annual percentage changes per return on 300 Canadian stocks with the following conclusions:

5 year (1982-1986) standard deviation = 15.40

10 year (1977-1986) standard deviation = 17.83

15 year (1972-1986) standard deviation = 18.89

20 year (1962-1986) standard deviation = 16.53

These results may suggest a possible downward trend in standard deviations if analysis were restricted to more current time periods to forecast market variability.

Homogeneity tests of crop revenue correlations may be used to determine if one coefficient should be used in analysis when more than one crop have homogeneous correlation coefficients. To test for homogeneity of correlations, the correlation coefficients were coverted to the Z transformation. If the correlations are homogeneous, a single pooled coefficient may be used. The test criterion is X^2 with the degrees of freedom equal to one less than the number of correlations used in the calculation.

$$X^2 = \sum_{i=1}^{n} (Z_i - \bar{Z}_w)^2 / 1/\sqrt{n_i - 3} = \sum_{i=1}^{n} (n_i - 3)(Z_i - \bar{Z}_w)^2$$

Converting $\bar{Z}_w$ back to 'ρ' gives a pooled value of 'ρ'.

$$\bar{Z}_w = \sum_{i=1}^{n} (n_i - 3) Z_i / \sum_{i=1}^{n} (n_i - 3)$$

The results of this test produced homogeneous correlations for the following crop revenues within certain regions:

Table 4.19: TESTS FOR HOMOGENEITY OF CORRELATIONS

	Regions	$\bar{Z}_w$	ρ
Wheat-Barley	1& 15	.909	.721
	4 & 5	.81	.67
	11 & 12	.67	.58
	7 & 13	.70	.59
Wheat-Canola	3 & 6	.50	.46
Barley-Canola	2,8,6 & 10	.26	.25

C. Diversification Effects of Crop Combinations

The diversification effect on risk reduction was examined by region. Monoculture risk was compared to results obtained by combining two and three crop revenues. The two and three component single period models contain the proportion of crop, the associated mean square error of estimate , and the covariances between the crop revenue error. The importance of correlations and covariances is implicit. Tables indicating these correlations and covariances appear in the appendix. Table 4.20 was constructed to illustrate the combinations which resulted in the lowest risk as measured by the coefficient of variation. This table allows a comparison of the risk/return tradeoffs. Also indicated are the mean square error associated with the combination (MSE).

Multicrop decisions significantly reduced risk in all regions except Regions 4 and 8. The monocultures which resulted in the lowest risk were wheat and CWB barley, respectively. One should keep in mind not only the role that the covariances of revenue error play in risk reduction, but also the correlation and covariance of the price/non-price components. A strong positive interdependence was associated with prices between crops. The yield components likewise demonstrated positive interdependence. Negative correlations exist between price and non-price components. Recall that as 'ρ' approaches -1, the greater the reduction in risk. In the stock market risk may be priced with extension to the capital market line. The slope of the line is the price of risk.

$$r_i = r_f + S_i(r_m - r_f)/S_m$$

where: r_f represents the riskless rate of return; S_i can be generalized for application to be the C.V. of the risky asset; r_m is the market rate of return; and S_m is the standard deviation of the market portfolio. Direct comparison will require adjustment of C.V.s to market standard deviations. In comparison to the risk/return tradeoffs available in the market, such as the 10 year rate of .1783 [14], Regions 11 and 12 show diversified crop production as providing a viable risk alternative.

[14] Boyle P., H. H. Panjer and K. P. Sharp. *Report on Canadian Economic Statistics, 1924-1986* Canadian Institute of Actuaries, Ottawa, June 1987.

Table 4.20: MULTICROP DIVERSIFICATION EFFECTS

	ONE CROP		TWO CROP		THREE CROP	
	MSE	C.V.	MSE	C.V.	MSE	C.V.
REG.1		wheat		.7w:.3c.		.7w:.0b:.3c
	892.89	.270	579.1	.196	579.1	.196
REG.2		CWB brly		.7CWBb:.3c.		.1cwbw:.6cwbb:.3c
	1492.3	.255	1286.1	.223	1246.3	.22
REG.3		cwb brly		.6w.:.4c.		.6w:.0b:.4c
	1659.7	.345	1444.7	.287	1444.7	.287
REG.4		wheat		.8w:.2b		.5w:.3b:.2c
	563.9	.248	570.8	.239	502.0	.231
REG.5		wheat		.7w:.3c.		.5w:.2b:.3c
	1045.4	.264	958.2	.236	94[illegible]3	.235
REG.6		CWB brly		.8cwbb:.2c		.5w:.3b:.2c
	1032.6	.262	1004.75	.245	995.2	.239
REG.7		CWB brly		.8CWBb:.2c		.3CWBw:.5CWBb:.2c
	762.0	.249	787.1	.233	828.0	.230
REG.8		CWB brly		.2CWBw:.8CWBb		.1cwbw:.8cwbb:.1c
	680.6	.207	680.3	.201	681.5	.195
REG.10		wheat		.6w:.4c		.6w:.0b:.4c
	849.8	.249	698.0	.198	698.0	.198
REG.11		cwb brly		.7cwbb:.3c		.1cwbw:.6cwbb:.3c
	521.6	.198	438.3	.167	442.6	.164
REG.12		cwb brly		.3cwbw:.7cwbb		.3cwbw:.5cwbb:.2c
	412.5	.197	326.9	.178	362.4	.168
REG.13		cwb brly		.3cwbw:.7cwbb		.3cwbw:.5cwbb:.2c
	550.4	.203	1118.0	.189	498.8	.183
REG.15		wheat		.6w:.4c		.6w:.0b:.4c
	1062.2	.295	803.8	.253	803.8	.253

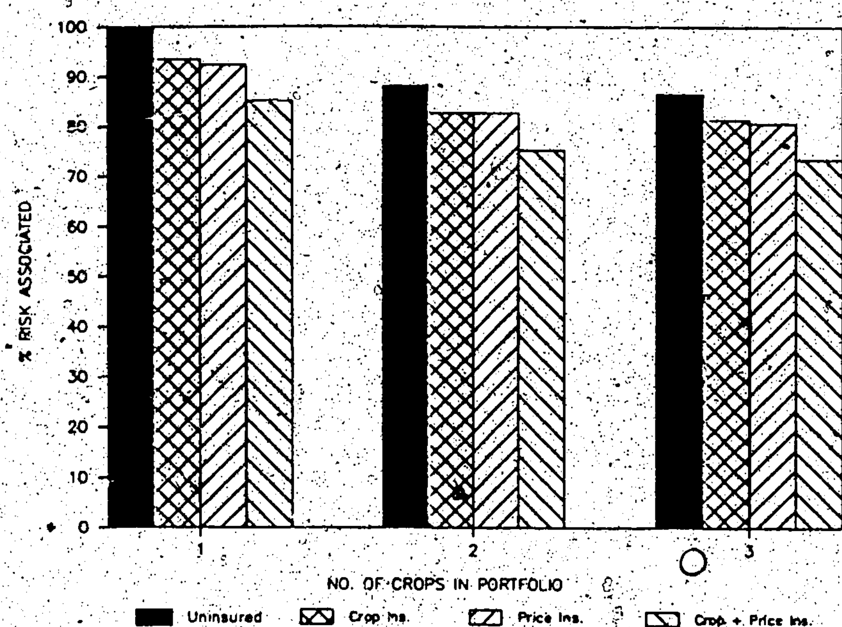
*Proportions of wheat(w), barley(b), canola(c), Canadian Wheat Board wheat(CWBw) and Canadian Wheat Board barley(CWBb).

The following Figure 4.6 demonstrates the proportion of reduction which results from diversifying across crops on insured and uninsured revenue variation. The base used for comparison is the uninsured monoculture which resulted in the least relative variability in each region. The two and three crop combinations which produced the lowest relative variability for three scenarios were compared to determine overall risk reduction. The scenarios include:

1. Risk reduction from crop diversification on uninsured crop revenues.
2. Risk reduction from crop diversification on crop revenues with crop insurance.
3. Risk reduction resulting from crop diversification on crop revenues with crop insurance and price insurance ($\hat{p}=p$).

Diversifying uninsured crops from one crop to two crops resulted in risk reduction between 4.89% in Region 8 to 29.25% in Region 1, an average of 11.94% overall. Diversifying from two crops to three crops in uninsured crops resulted in risk reduction of an additional 1.63% overall. Crop insurance reduced risk by 6.496% in monoculture uninsured crops. Diversifying insured crops from one to two crops reduced risk by an additional 10.894% and an additional 1.336% on three crop combinations for an overall 18.7% reduction from uninsured crops based on the coefficients of variation. The effect of price insurance reduced risk from uninsured monoculture crops by an overall 7.67%. Diversification from one crop to two crops in the price insured revenue resulted in an additional 9.745% risk reduction, and an additional 2.12% with diversification from two to three crops. The total possible risk reduction with diversification to three crops in price insured revenues was 19.539%. The combined effect of price and crop insurance reduced risk from uninsured monoculture crops by an overall 14.83%. An additional 9.995% and 1.89% resulted from diversifying to two and then three crop combinations, for an overall reduction of 26.694% in three crop combinations over uninsured monoculture crop revenue risk.

Figure 4.6: Risk Reduction Associated With Diversification



V. SUMMARY AND CONCLUSIONS

A. Summary

The purpose of this study was to investigate the risk-related rationale for farmer choice of multiple crop rather than single crop. Two theoretical representations of decisions relating to risk include the utility approach under variance and expected returns as developed by Markowitz, and the market approach of the Capital Asset Pricing Model, pioneered by Sharpe and Lintner. Both approaches use variance as the basic quantitative definition of risk.

This study characterizes the farm crop choice decision as a single-period investment decision. Input committment is undertaken in the present. Revenue from harvest is anticipated in the future. Value conversion between present and future is accomplished by a risk-sensitive discount rate. Risk in the single-period cropping model is ascribed to anticipated crop receipts, not to costs. Deviations from anticipated receipts became the basis for measurement of risk. The measurement of dispersion of revenue around the predicted revenue is the mean square error estimate (MSE) and its square root, RMSE or standard error of estimation,

Comparisons of riskiness in agriculture have commonly been restricted to comparison of variance. Historical variance may exaggerate the variability associated with anticipated receipts because a component of this variation may be predictable. This thesis demonstrates how the mean square error estimate may be applied to economic and statistical problems in crop decision making.

Evaluation of risk in anticipated revenues in the single-period crop model involved examination of each of the components of revenue separately; yield, price and grade factor. Variation in the yield component resulted from deviations of actual yield from predicted yield, using data obtained from Alberta Wheat Pool by grain elevator point for the period 1974 to 1986. Predicted yield for individual elevator points was determined as the mean yield at the elevator point plus each years' province-wide deviation from mean yield attributed to fertilizer differences. Price variability was also based on deviations from prediction. The predictor of price was the price for future delivery at the time of the cropping decision; Canadian Wheat Board adjusted initial payments or March price of December futures contracts for wheat and barley and the March price of January futures contract for canola. Realized Canadian Wheat Board payments as well as the November prices of the futures contracts served as the actual prices. Grade factors were based on AWP data on proportion of each crop within a grade class times a price discount associated with the grade. Predicted grade factors were developed from historical experience. The predicted revenue distribution was therefore based on predicted price times predicted yield times mean grade factor and actual revenue was based on the actual revenue components. Differences between actual and predicted revenues formed the measurement of risk.

One objective of this study was to determine the absolute and relative amounts of variability in revenue associated with wheat, barley and canola crop production. Absolute variability was measured by the RMSE, whereas the relative variability was determined by the coefficient of variation (C.V.) calculated as RMSE divided by mean of actual revenue. The provincial mean of country-elevator point RMSEs ranged from a low of $34.98/acre for CWB barley revenue to $48.86/acre for canola. RMSE for Chicago wheat revenue was $35.40/acre, $38.33/acre for Winnipeg barley and $43.09/acre for CWB wheat revenue. The southern regions, primarily Regions 2 and 3 reported higher RMSE for all crop revenues. Central Alberta, primarily Regions 4,10 and 12, reported lower RMSEs.

Provincially, coefficients of variation for crop revenue increased from .296 in Chicago wheat revenue to .338 in Winnipeg barley, with CWB barley, canola and CWB wheat reporting C.V.s of .306, .323, and .332, respectively. Again, the predominate regions to report higher C.V.s were Regions 2 and 3 for Chicago wheat, CWB wheat and Regions 1 and 3 for Winnipeg barley, canola and CWB barley. Region 15 reported higher C.V.s for Chicago wheat, Winnipeg barley and canola. Central Alberta reported the lowest C.V.s for the crop revenues, especially Regions 10 and 12 for Chicago wheat, canola, CWB wheat and CWB barley resulting primarily from the lower RMSEs associated with the regions. Higher actual incomes in Regions 2 and 8 served to reduce the C.V.s of these regions somewhat.

To determine the significance of risk differences between crops, various homogeneity tests were conducted between crops within regions. The Bartlets's test of homogeniety was used in the calculations, providing a Q/1 statistic which is distributed as chi-squared. Region 4 showed homogeniety between wheat and CWB barley revenues at the 95% confidence interval. Within Region 15, wheat and barley were also homogeneous at the 95% confidence interval. Canola and CWB wheat were homogeneous in Region 11 at the 90% confidence level. All other revenue risks were significantly different between crops.

Homogeniety within crops but between regions was also tested. The only crop revenue to show homogeneity between regional variances at the 95% confidence interval was canola. Regions 4, 11, 12, 13 and 15 were homogeneous at a risk level slightly lower than the provincial average, whereas Regions 1 and 5 were homogeneous at a risk level slightly higher than the provincial average. Regions 2, 3, 6 and 8 were homogeneous at the highest reported risk level. Such non-homgeniety between crop risk of different regions lends support to the use of the census divisions as the reporting regions. At the 90% confidence level, CWB wheat was homogeneous in Regions 6 and 10 and 7, 11 and 15. Chicago wheat was homogeneous in Regions 5, 8, 13 and 15 at this level of significance and CWB barley was homogeneous in Regions 11 and 13.

Stability over time may be determined by use of the same homogeneity tests within crops but between years. Heteroskedascity in variability was reported resulting primarily from the yield component. Fluctuations in yield are attributed to weather. No trend or climatic pattern was detected.

Tests for absence of serial correlation in the crop revenues were not rejected at the 95 % confidence interval. The components of revenue were also tested separately with similar results with the exception of the wheat grade factor in Region 1. Such results are consistent with efficient market theory and with the belief that the greater proportion of variability of yield is from weather which is unpredictable.

Crop insurance significantly reduced risk in all crops except barley. The coefficient of variation were more consistent but only in Regions 1, 2, 3 and 15 was barley significantly affected by crop insurance in this revenue series. Crop insurance most noticeably helped mitigate risk in the southern regions.

Price insurance determined by the hypothetical elimination of price risk likewise significantly reduced risk in all crops. In general, the southern regions and Region 13 were not significantly affected by price insurance, suggesting that the majority of risk associated with these regions was attributable to non-price component risk and test a natural hedge was operating.

The relative benefits from diversification depend on the degree of correlation between crop revenues. Comparisons of risk reduction effects from crop diversification were based on uninsured revenues, crop insured revenues and on crop and price insured revenues. Diversification of uninsured crops to two crop combinations resulted in 11.94% reduction of C.V. amounts but only an additional 1.63 % resulted from diversification to three crops. Diversification of crop insured revenues resulted in risk reduction of 10.9% on two crop combinations and an additional 1.34% on three crop. Diversifying price and crop insured revenues resulted in 9.99% risk reduction for two crops and an additional 1.89% for three crops. Risk was significantly reduced in all three scenarios when planting two crops instead of single crop, however additional risk reduction from planting three crops was not significant.

B. Conclusions

In testing the hypothesis that economic benefits to farmers from risk reduction through crop diversification are significant, the following conclusions may be made:

1. The hypothesis was not rejected when monoculture crops were diversified from one to two crop combinations of wheat, barley, and canola. Significant relative risk reduction resulted from this diversification in uninsured, crop insured, perfect price insured and both crop and price insured revenues in the magnitudes of approximately 11.9%, 10.9%, 9.7% and 10%, respectively.
2. The hypothesis of significant risk reduction from diversification from two to three wheat, barley and canola crop combinations was rejected for each crop revenue series. The risk reduction that did occur from this diversification was approximately 1.63% in uninsured revenues, 1.34% in crop insured revenues, 2.12% in perfect price insured revenues and 1.89% in crops with both perfect price and crop insurance.
3. The combined effect of hypothetical perfect price and crop insurance in risk reduction of uninsured monoculture crops was greater than diversification effects on uninsured crops;

a risk reduction of 14.8% with both insurances rather than 11.94% with diversification of monoculture crops to two crop combinations and 13.59% with diversification of monoculture uninsured crops to three crop combinations.

4. Although overall, diversification from one to two crop combinations significantly reduced risk, regional exceptions were found. In the uninsured crop revenues, risk was not significantly reduced from diversification in Region 4 for wheat priced in the Chicago futures, and Regions 6, 8 and 13 for CWB barley. In the crop insured revenues, risk was not significantly reduced from diversification in Regions 6, 8 and 13 for CWB barley. In the perfect price insured revenues, Regions 2 and 3 for canola, Regions 6 and 7 for CWB barley, Region 12 for wheat and CWB barley, and Regions 13 and 15 for Winnipeg barley and CWB barley were not significantly affected by diversification to two crop combinations. In the crops with both perfect price and crop insurance, Regions 6, 7 and 15 in CWB barley and Region 12 in wheat were not significantly affected by diversification.

Risk control at the farm portfolio level and the incremental effects of crop investment changes should also be considered. The variability added to the farm portfolio by the incremental crop investment is dependent on the proportion of the crop investment, the risk of the investment and the covariance between crop risk and other farm and non-farm risk exposure.

The incidence of multiple crop rather than single crop is not likely to be primarily due to risk reduction from diversification. Because some regions do not report significant risk reduction, it is likely that the causal influence of risk reduction in multicrop situations is minor. Gains from risk reduction may be obtained through alternative risk responses (ie: crop insurance, other insurance, and investment diversification outside of agriculture) without necessitating additional cost and management incurred by growing a greater variety of crops.

C. Further Research

The extension of this research may follow two channels, that of the utility approach or the market approach. The measurements of risk developed in this study provide the building blocks for research in either of the two approaches. Cost information would be required, whether it be to construct E-V frontiers or to estimate the expected return on equity from the assets' returns covariance with market returns. Additionally in a CAPM context, covariance between crops and a broader market portfolio would need to be investigated to generate equivalents of security market beta values for crops.

There are other needs for more research that relate more directly to the details of MSE identification. These include the following:

1. Research into adjustment of aggregrate data to farm-level variability would be useful. This study reports variability associated with crop production at the elevator point. Farm-level variability may embrace more risk associated with spot or local climatic disturbances such as hail. This type of research may require the development of vectors for each crop that vary from year-to-year. Such measurement is difficult and must be based on a large micro-level data base.
2. Risk emerges in part from variability in natural climatic and biological systems. Extension is recommended into the relationship between physical properties and the stochastic statistical nature. Such research should include rotational and agronomic information to determine variability effects of disease control, pest control and soil maintenance.
3. Further research is required to incorporate *basis* into risk analysis. This study has treated basis as an implicit cost, however variability is present in basis. Basis could enter the model directly in the determination of prices.
4. Another area of extension could involve investigation into how farmers form their expectations. Problems currently exist in constructing yield predictions which can be updated as the crop progresses and price that is wholly dependent upon future price. The application of econometrics in predicting future values is recommended.
5. Verification of the Alberta Wheat Pool estimates with aggregate data on grain production is desirable. This study did a comparison of AWP data to provincial and federal sources,

however an ideal source would be one which was based on a larger sample and which had access to the physical quantity of grain shipments or sales.

Substantial latitude for further research and application exists. By drawing from non-agricultural business, finance theory can be applied to assess and value risk. Application of these concepts rests on availability of data. The most effective way to improve the efficiency of risky decision making may be to provide an adequate program of data collection, appropriate forecasting and information dissemination to assist farmers in forming revenue expectations (Newberry and Stiglitz, 1981).

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DIST: 11

VARIABLE	CASES	MEAN	STD DEV
DIFFPW	208	-.0025	.0231
CWBWDIF	208	-.0060	.0333
DIFFPB	208	-.0020	.0220
CWBBDIF	208	-.0023	.0154
DIFFPC	208	.0126	.0636
ZDW	208	.4396	15.9854
ZDB	208	1.0762	2.3783
ZDC	207	-1.0126	6.0530

DIST: 11

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
DIFFPW	CWBWDIF	208	.0884	.0004
DIFFPW	CWBBDIF	208	.0245	.0001
DIFFPW	ZDW	208	6.0335	.0291
DIFFPW	ZDC	207	-2.9370	-.0143
CWBWDIF	CWBBDIF	208	.0743	.0004
CWBWDIF	ZDW	208	33.4717	.1617
CWBWDIF	ZDC	207	1.2793	.0062
DIFFPB	DIFFPC	208	.0725	.0004
DIFFPB	ZDB	208	1.8035	.0087
CWBBDIF	DIFFPC	208	.1178	.0006
CWBBDIF	ZDB	208	2.3744	.0115
DIFFPC	ZDW	208	63.0684	.3047
DIFFPC	ZDC	207	7.1644	.0348
ZDW	ZDC	207	4361.1828	21.1222
DIFFPW	DIFFPB	208	.0669	.0003
DIFFPW	DIFFPC	208	-.0113	-.0001
DIFFPW	ZDB	208	2.7432	.0133
CWBWDIF	DIFFPB	208	.0733	.0004
CWBWDIF	DIFFPC	208	.2047	.0010
CWBWDIF	ZDB	208	2.2141	.0107
DIFFPB	CWBBDIF	208	.0468	.0002
DIFFPB	ZDW	208	-2.0455	-.0099
DIFFPB	ZDC	207	1.3666	.0066
CWBBDIF	ZDW	208	11.7010	.0566
CWBBDIF	ZDC	207	1.6774	.0081
DIFFPC	ZDB	208	6.6865	.0323
ZDW	ZDB	208	608.6133	2.9402
ZDB	ZDC	207	-741.3224	-3.5987

DIST: 11

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S - - - - - - - - - - - - - -

	DIFFPW	CWBWDIF	DIFFPB	CWBBDIF	DIFFPC	ZDW	ZDB	ZDC
DIFFPW	1.0000	.5613**	.6360**	.3318**	-.0371	.0788	.2408**	-.1217
CWBWDIF	.5613**	1.0000	.4845**	.7006**	.4671**	.3042**	.1352	.0369
DIFFPB	.6360**	.4845**	1.0000	.6678**	.2504**	-.0281	.1667	.0696
CWBBDIF	.3318**	.7006**	.6678**	1.0000	.5806**	.2296**	.3134**	.1044
DIFFPC	-.0371	.4671**	.2504**	.5806**	1.0000	.2885**	.2134*	.1079
ZDW	.0788	.3042**	-.0281	.2296**	.2885**	1.0000	.0773	.2608**
ZDB	.2408**	.1352	.1667	.3131**	.2134*	.0773	1.0000	-.3007**
ZDC	-.1217	.0369	.0696	.1044	.1079	.2608**	-.3007**	1.0000

* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED)   " . " PRINTED IF A COEFFICIENT CANNOT BE COMPUTED)

DIST: 12

VARIABLE	CASES	MEAN	STD DEV
DIFFPW	102	-.0015	.0231
CWBWDIF	102	-.0077	.0337
DIFFPB	102	-.0006	.0219
CWBBDIF	102	-.0016	.0155
DIFFPC	102	.0148	.0650
ZDW	102	-1.3311	8.2206
ZDB	102	.2428	1.1009
ZDC	102	-1.2445	3.8952

DIST: 12

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR	VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
DIFFPW	CWBWDIF	102	-.0436	.0004	DIFFPW	DIFFPB	102	.0311	.0003
DIFFPW	CWBBDIF	102	.0105	.0001	DIFFPW	DIFFPC	102	-.0072	-.0001
DIFFPW	ZDW	102	-.5724	-.0057	DIFFPW	ZDB	102	.2533	.0025
DIFFPW	ZDC	102	-1.0398	-.0103	CWBWDIF	DIFFPB	102	.0339	.0003
CWBWDIF	CWBBDIF	102	.0356	.0004	CWBWDIF	DIFFPC	102	.1088	.0011
CWBWDIF	ZDW	102	1.9512	.0193	CWBWDIF	ZDB	102	-1.0437	-.0103
CWBWDIF	ZDC	102	-.6888	-.0068	DIFFPB	CWBBDIF	102	.0221	.0002
DIFFPB	DIFFPC	102	.0358	.0004	DIFFPB	ZDW	102	1.1558	.0114
DIFFPB	ZDB	102	-.4164	-.0041	DIFFPB	ZDC	102	.3767	.0037
CWBBDIF	DIFFPC	102	.0626	.0006	CWBBDIF	ZDW	102	1.6586	.0164
CWBBDIF	ZDB	102	-.4825	-.0048	CWBBDIF	ZDC	102	.1268	.0013
DIFFPC	ZDW	102	12.3578	.1224	DIFFPC	ZDB	102	-1.6112	-.0160
DIFFPC	ZDC	102	.3948	.0039	ZDW	ZDB	102	-283.6670	-2.8086
ZDW	ZDC	102	638.7508	6.3243	ZDB	ZDC	102	-222.7028	-2.2050

DIST: 12

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	DIFFPW	CWBWDIF	DIFFPB	CWBBDIF	DIFFPC	ZDW	ZDB	ZDC
DIFFPW	1.0000	.5534**	.6102**	.2909*	-.0476	-.0266	.0985	-.1143
CWBWDIF	.5534**	1.0000	.4556**	.6752**	.4918**	.0621	-.2784*	-.0519
DIFFPB	.6102**	.4556**	1.0000	.6457**	.2494	.0568	-.1714	.0438
CWBBDIF	.2909*	.6752**	.6457**	1.0000	.6157**	.1150	-.2801*	.0208
DIFFPC	-.0476	.4918**	.2494	.6157**	1.0000	.2042	-.2230	.0154
ZDW	-.0266	.0621	.0568	.1150	.2042	1.0000	-.2767*	.1761
ZDB	.0985	-.2784*	-.1714	-.2801*	-.2230	-.2767*	1.0000	-.5142**
ZDC	-.1143	-.0519	.0438	.0208	.0154	.1761	-.5142**	1.0000

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DIST: 19

VARIABLE	CASES	MEAN	STD DEV
DIFFPW	189	-.0029	.0227
CWBWDIF	189	-.0067	.0334
DIFFPB	189	-.0027	.0214
CWBBDIF	189	-.0031	.0150
DIFFPC	189	.0124	.0641
ZDW	186	1.5075	12.2168
ZDB	189	1.9509	6.9084
ZDC	189	-.7124	10.3618

DIST: 19

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR	VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
DIFFPW	CWBWDIF	189	.0762	.0004	DIFFPW	DIFFPB	189	.0589	.0003
DIFFPW	CWBBDIF	189	.0216	.0001	DIFFPW	DIFFPC	189	-.0124	-.0001
DIFFPW	ZDW	186	-7.9090	-.0428	DIFFPW	ZDB	189	4.0489	.0215
DIFFPW	ZDC	189	-4.3278	-.0230	CWBWDIF	DIFFPB	189	.0653	.0003
CWBWDIF	CWBBDIF	189	.0696	.0004	CWBWDIF	DIFFPC	189	.1932	.0010
CWBWDIF	ZDW	186	-3.0009	-.0162	CWBWDIF	ZDB	189	-5.9307	-.0315
CWBWDIF	ZDC	189	-31.2045	-.1660	DIFFPB	CWBBDIF	189	.0386	.0002
DIFFPB	DIFFPC	189	.0578	.0003	DIFFPB	ZDW	186	-11.3249	-.0612
DIFFPB	ZDB	189	-4.1945	-.0223	DIFFPB	ZDC	189	-5.8009	-.0309
CWBBDIF	DIFFPC	189	.1014	.0005	CWBBDIF	ZDW	186	-3.7649	-.0204
CWBBDIF	ZDB	189	-2.7601	-.0147	CWBBDIF	ZDC	189	-13.8904	-.0739
DIFFPC	ZDW	186	13.5387	.0732	DIFFPC	ZDB	189	-16.3870	-.0872
DIFFPC	ZDC	189	-41.1995	-.2191	ZDW	ZDB	186	-2770.2812	-14.9745
ZDW	ZDC	186	4913.7062	26.5606	ZDB	ZDC	189	-918.4169	-4.8852

DIST: 19

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	DIFFPW	CWBWDIF	DIFFPB	CWBBDIF	DIFFPC	ZDW	ZDB	ZDC
DIFFPW	1.0000	.5342**	.6417**	.3366**	-.0453	-.1537	.1395	-.0880
CWBWDIF	.5342**	1.0000	.4856**	.7364**	.4797**	-.0399	-.1386	-.4790**
DIFFPB	.6417**	.4856**	1.0000	.6386**	.2245*	-.2349*	-.1533	-.1393
CWBBDIF	.3366**	.7364**	.6386**	1.0000	.5603**	-.1108	-.1435	-.4745**
DIFFPC	-.0453	.4797**	.2245*	.5603**	1.0000	.0842	-.1998*	-.3301**
ZDW	-.1537	-.0399	-.2349*	-.1108	.0842	1.0000	-.1787	.2149*
ZDB	.1395	-.1386	-.1533	-.1435	-.1998*	-.1787	1.0000	-.0692
ZDC	-.0880	-.4790**	-.1393	-.4745**	-.3301**	.2149*	-.0692	1.0000

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DIST: 18

VARIABLE	CASES	MEAN	STD DEV
DIFEPW	345	-.0033	.0234
CWBWDIF	345	-.0074	.0333
DIFFPB	345	-.0017	.0218
CWBBDIF	345	-.0020	.0151
DIFFPC	345	.0174	.0628
ZDW	343	1.9168	10.0764
ZDB	345	1.0168	5.5539
ZDC	337	.3220	3.2256

DIST: 18

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
DIFFPW	CWBWDIF	345	.1515	.0004
DIFFPW	CWBBDIF	345	.0421	.0001
DIFFPW	ZDW	343	-1.7092	-.0050
DIFFPW	ZDC	337	-3.7720	-.0112
CWBWDIF	CWBBDIF	345	.1220	.0004
CWBWDIF	ZDW	343	-9.0136	-.0264
CWBWDIF	ZDC	337	-2.5596	-.0076
DIFFPB	DIFFPC	345	.0931	.0003
DIFFPB	ZDB	345	-4.8521	-.0132
CWBBDIF	DIFFPC	345	.1765	.0005
CWBBDIF	ZDB	345	-1.3850	-.0040
DIFFPC	ZDW	343	-5.2406	-.0153
DIFFPC	ZDC	337	5.0710	.0151
ZDW	ZDC	335	1071.4246	3.2079

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
DIFFPW	DIFFPB	345	.1140	.0003
DIFFPW	DIFFPC	345	-.0236	-.0001
DIFFPW	ZDB	345	1.7079	.0050
CWBWDIF	DIFFPB	345	.1171	.0003
CWBWDIF	DIFFPC	345	.3210	.0009
CWBWDIF	ZDB	345	8.1705	.0238
DIFFPB	CWBBDIF	345	.0721	.0002
DIFFPB	ZDW	343	2.8321	.0083
DIFFPB	ZDC	337	-1.8115	-.0057
CWBBDIF	ZDW	343	1.3213	.0039
CWBBDIF	ZDC	337	-1.8558	-.0055
DIFFPC	ZDB	345	-3.1873	-.0092
ZDW	ZDB	343	3172.8227	9.2776
ZDB	ZDC	337	1000.2768	2.9770

DIST: 18

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	DIFFPW	CWBWDIF	DIFFPB	CWBBDIF	DIFFPC	ZDW	ZDB	ZDC
DIFFPW	1.0000	.5637**	.6489**	.3461**	-.0466	-.0212	.0382	-.1497*
CWBWDIF	.5637**	1.0000	.4683**	.7048**	.4453**	-.0788	.1282	-.0705
DIFFPB	.6489**	.4683**	1.0000	.6376**	.1977**	.0378	-.1093	-.0814
CWBBDIF	.3461**	.7048**	.6376**	1.0000	.5412**	.0255	-.0481	-.1146
DIFFPC	-.0466	.4453**	.1977**	.5412**	1.0000	-.0243	-.0263	.0742
ZDW	-.0212	-.0788	.0378	.0255	-.0243	1.0000	.1655*	.0874
ZDB	.0382	.1282	-.1093	-.0481	-.0263	.1655*	1.0000	.1667*
ZDC	-.1497*	-.0705	-.0814	-.1146	.0742	.0874	.1667*	1.0000

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Appendix C Crop Revenue Covariance and Correlation Coefficients

Uninsured Revenue Error

Variable Names:

Wdif=error in Chicago Wheat Revenue

Wdif1=error in CWB Wheat Revenue

Bdif=error in Winnipeg Barley Revenue

Bdif1=error in CWB Barley Revenue

Cdif=error in Winnipeg Canola Revenue

Crop Insured Revenue Error

Inswdif=error in Chicago Wheat Revenue

Inswdif1=error in CWB Wheat Revenue

Insbdif=error in Winnipeg Barley Revenue.

Insbdif1=error in CWB Barley Revenue

Inscdif=error in Winnipeg Canola Revenue

Dist 1:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	183	175519.7171	964.3941
WDIF	WDIF1	184	192733.4381	1053.1882
BDIF	CDIF	53	-27723.3939	-533.1422
BDIF	BDIF1	183	244254.2826	1342.0565
CDIF	BDIF1	53	-3803.9782	-73.1534

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	53	-8429.7197	-162.1100
WDIF	BDIF1	183	143549.4114	788.7330
BDIF	WDIF1	183	184982.3607	1016.3866
CDIF	WDIF1	53	21639.8443	416.1509
WDIF1	BDIF1	183	190701.6046	1047.8110

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.7454**	-.0961	.8461**	.6525**
BDIF	.7454**	1.0000	-.2514	.6547**	.8905**
CDIF	-.0961	-.2514	1.0000	.2252	-.0413
WDIF1	.8461**	.6547**	.2252	1.0000	.7223**
BDIF1	.6525**	.8905**	-.0413	.7223**	1.0000

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Dist 2:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	287	180661.6826	[illegible].5842
WDIF	BDIF1	352	333467.6773	950.0904
BDIF	WDIF1	352	376589.1557	1072.9036
CDIF	WDIF1	287	210762.3623	736.9313
WDIF1	BDIF1	352	406928.1043	1159.3393

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	352	413093.9059	1176.9057
WDIF	WDIF1	353	830187.3310	2358.4867
BDIF	CDIF	286	230664.0190	809.3474
BDIF	BDIF1	352	561912.2827	1600.8897
CDIF	BDIF1	286	212585.4406	745.9138

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.5407**	.2443**	.9176**	.5172**
BDIF	.5407**	1.0000	.2980**	.4030**	.8427**
CDIF	.2443**	.2980**	1.0000	.2349**	.3403**
WDIF1	.9176**	.4030**	.2349**	1.0000	.5160**
BDIF1	.5172**	.8427**	.3403**	.5160**	1.0000

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Dist 3:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	110	227998.5186	2091.7295
WDIF	WDIF1	110	290613.7820	2666.1815
BDIF	CDIF	98	157249.1387	1621.1251
BDIF	BDIF1	110	262047.9855	2404.1100
CDIF	BDIF1	98	173186.1532	1785.4243

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	98	148345.7855	1529.3380
WDIF	BDIF1	110	218292.4109	2002.6827
BDIF	WDIF1	110	278439.1494	2554.4876
CDIF	WDIF1	98	194453.9069	2004.6795
WDIF1	BDIF1	110	288104.1946	2643.1577

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.8531**	.5738**	.9420**	.8526**
BDIF	.8531**	1.0000	.5566**	.8303**	.9416**
CDIF	.5738**	.5566**	1.0000	.5857**	.6301**
WDIF1	.9420**	.8303**	.5857**	1.0000	.8968**
BDIF1	.8526**	.9416**	.6301**	.8968**	1.0000

* - SIGNIF. LE .01   ** - SIGNIF. LE .001

Dist 4:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	172	67914.2059	397.1591
WDIF	WDIF1	185	138166.8254	750.9067
BDIF	CDIF	89	30399.1141	345.4445
BDIF	BDIF1	172	91824.9947	536.9883
CDIF	BDIF1	89	41434.8015	470.8500

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	90	44790.9721	503.2693
WDIF	BDIF1	172	57367.7246	335.4838
BDIF	WDIF1	172	89675.8142	524.4200
CDIF	WDIF1	90	82297.9439	924.6960
WDIF1	BDIF1	172	100262.2001	586.3287

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.6644**	.5147**	.8697**	.5925**
BDIF	.6644**	1.0000	.3382**	.6165**	.8615**
CDIF	.5147**	.3382**	1.0000	.6357**	.5068**
WDIF1	.8697**	.6165**	.6357**	1.0000	.7276**
BDIF1	.5925**	.8615**	.5068**	.7276**	1.0000

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Dist 5:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	452	436314.5364	967.4380
WDIF	WDIF1	452	550507.4896	1220.6374
BDIF	CDIF	429	231500.9514	540.8901
BDIF	BDIF1	452	743154.2495	1647.7921
CDIF	BDIF1	429	350305.3810	818.4705

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	429	246801.9566	576.6401
WDIF	BDIF1	452	444286.3432	985.1138
BDIF	WDIF1	452	513386.4206	1138.3291
CDIF	WDIF1	429	379515.8074	886.7192
WDIF1	BDIF1	452	857915.5065	1902.2517

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.6783**	.3416**	.8087**	.5429**
BDIF	.6783**	1.0000	.2578**	.5914**	.7123**
CDIF	.3416**	.2578**	1.0000	.3826**	.2971**
WDIF1	.8087**	.5914**	.3826**	1.0000	.7770**
BDIF1	.5429**	.7123**	.2971**	.7770**	1.0000

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Dist 6:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	220	209779.8420	957.8988
WDIF	BDIF1	222	169771.1588	768.1953
BDIF	WDIF1	222	199613.0352	903.2264
CDIF	WDIF1	220	334667.8048	1528.1635
WDIF1	BDIF1	222	222935.7290	1008.7590

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	222	194028.1689	877.9600
WDIF	WDIF1	222	293620.3609	1328.5988
BDIF	CDIF	220	126447.1682	577.3843
BDIF	BDIF1	222	236755.7794	1071.2931
CDIF	BDIF1	220	181529.5914	828.9022

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.6626**	.4841**	.8589**	.6386**
BDIF	.6626**	1.0000	.2793**	.5604**	.8548**
CDIF	.4841**	.2793**	1.0000	.6325**	.4409**
WDIF1	.8589**	.5604**	.6325**	1.0000	.6895**
BDIF1	.6386**	.8548**	.4409**	.6895**	1.0000

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Dist 7:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	371	251096.5541	678.6393
WDIF	WDIF1	371	423157.7346	1143.6696
BDIF	CDIF	357	204770.8382	575.1990
BDIF	BDIF1	371	345434.2298	933.6061
CDIF	BDIF1	357	220012.9883	618.0140

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	357	166690.9026	468.2329
WDIF	BDIF1	371	164156.7209	443.6668
BDIF	WDIF1	371	248827.1699	672.5059
CDIF	WDIF1	357	297693.7980	836.2185
WDIF1	BDIF1	371	234751.9102	634.4646

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.5651**	.2966**	.8525**	.4602**
BDIF	.5651**	1.0000	.3278**	.4532**	.8756**
CDIF	.2966**	.3278**	1.0000	.4269**	.4378**
WDIF1	.8525**	.4532**	.4269**	1.0000	.5326**
BDIF1	.4602**	.8756**	.4378**	.5326**	1.0000

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Dist 8:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	224	153236.3262	687.1584
WDIF	WDIF1	225	291985.2925	1303.5058
BDIF	CDIF	224	116513.8313	522.4835
BDIF	BDIF1	224	184804.9944	828.7219
CDIF	BDIF1	224	149195.3288	669.0373

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	225	58112.7581	259.4320
WDIF	BDIF1	224	92262.7996	413.7345
BDIF	WDIF1	224	137018.1267	614.4311
CDIF	WDIF1	225	154209.4250	688.4349
WDIF1	BDIF1	224	128261.2252	575.1624

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.5317**	.1379	.8413**	.4267**
BDIF	.5317**	1.0000	.2721**	.3878**	.8393**
CDIF	.1379	.2721**	1.0000	.2986**	.4644**
WDIF1	.8413**	.3878**	.2986**	1.0000	.4838**
BDIF1	.4267**	.8393**	.4644**	.4838**	1.0000

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Dist 10:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	513	398416.1087	778.1565
WDIF	WDIF1	513	418972.0712	818.3048
BDIF	CDIF	508	210298.8120	414.7906
BDIF	BDIF1	513	470432.7617	918.8140
CDIF	BDIF1	508	218230.3843	430.4347

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	508	130803.4391	257.9949
WDIF	BDIF1	513	249809.6214	487.9094
BDIF	WDIF1	513	290212.8153	566.8219
CDIF	WDIF1	508	242609.4836	478.5197
WDIF1	BDIF1	513	242504.1984	473.6410

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.6951**	.1977**	.7920**	.5877**
BDIF	.6951**	1.0000	.2599**	.4444**	.8967**
CDIF	.1977**	.2599**	1.0000	.3220**	.3618**
WDIF1	.7920**	.4444**	.3220**	1.0000	.5008**
BDIF1	.5877**	.8967**	.3618**	.5008**	1.0000

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Dist 11:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	208	157462.9284	760.6905
WDIF	WDIF1	208	252394.9792	1219.2994
BDIF	CDIF	207	8013.4267	38.9001
BDIF	BDIF1	208	142564.9165	688.7194
CDIF	BDIF1	207	33312.2552	161.7100

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	207	25486.9117	123.7229
WDIF	BDIF1	208	96849.3117	467.8711
BDIF	WDIF1	208	110638.9196	534.4875
CDIF	WDIF1	207	62825.5331	304.9783
WDIF1	BDIF1	208	102339.8031	494.3952

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.6012**	.0803	.7957**	.5277**
BDIF	.6012**	1.0000	.0275	.3788**	.8437**
CDIF	.0803	.0275	1.0000	.1772*	.1635*
WDIF1	.7957**	.3788**	.1772*	1.0000	.5000**
BDIF1	.5277**	.8437**	.1635*	.5000**	1.0000

* - SIGNIF. LE .01   ** - SIGNIF. LE .001

Dist 12:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	102	47297.0495	468.2876
WDIF	WDIF1	102	56859.2559	562.9629
BDIF	CDIF	102	19531.0813	193.3770
BDIF	BDIF1	102	50398.9563	498.9996
CDIF	BDIF1	102	19386.8228	191.9487

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	102	13725.4331	135.8954
WDIF	BDIF1	102	25844.6582	255.8877
BDIF	WDIF1	102	28062.8632	277.8501
CDIF	WDIF1	102	20530.0451	203.2678
WDIF1	BDIF1	102	24411.5417	241.6984

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.5997**	.1283	.7342**	.4722**
BDIF	.5997**	1.0000	.1644	.3262**	.8289**
CDIF	.1283	.1644	1.0000	.1760	.2351*
WDIF1	.7342**	.3262**	.1760	1.0000	.4089**
BDIF1	.4722**	.8289**	.2351*	.4089**	1.0000

* - SIGNIF. LE .01   ** - SIGNIF. LE .001

Dist 13:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	186	145815.1199	788.1898
WDIF	WDIF1	186	213911.8522	1156.2803
BDIF	CDIF	189	87994.6732	468.0568
BDIF	BDIF1	189	137295.6566	730.2960
CDIF	BDIF1	189	68794.7455	365.9295

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	186	77891.1956	421.0335
WDIF	BDIF1	186	87526.8452	473.1181
BDIF	WDIF1	186	85021.2927	459.5746
CDIF	WDIF1	186	66254.6288	358.1331
WDIF1	BDIF1	186	68044.0785	367.8058

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.6150**	.2794**	.8114**	.5500**
BDIF	.6150**	1.0000	.3180**	.3320**	.8697**
CDIF	.2794**	.3180**	1.0000	.2201*	.3744**
WDIF1	.8114**	.3320**	.2201*	1.0000	.3959**
BDIF1	.5500**	.8697**	.3744**	.3959**	1.0000

* - SIGNIF. LE .01   ** - SIGNIF. LE .001

Dist 15:

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	BDIF	343	287874.4164	841.7381
WDIF	WDIF1	343	423513.3878	1238.3432
BDIF	CDIF	337	183139.1700	545.0571
BDIF	BDIF1	345	286586.7123	833.1009
CDIF	BDIF1	337	191463.3643	569.8314

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
WDIF	CDIF	335	131518.9373	393.7693
WDIF	BDIF1	343	215648.8909	630.5526
BDIF	WDIF1	343	301774.1699	882.3806
CDIF	WDIF1	335	223491.3581	669.1358
WDIF1	BDIF1	343	279841.9258	818.2512

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	WDIF	BDIF	CDIF	WDIF1	BDIF1
WDIF	1.0000	.7313**	.2827**	.8727**	.6382**
BDIF	.7313**	1.0000	.4116**	.6580**	.8940**
CDIF	.2827**	.4116**	1.0000	.4127**	.5070**
WDIF1	.8727**	.6580**	.4127**	1.0000	.7109**
BDIF1	.6382**	.8940**	.5070**	.7109**	1.0000

* - SIGNIF. LE .01   ** - SIGNIF. LE .001

PROVINCIAL ANALYSIS

0VARIABLE	CASES	MEAN	STD DEV
INSWDIF	3454	.3152	33.3268
INSWDIF1	3454	-2.0354	40.6825
INSBDIF	3443	-1.5457	39.1648
INSBDIF1	3443	-2.2200	31.1304
INSCDIF	3102	9.1808	46.0091

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	3454	3913048.4813	1133.2315
INSWDIF	INSBDIF1	3438	1982732.0745	576.8787
INSWDIF1	INSBDIF	3438	2537745.5888	738.3607
INSWDIF1	INSCDIF	3097	2038503.9567	658.4315
INSBDIF	INSCDIF	3099	1383721.7224	446.6500
INSWDIF	INSBDIF	3438	2658843.6638	773.5943
INSWDIF	INSCDIF	3097	1221413.3654	394.5134
INSWDIF1	INSBDIF1	3438	2640058.9808	768.1289
INSBDIF	INSBDIF1	3443	3326193.0542	966.3548
INSBDIF1	INSCDIF	3099	1578772.9421	509.6104

\- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8358**	.5929**	.5558**	.2577**
INSWDIF1	.8358**	1.0000	.4640**	.6068**	.3530**
INSBDIF	.5929**	.4640**	1.0000	.7926**	.2626**
INSBDIF1	.5558**	.6068**	.7926**	1.0000	.3643**
INSCDIF	.2577**	.3530**	.2626**	.3643**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001

DIST: 1

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	184	166051.5618	907.3856
INSWDIF	INSBDIF1	183	119393.5245	656.0084
INSWDIF1	INSBDIF	183	202260.9362	1111.3238
INSWDIF1	INSCDIF	53	20814.7741	400.2841
INSBDIF	INSCDIF	53	3854.1685	74.1186
INSWDIF	INSBDIF	183	121465.6684	667.3938
INSWDIF	INSCDIF	53	-11021.3569	-211.9492
INSWDIF1	INSBDIF1	183	161150.4943	885.4423
INSBDIF	INSBDIF1	183	215553.0573	1184.3575
INSBDIF1	INSCDIF	53	-4116.2921	-79.1595

DIST: 1

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8312**	.3322**	.6278**	-.1382
INSWDIF1	.8312**	1.0000	.4538**	.6952**	.2301
INSBDIF	.3322**	.4538**	1.0000	.5054**	.0344
INSBDIF1	.6278**	.6952**	.5054**	1.0000	-.0504
INSCDIF	-.1382	.2301	.0344	-.0504	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 2

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	353	711519.6617	2021.3627
INSWDIF	INSBDIF1	352	300666.5049	856.5997
INSWDIF1	INSBDIF	352	342598.7328	976.0648
INSWDIF1	INSCDIF	287	185902.7385	650.0096
INSBDIF	INSCDIF	286	197779.1802	693.9620
INSWDIF	INSBDIF	352	380430.4110	1083.8473
INSWDIF	INSCDIF	287	150459.9170	526.0836
INSWDIF1	INSBDIF1	352	370436.0583	1055.3734
INSBDIF	INSBDIF1	352	520345.4642	1482.4657
INSBDIF1	INSCDIF	286	194749.9010	683.3330

DIST: 2

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.9052**	.5514**	.5176**	.2274**
INSWDIF1	.9052**	1.0000	.4066**	.5221**	.2317**
INSBDIF	.5514**	.4066**	1.0000	.8343**	.2735**
INSBDIF1	.5176**	.5221**	.8343**	1.0000	.3334**
INSCDIF	.2274**	.2317**	.2735**	.3334**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 3

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	110	200246.1424	1837.1206
INSWDIF	INSBDIF1	110	143221.8737	1313.9621
INSWDIF1	INSBDIF	110	189348.4664	1737.1419
INSWDIF1	INSCDIF	98	118150.0912	1218.0422
INSBDIF	INSCDIF	98	93790.9192	966.9167
INSWDIF	INSBDIF	110	158812.6637	1456.9969
INSWDIF	INSCDIF	98	87403.9460	901.0716
INSWDIF1	INSBDIF1	110	193659.2205	1776.6901
INSBDIF	INSBDIF1	110	182955.8894	1678.4944
INSBDIF1	INSCDIF	98	105937.1789	1092.1359

DIST: 3

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.9120**	.8126**	.8018**	.4652**
INSWDIF1	.9120**	1.0000	.7712**	.8630**	.4847**
INSBDIF	.8126**	.7712**	1.0000	.9160**	.4403**
INSBDIF1	.8018**	.8630**	.9160**	1.0000	.5364**
INSCDIF	.4652**	.4847**	.4403**	.5364**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 4

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	185	128425.6465	697.9655
INSWDIF	INSBDIF1	172	52734.6829	308.3900
INSWDIF1	INSBDIF	172	83805.2387	490.0891
INSWDIF1	INSCDIF	90	76983.4343	864.9824
INSBDIF	INSCDIF	89	28907.6601	328.4961
INSWDIF	INSBDIF	172	63501.7625	371.3553
INSWDIF	INSCDIF	90	41331.6561	464.4006
INSWDIF1	INSBDIF1	172	94355.5389	551.7868
INSBDIF	INSBDIF1	172	85791.7338	501.7060
INSBDIF1	INSCDIF	89	39845.7539	452.7927

DIST: 4

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8602**	.6624**	[illegible]37**	.5102**
INSWDIF1	.8602**	1.0000	.609[illegible]	.7284**	.6349**
INSBDIF	.6624**	.6097**	1.0000	.8524**	.3401*
INSBDIF1	.5837**	.7284**	.8524**	1.0000	.5152**
INSCDIF	.5102**	.6349**	.3401*	.5152**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 5

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	452	503828.5081	1117.1364
INSWDIF	INSBDIF1	452	358775.7472	795.5116
INSWDIF1	INSBDIF	452	441731.6123	979.4493
INSWDIF1	INSCDIF	429	338052.1727	789.8415
INSBDIF	INSCDIF	429	183878.9812	429.6238
INSWDIF	INSBDIF	452	402988.0197	893.5433
INSWDIF	INSCDIF	429	214605.9436	501.4158
INSWDIF1	INSBDIF1	452	622220.5984	1379.6466
INSBDIF	INSBDIF1	452	592055.5640	1312.7618
INSBDIF1	INSCDIF	429	270156.1743	631.2060

DIST: 5

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	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.7980**	.6696**	.6032**	.3233**
INSWDIF1	.7980**	1.0000	.5489**	.7823**	.3739**
INSBDIF	.6696**	.5489**	1.0000	.7808**	.2231**
INSBDIF1	.6032**	.7823**	.7808**	1.0000	.3272**
INSCDIF	.3233**	.3739**	.2231**	.3272**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 6

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	222	267162.0310	1208.8780
INSWDIF	INSBDIF1	222	156437.2801	707.8610
INSWDIF1	INSBDIF	222	183153.9689	828.7510
INSWDIF1	INSCDIF	220	297714.8177	1359.4284
INSBDIF	INSCDIF	220	102052.0811	465.9912
INSWDIF	INSBDIF	222	181725.7533	822.2885
INSWDIF	INSCDIF	220	182730.7266	834.3869
INSWDIF1	INSBDIF1	222	205680.2554	930.6799
INSBDIF	INSBDIF1	222	216251.1176	978.5118
INSBDIF1	INSCDIF	220	156073.5949	712.6648

DIST: 6

- - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8463**	.6650**	.6421**	.4600**
INSWDIF1	.8463**	1.0000	.5517**	.6950**	.6142**
INSBDIF	.6650**	.5517**	1.0000	.8441**	.2435**
INSBDIF1	.6421**	.6950**	.8441**	1.0000	.4169**
INSCDIF	.4600**	.6142**	.2435**	.4169**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 7

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	371	375405.3667	1014.6091
INSWDIF	INSBDIF1	371	152578.2720	412.3737
INSWDIF1	INSBDIF	371	238083.0054	643.4676
INSWDIF1	INSCDIF	357	277410.7764	779.2438
INSBDIF	INSCDIF	357	190399.2560	534.8294
INSWDIF	INSBDIF	371	246286.1012	665.6381
INSWDIF	INSCDIF	357	149677.8314	420.4433
INSWDIF1	INSBDIF1	371	217859.3383	588.8090
INSBDIF	INSBDIF1	371	311414.7523	841.6615
INSBDIF1	INSCDIF	357	204261.8863	573.7693

DIST: 7

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8352**	.6065**	.4790**	.2901**
INSWDIF1	.8352**	1.0000	.4692**	.5474**	.4284**
INSBDIF	.6065**	.4692**	1.0000	.8660**	.3255**
INSBDIF1	.4790**	.5474**	.8660**	1.0000	.4444**
INSCDIF	.2901**	.4284**	.3255**	.4444**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 8

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	225	250379.5302	1117.7658
INSWDIF	INSBDIF1	224	89168.2874	399.8578
INSWDIF1	INSBDIF	224	128330.8553	575.4747
INSWDIF1	INSCDIF	225	154065.0057	687.7902
INSBDIF	INSCDIF	224	105916.1245	474.9602
INSWDIF	INSBDIF	224	147115.0279	659.7086
INSWDIF	INSCDIF	225	60108.6449	268.3422
INSWDIF1	INSBDIF1	224	123090.8980	551.9771
INSBDIF	INSBDIF1	224	172398.6855	773.0883
INSBDIF1	INSCDIF	224	137975.6393	618.7248

DIST: 8

- - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8195**	.5603**	.4622**	.1570
INSWDIF1	.8195**	1.0000	.3911**	.5106**	.3220**
INSBDIF	.5603**	.3911**	1.0000	.8320**	.2580**
INSBDIF1	.4622**	.5106**	.8320**	1.0000	.4574**
INSCDIF	.1570	.3220**	.2580**	.4574**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 12

VARIABLES	CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF INSWDIF1	102	50049.2240	495.5369
INSWDIF INSBDIF1	102	23826.7868	235.9088
INSWDIF1 INSBDIF	102	24747.4407	245.0242
INSWDIF1 INSCDIF	102	19573.7899	193.7999
INSBDIF INSCDIF	102	20323.6459	201.2242
INSWDIF INSBDIF	102	42785.6292	423.6201
INSWDIF INSCDIF	102	13275.8442	131.4440
INSWDIF1 INSBDIF1	102	22817.4896	225.9157
INSBDIF INSBDIF1	102	49152.2233	486.6557
INSBDIF1 INSCDIF	102	19386.7592	191.9481

DIST: 12

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	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.7160**	.5874**	.4678**	.1397
INSWDIF1	.7160**	1.0000	.3030*	.3995**	.1836
INSBDIF	.5874**	.3030*	1.0000	.8258**	.1830
INSBDIF1	.4678**	.3995**	.8258**	1.0000	.2496
INSCDIF	.1397	.1836	.1830	.2496	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 13

VARIABLES	CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF INSWDIF1	186	182058.9046	984.1022
INSWDIF INSBDIF1	186	78136.3863	422.3588
INSWDIF1 INSBDIF	186	72889.1954	393.9957
INSWDIF1 INSCDIF	186	69487.2681	375.6069
INSBDIF INSCDIF	189	84941.1879	451.8148
INSWDIF INSBDIF	186	132143.4289	714.2888
INSWDIF INSCDIF	186	79880.0132	431.7839
INSWDIF1 INSBDIF1	186	59185.5484	319.9219
INSBDIF INSBDIF1	189	132375.3685	704.1243
INSBDIF1 INSCDIF	189	67489.7179	358.9879

DIST: 13

- - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.7907**	.6103**	.5320**	.3141**
INSWDIF1	.7907**	1.0000	.3081**	.3688**	.2501**
INSBDIF	.6103**	.3081**	1.0000	.8599**	.3193**
INSBDIF1	.5320**	.3688**	.8599**	1.0000	.3780**
INSCDIF	.3141**	.2501**	.3193**	.3780**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 10

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	513	388424.6896	758.6420
INSWDIF	INSBDIF1	513	234684.9338	458.3690
INSWDIF1	INSBDIF	513	275768.1574	538.6097
INSWDIF1	INSCDIF	508	221358.1379	436.6038
INSBDIF	INSCDIF	508	197034.4463	388.6281
INSWDIF	INSBDIF	513	383813.0314	749.6348
INSWDIF	INSCDIF	508	110993.7249	218.9225
INSWDIF1	INSBDIF1	513	226528.9421	442.4393
INSBDIF	INSBDIF1	513	451308.7448	881.4624
INSBDIF1	INSCDIF	508	202399.0956	399.2093

DIST: 10

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.7797**	.7014**	.5847**	.1793**
INSWDIF1	.7797**	1.0000	.4405**	.4932**	.3125**
INSBDIF	.7014**	.4405**	1.0000	.8946**	.2555**
INSBDIF1	.5847**	.4932**	.8946**	1.0000	.3560**
INSCDIF	.1793**	.3125**	.2555**	.3560**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 11

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	208	212847.7003	1028.2498
INSWDIF	INSBDIF1	208	79891.3401	385.9485
INSWDIF1	INSBDIF	208	91454.4972	441.8092
INSWDIF1	INSCDIF	207	46513.8078	225.7952
INSBDIF	INSCDIF	207	-175.8211	-.8535
INSWDIF	INSBDIF	208	140423.0123	678.3720
INSWDIF	INSCDIF	207	13007.1497	63.1415
INSWDIF1	INSBDIF1	208	82507.2957	398.5860
INSBDIF	INSBDIF1	208	130970.8896	632.7096
INSBDIF1	INSCDIF	207	22738.7440	110.3823

DIST: 11

- - - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.7668**	.5860**	.4883**	.0469
INSWDIF1	.7668**	1.0000	.3443**	.4550**	.1511
INSBDIF	.5860**	.3443**	1.0000	.8367**	-.0007
INSBDIF1	.4883**	.4550**	.8367**	1.0000	.1263
INSCDIF	.0469	.1511	-.0007	.1263	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

DIST: 15

VARIABLES		CASES	CROSS-PROD DEV	VARIANCE-COVAR
INSWDIF	INSWDIF1	343	364529.8384	1065.8767
INSWDIF	INSBDIF1	343	188800.2239	552.0474
INSWDIF1	INSBDIF	343	269793.8879	788.8710
INSWDIF1	INSCDIF	335	206343.6949	617.7955
INSBDIF	INSCDIF	337	175217.1303	521.4796
INSWDIF	INSBDIF	343	260326.1821	761.1877
INSWDIF	INSCDIF	335	118010.9718	353.3263
INSWDIF1	INSBDIF1	343	248608.4297	726.9252
INSBDIF	INSBDIF1	345	271582.2712	789.4833
INSBDIF1	INSCDIF	337	182176.5375	542.1921

DIST: 15

- - - - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C

	INSWDIF	INSWDIF1	INSBDIF	INSBDIF1	INSCDIF
INSWDIF	1.0000	.8559**	.7212**	.6174**	.2772**
INSWDIF1	.8559**	1.0000	.6374**	.6933**	.4129**
INSBDIF	.7212**	.6374**	1.0000	.8900**	.4142**
INSBDIF1	.6174**	.6933**	.8900**	1.0000	.5141**
INSCDIF	.2772**	.4129**	.4142**	.5141**	1.0000

-* - SIGNIF. LE .01   ** - SIGNIF. LE .001   (2-TAILED, " . " PRINTED

Appendix D Regional Coefficients of Variations for Price Insured and Price and Crop Insured Revenues

REGIONAL ANALYIS
--WHEAT(PRICE UNINSURED)

Region	Uninsur Income	Expecte Income	MSE	RMSE	CL(RMSE) (1)	(2)	CV	CLcv (1)	(2)
1	109.39	108.34	1095.9	33.105	35.428	30.782	0.3026	0.3238	0.2813
2	137.05	120.35	2246.2	47.395	50.536	44.254	0.3458	0.3687	0.3228
3	117.80	115.31	2020.3	44.948	50.287	39.608	0.3815	0.4268	0.3362
4	95.210	94.209	581.01	24.104	26.181	22.027	0.2531	0.2749	0.2313
5	121.51	118.09	956.63	30.929	32.859	28.999	0.2545	0.2704	0.2386
6	127.61	126.30	1113.1	33.363	36.236	30.491	0.2614	0.2839	0.2389
7	115.81	115.00	889.46	29.823	31.940	27.707	0.2575	0.2757	0.2392
8	132.47	130.33	1007.0	31.733	34.754	28.712	0.2395	0.2623	0.2167
10	116.70	115.52	639.82	25.294	26.764	23.824	0.2167	0.2293	0.2041
11	130.67	137.33	1190.7	34.507	37.678	31.337	0.2640	0.2883	0.2398
12	110.27	110.40	443.33	21.055	23.560	18.550	0.1909	0.2136	0.1682
13	124.20	123.06	1165.2	34.136	37.722	30.549	0.2748	0.3037	0.2459
15	108.69	108.20	996.35	31.565	33.704	29.426	0.2903	0.3100	0.2707
Prov.	119.80	117.26	1082.8	32.906	33.648	32.163	0.2746	0.2808	0.2684

REGIONAL ANALYIS
--BARLE(PRICE UNINSURED)

Region	Uninsur Income	EXP. INC.	MSE	RMSE	CL(RMSE) (1)	(2)	CV	CLcv (1)	(2)
1	103.41	103.76	1226.4	35.020	38.113	31.927	0.3386	0.3685	0.3087
2	148.60	148.77	1832.4	42.807	46.821	38.793	0.2880	0.3150	0.2610
3	112.35	111.64	1997.5	44.694	49.034	40.354	0.3977	0.4364	0.3591
4	84.680	85.245	376.71	19.409	20.966	17.851	0.2292	0.2475	0.2108
5	120.82	118.41	1255.0	35.426	38.842	32.011	0.2932	0.3214	0.2649
6	120.99	121.78	975.28	31.229	34.249	28.209	0.2580	0.2830	0.2331
7	109.83	109.88	748.60	27.360	30.029	24.691	0.2491	0.2733	0.2248
8	124.91	124.91	550.25	23.457	25.746	21.168	0.1877	0.2061	0.1694
10	106.20	105.80	798.83	28.263	30.965	25.562	0.2661	0.2915	0.2406
11	114.05	114.74	748.67	27.361	29.942	24.781	0.2398	0.2625	0.2172
12	102.83	103.92	495.05	22.249	24.477	20.021	0.2163	0.2380	0.1946
13	114.84	113.98	842.50	29.025	31.659	26.392	0.2527	0.2756	0.2298
15	91.981	91.413	520.31	22.810	24.875	20.745	0.2479	0.2704	0.2255
Prov.	113.41	113.02	956.58	30.928	33.939	27.918	0.2726	0.2992	0.2461

REGIONAL ANALYIS
--CANOL(PRICE UNINSURED)

Region	UNINS. INC.	EXP. INC.	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	150.73	114.59	1535.9	39.191	46.325	32.057	0.2600	0.3073	0.2126
2	179.84	176.43	3006.9	54.835	58.903	50.766	0.3049	0.3275	0.2822
3	143.36	142.50	2365.6	48.638	54.538	42.737	0.3392	0.3804	0.2981
4	116.72	104.86	920.99	30.347	34.537	26.157	0.2599	0.2958	0.2240
5	149.90	146.80	2120.4	46.048	49.023	43.073	0.3071	0.3270	0.2873
6	155.80	154.15	1897.3	43.558	47.214	39.901	0.2795	0.3030	0.2560
7	159.26	159.01	1375.3	37.086	39.567	34.604	0.2328	0.2484	0.2172
8	182.16	181.02	1457.6	38.178	41.227	35.130	0.2095	0.2263	0.1928
10	157.17	157.53	1390.1	37.284	39.484	35.084	0.2372	0.2512	0.2232
11	147.84	149.13	1757.4	41.922	45.772	38.071	0.2835	0.3098	0.2575
12	128.98	129.78	1542.1	39.269	44.299	34.239	0.3044	0.3434	0.2654
13	142.45	131.48	1980.9	44.507	49.134	39.881	0.3124	0.3449	0.2799
15	113.84	114.72	1174.3	34.268	36.581	31.956	0.3010	0.3213	0.2807
Prov.	151.34	146.95	1741.6	41.733	42.714	40.752	0.2757	0.2822	0.2692

REGIONAL ANALYSIS
--CWB-WHEAT(PRICE UNINSURED)

Region	Uninsur Income	Expecte Income	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	118.39	115.90	1209.9	34.783	32.440	37.126	0.2937	0.2740	0.3135
2	148.92	129.21	2651.0	51.488	48.067	54.909	0.3457	0.3227	0.3687
3	127.22	123.72	2174.8	46.634	[illegible]	52.023	0.3665	0.3241	0.4088
4	102.76	100.70	688.48	26.238	23.978	28.498	0.2553	0.2333	0.2773
5	135.28	133.09	1229.4	35.064	32.933	37.194	0.2591	0.2434	0.2749
6	137.83	135.77	1291.9	35.944	32.848	39.039	0.2607	0.2383	0.2832
7	125.31	123.67	1012.2	31.815	29.584	34.046	0.2538	0.2360	0.2716
8	143.36	140.04	1171.8	34.232	30.974	37.490	0.2387	0.2160	0.2615
10	125.69	124.08	715.82	26.754	25.216	28.293	0.2128	0.2006	0.2250
11	139.72	146.83	1356.4	36.816	33.424	40.209	0.2634	0.2392	0.2877
12	117.86	117.82	491.13	22.161	19.565	24.757	0.1880	0.1659	0.2100
13	132.11	131.25	1321.8	36.357	32.532	40.182	0.2739	0.2451	0.3027
15	117.60	115.19	1181.6	34.375	32.034	36.716	0.2922	0.2723	0.3121
Prov.	129.83	126.61	1261.5	35.517	34.721	36.314	0.2735	0.2674	0.2796

REGIONAL ANALYSIS

--CWB-BARLEY(PRICE UNINSURED)

Region	Uninsur Income	Exp. INC.	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	104.69	103.77	1226.4	35.020	38.113	31.927	0.3345	0.3640	0.3049
2	150.70	149.16	1832.4	42.807	46.821	38.793	0.2840	0.3106	0.2574
3	113.56	112.11	1997.5	44.694	49.034	40.354	[illegible]	0.4317	0.3553
4	84.749	85.171	376.71	19.409	20.966	17.851	0.2290	0.2473	0.2106
5	121.54	118.06	1255.0	35.426	38.842	32.011	0.2914	0.3195	0.2633
6	121.83	121.88	975.28	31.229	34.249	28.209	0.2563	0.2811	0.2315
7	110.06	110.19	748.60	27.360	30.029	24.691	0.2485	0.2728	0.2243
8	125.97	125.24	550.25	23.457	25.746	21.168	0.1862	0.2043	0.1680
10	106.45	106.12	798.83	28.263	30.965	25.562	0.2654	0.2908	0.2401
11	114.92	115.27	748.67	27.361	29.942	24.781	0.2380	0.2605	0.2156
12	103.20	103.88	495.05	22.249	24.477	20.021	0.2155	0.2371	0.1940
13	115.71	114.46	842.50	29.025	31.659	26.392	0.2508	0.2736	0.2280
15	91.953	91.657	520.31	22.810	24.875	20.745	0.2480	0.2705	0.2256
Prov.	114.13	113.22	956.58	30.928	33.939	27.918	0.2709	0.2973	0.2446

--WHEAT(Price + Crop INSURED)

Region	Insured Income	Exp. Income	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	110.78	109.72	954.30	30.891	32.974	28.809	0.2788	0.2976	0.2600
2	138.87	121.95	1977.4	44.468	47.420	41.515	0.3202	0.3414	0.2989
3	122.80	120.15	1349.2	36.732	40.882	32.583	0.2991	0.3329	0.2653
4	95.734	94.261	544.48	23.334	25.326	21.341	0.2437	0.2645	0.2229
5	122.23	118.79	892.90	29.881	31.748	28.014	0.2444	0.2597	0.2291
6	128.48	127.16	1022.4	31.976	34.708	29.244	0.2488	0.2701	0.2276
7	116.85	116.04	756.36	27.502	29.381	25.622	0.2353	0.2514	0.2192
8	133.88	131.71	829.41	28.799	31.472	26.127	0.2150	0.2350	0.1951
10	117.26	116.08	567.21	23.816	25.149	22.482	0.2031	0.2144	0.1917
11	132.11	138.84	1018.3	31.911	34.707	29.115	0.2415	0.2627	0.2203
12	111.38	111.51	359.86	18.970	21.108	16.831	0.1703	0.1895	0.1511
13	125.89	124.73	967.91	31.111	34.318	27.904	0.2471	0.2725	0.2216
15	110.31	109.82	853.51	29.214	31.159	27.270	0.2648	0.2824	0.2472
Prov.	121.05	118.46	935.98	30.593	31.269	29.917	0.2527	0.2583	0.2471

--BARLE(PRICE + CROP INSURED)

Region	Insured Income	Exp. Inc.	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	104.90	115.39	1226.4	35.019	40.529	29.510	0.3338	0.3863	0.2813
2	149.47	149.65	1688.4	41.091	44.870	37.312	0.2748	0.3001	0.2496
3	116.69	116.00	1378.0	37.122	40.544	33.700	0.3181	0.3474	0.2887
4	85.042	85.586	351.52	18.748	20.207	17.290	0.2204	0.2376	0.2033
5	122.41	119.95	1173.4	34.256	37.501	31.010	0.2798	0.3063	0.2533
6	121.66	122.45	880.76	29.677	32.451	26.904	0.2439	0.2667	0.2211
7	110.54	110.54	651.93	25.532	27.910	23.155	0.2309	0.2524	0.2094
8	125.21	125.16	509.38	22.569	24.711	20.427	0.1802	0.1973	0.1631
10	106.56	106.12	763.73	27.635	30.250	25.021	0.2593	0.2838	0.2348
11	114.64	115.32	673.92	25.960	28.327	23.592	0.2264	0.2470	0.2057
12	103.01	103.90	472.53	21.737	23.884	19.590	0.2110	0.2318	0.1901
13	115.11	114.21	801.45	28.309	30.827	25.792	0.2459	0.2677	0.2240
15	92.358	91.779	485.38	22.031	23.988	20.074	0.2385	0.2597	0.2173
Prov.	114.23	114.35	822.72	28.683	31.906	25.459	0.2510	0.2792	0.2228

--CANOL(PRICE + CROP-INSURED)

Region	Insured Income	Exp. Inc.	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	151.78	115.57	2481.4	49.814	57.622	42.006	0.3281	0.3796	0.2767
2	181.52	178.02	2641.4	51.394	55.062	47.726	0.2831	0.3033	0.2629
3	147.12	146.20	1825.1	42.721	47.687	[illegible]	0.2903	0.3241	0.2566
4	117.87	105.91	752.14	27.425	30.964	23.88[illegible]	0.2326	0.2626	0.2026
5	151.32	148.12	1883.1	43.395	46.150	40.639	0.2867	0.3049	0.2685
6	157.35	155.70	1671.0	40.878	44.208	37.548	0.2597	0.2809	0.2386
7	160.00	159.80	1256.7	35.451	37.750	33.151	0.2215	0.2359	0.2071
8	182.68	181.56	1372.3	37.045	39.937	34.153	0.2027	0.2186	0.1869
10	157.89	158.32	1244.2	35.273	37.275	33.271	0.2233	0.2360	0.2107
11	149.44	150.77	[illegible]	38.253	41.569	34.937	0.2559	0.2781	0.2337
12	130.21	131.08	[illegible]	36.957	41.561	32.353	0.2838	0.3191	0.2484
13	143.13	132.14	1882.7	43.390	47.905	38.875	0.3031	0.3346	0.2715
15	114.72	115.63	1058.8	32.540	34.660	30.420	0.2836	0.3021	0.2651
Prov.	152.50	148.11	1565.4	39.566	40.467	38.664	0.2594	0.2653	0.2535

--CWB WHEAT(PRICE + CROP INSURED)

Region	Insured Income	Exp. Income	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	119.82	117.29	1063.6	32.612	30.233	34.991	0.2721	0.2523	0.2920
2	151.05	131.02	233.5	15.280	11.853	18.707	0.1011	0.0784	0.1238
3	133.41	129.78	1365.7	36.956	34.068	39.844	0.2769	0.2553	0.2986
4	103.41	101.31	1102.2	33.199	31.185	35.212	0.3210	0.3015	0.3405
5	136.43	134.29	1179.6	34.345	31.733	36.957	0.2517	0.2325	0.2708
6	138.86	136.72	859.12	29.310	26.761	31.859	0.2110	0.1927	0.2294
7	126.51	124.9	965.8	31.077	28.561	33.592	0.2456	0.2257	0.2655
8	144.92	141.58	631.92	25.138	22.351	27.924	0.1734	0.1542	0.1926
10	126.28	124.7	1122.8	33.508	31.452	35.563	0.2653	0.2490	0.2816
11	141.41	148.6	409.54	20.237	17.752	22.721	0.1431	0.1255	0.1606
12	118.90	118.88	1110.1	33.318	31.572	35.064	0.2802	0.2655	0.2949
13	134.42	132.96	1000	31.622	29.179	34.065	0.2352	0.2170	0.2534
15	119.39	117.93	1470.6	38.349	35.970	40.728	0.3211	0.3012	0.3411
Prov.	131.29	128.04	1080.3	32.867	30.274	35.461	0.2503	0.2305	0.2700

--CWB-BARLEY(PRICE + CROP INSURED)

Region	Insured Income	Exp. Inc.	MSE	RMSE	CL(RMSE) (1)	CL(RMSE) (2)	CV	CLcv (1)	CLcv (2)
1	106.16	105.22	853.1	29.207	31.758	26.657	0.2751	0.2991	0.2510
2	151.46	149.91	1436.8	37.905	41.432	34.379	0.2502	0.2735	0.2269
3	118.15	116.59	1143.3	33.812	36.93	30.696	0.2861	0.3125	0.2598
4	85.126	85.512	337.4	18.368	19.842	16.894	0.2157	0.2330	0.1984
5	127.84	124.2	1407.8	37.520	40.937	34.106	0.2934	0.3202	0.2667
6	122.56	122.61	841	29	31.705	26.294	0.2366	0.2586	0.2145
7	110.78	110.96	590.29	24.295	26.542	22.049	0.2193	0.2395	0.1990
8	126.29	125.62	477.79	21.858	23.891	19.825	0.1730	0.1891	0.1569
10	106.81	106.44	625.73	25.014	27.332	22.696	0.2341	0.2558	0.2124
11	115.50	115.85	611.96	24.737	26.943	22.532	0.2141	0.2332	0.1950
12	103.30	103.98	418.1	20.447	22.389	18.505	0.1979	0.2167	0.1791
13	115.79	114.57	710.23	26.650	28.977	24.322	0.2301	0.2502	0.2100
15	92.372	92.115	462.36	21.502	23.431	19.573	0.2327	0.2536	0.2118
Prov.	115.56	114.63	807.28	28.412	31.094	25.731	0.2458	0.2690	0.2226

Appendix E Regional Autocorrelation Tests

SERIAL CORRELATION TESTS

VARIABLE	RHO	T-STAT.
Region#1		
Chicago Wheat	-.09399	-.3053
Winn. Barley	.07932	.2892
Winn. Canola	-.3366	-1.137
CWB wheat	-.1953	-.6297
CWB Barley	-.1652	-.5991
Chic. Wheat price	-.2293	-.7058
Winn. Brly price	-.5495	-2.080
Winn. Canola price	-.2926	-1.2765
CWB wheat price	-.0245	-.0863
CWB barley price	-.1995	-.6284
wheat yield	.0265	.0912
barley yield	-.2533	-1.223
canola yield	-.0876	.3964
wheat discount ft.	.7095	3.207**
barley discount ft.	.3032	1.0095
canola discount ft.	.3441	1.1589
Region#2		
Chicago Wheat	.1399	.4350
Winn. Barley	.0769	.2616
Winn. Canola	.4288	1.2809
CWB wheat	.3438	1.1444
CWB Barley	.1023	.3208
Chic. Wheat price	.2784	1.0113
Winn. Brly price	.1237	.4491
Winn. Canola price	-.238	-.7762
CWB wheat price	.3161	1.0894
CWB barley price	-.0448	.1461
wheat yield	.2114	.69242
barley yield	-.1911	-.5691
canola yield	.6984	2.1053
wheat discount ft.	.9512	6.1594**
barley discount ft.	-.1198	-.4197
canola discount ft.	-.1303	-.4019
Region#3		
Chicago Wheat	.2023	.6714
Winn. Barley	.07843	.2500
Winn. Canola	.3417	1.1191
CWB wheat	.3269	1.1199
CWB Barley	.05805	.1838
Chic. Wheat price	.4148	1.5878
Winn. Brly price	.0527	.1648
Winn. Canola price	.1245	.3904
CWB wheat price	-.09112	-.2896
CWB barley price	.1792	.5760
wheat yield	.1769	.5850
barley yield	.1341	.4287
canola yield	.3236	1.0572
wheat discount ft.	-.09431	-.2996
barley discount ft.	.1825	.5869
canola discount ft.	-.0911	-.2893

Region#4		
Chicago Wheat	.1201	.3749
Winn. Barley	.0118	.0321
Winn. Canola	-.0685	-.2056
CWB wheat	.3231	1.0649
CWB Barley	.0634	.1968
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.325
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.04759	.1583
wheat yield	-.1075	-.3583
barley yield	-.1885	-.6121
canola yield	.0070	.0219
wheat discount ft.	.1257	.4301
barley discount ft.	-.28113	-.9287
canola discount ft.	-.0352	-.1123
Region#5		
Chicago Wheat	.2058	.8893
Winn. Barley	-.0390	-.0999
Winn. Canola	.2710	.8649
CWB wheat	.2721	1.0929
CWB Barley	.1204	.4010
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.3254
Winn. Canola price	-.4578	-1.7596
CWB wheat price	.4323	1.4932
CWB barley price	.0476	.1583
wheat yield	.1808	.9495
barley yield	.2253	.8318
canola yield	.4361	1.566
wheat discount ft.	.1204	.3915
barley discount ft.	-.0320	-.1015
canola discount ft.	-.0351	-.1069
Region#6		
Chicago Wheat	.5153	1.9583
Winn. Barley	.5217	1.2681
Winn. Canola	.1995	.60812
CWB wheat	.5453	2.097
CWB Barley	.2558	.6868
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.3254
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.0476	.1583
barley yield	-.0414	-.10233
canola yield	-.0986	-.3084
wheat discount ft.	.1966	.6541
barley discount ft.	-.2196	-.8319
canola discount ft.	.0140	.0447

Region#7		
Chicago Wheat	.1613	.5219
Winn. Barley	-.0605	-.1774
Winn. Canola	-.1758	-.5904
CWB wheat	.3183	1.0748
CWB Barley	.0179	.0636
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.3254
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.0476	.1583
wheat yield	-.2309	-.7513
barley yield	-.3917	-1.361
canola yield	.03015	.0967
wheat discount ft.	.1355	.4650
barley discount ft.	-.4261	-1.475
canola discount ft.	-.1161	-.3677
Region#8		
Chicago Wheat	.0614	.1840
Winn. Barley	-.1125	-.3245
Winn. Canola	-.1895	-.6129
CWB wheat	.3827	1.230
CWB Barley	-.4044	-1.3844
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.325
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.0476	.1583
wheat yield	-.4471	-1.5817
barley yield	-.3540	-1.2189
canola yield	-.3119	-1.0249
wheat discount ft.	.2135	.7597
barley discount ft.	.2628	.9132
canola discount ft.	-.0851	-.2721
Region#10		
Chicago Wheat	-.1514	-.4778
Winn. Barley	-.3403	-1.2497
Winn. Canola	-.3367	-1.1322
CWB wheat	.3527	1.1903
CWB Barley	-.1577	-.5621
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.3254
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.0476	.1583
wheat yield	-.1770	-.5517
barley yield	-.5278	-1.958
canola yield	-.3982	-1.3487
wheat discount ft.	.2993	1.193
barley discount ft.	-.0419	-.1904
canola discount ft.	-.0575	-.1801

Region#11		
Chicago Wheat	.2281	.8589
Winn. Barley	.4393	1.0877
Winn. Canola	-.1526	-.4776
CWB wheat	.3678	1.4089
CWB Barley	.1309	.4209
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.3254
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.0476	.1583
wheat yield	.1355	.4733
barley yield	-.3319	-.1138
canola yield	-.0638	-.2109
wheat discount ft.	.01666	.0566
barley discount ft.	-.1621	-.5208
canola discount ft.	-.1581	-.5116
Region#12		
Chicago Wheat	.3003	.9230
Winn. Barley	.2247	.6896
Winn. Canola	.01279	.0431
CWB wheat	.4058	1.307
CWB Barley	.0196	.0633
Chic. Wheat price	.5461	1.9916
Winn. Brly price	.4182	1.3254
Winn. Canola price	-.2143	-.7178
CWB wheat price	.4323	1.4932
CWB barley price	.0478	.1583
wheat yield	-.2121	-.6851
barley yield	.0976	.3075
canola yield	.0022	.00713
wheat discount ft.	-.097	-.356
barley discount ft.	-.1162	-.3990
canola discount ft.	.3629	1.2023
Region#13		
Chicago Wheat	.0563	.1755
Winn. Barley	-.0093	-.0288
Winn. Canola	.0884	.2656
CWB wheat	.1338	.4219
CWB Barley	.01414	.0442
Chic. Wheat price	.5673	2.0813
Winn. Brly price	.3912	1.264
Winn. Canola price	-.2448	-.8296
CWB wheat price	.4087	1.3982
CWB barley price	.0515	.1715
wheat yield	-.0894	-.2874
barley yield	.1233	.3956
canola yield	.2911	.9273
wheat discount ft.	-.0472	-.1768
barley discount ft.	-.3838	-1.283
canola discount ft.	.3056	1.1944

Region#15		
Chicago Wheat	-.3153	-1.1092
Winn. Barley	-.0201	-.0683
Winn. Canola	-.1849	-.7118
CWB wheat	-.04558	-.1485
CWB Barley	-.1918	-.0319
Chic. Wheat price	.5671	1.576
Winn. Brly price	.1119	.4165
Winn. Canola price	.2837	.9772
CWB wheat price	.4850	1.826
CWB barley price	.0333	.1109
wheat yield	-.2355	-.7973
barley yield	-.1576	-.5048
canola yield	-.0299	-.1027
wheat discount ft.	.0505	.2371
barley discount ft.	.1478	.5326
canola discount ft.	-.3504	-1.2486

If cost data were available, mathematical portfolio analysis could be used to develop E,V frontiers. The following mathematical demonstration is purely illustrative. Mathematically, the problem may be approached as one of risk minimization given the constraints of income and resource use. A Lagrangian objective function (z) for risk minimization may be represented as:

$$Z=\Sigma\Sigma w_i w_j \sigma_{ij} + \lambda_1(\Sigma w_i E_i - E^*) + \lambda_2(\Sigma E w_i - 1)$$

where: w_i = weight of each crop

E = expected income

λ_1 = income constraint

λ_2 = resource constraint

$$Var(r_p) = w_1^2(\sigma_{11}+\sigma_{33}-2\sigma_{13}) + w_2^2(\sigma_{22}+\sigma_{33}-2\sigma_{23}) + w_1(2\sigma_{13}-2\sigma_{33}) + w_2(2\sigma_{23}-2\sigma_{33}) + w_1 w_2 (2\sigma_{33}+2\sigma_{12}-2\sigma_{13}-2\sigma_{23}) + \sigma_{33}.$$

Isovariance elipses are the locus of points which represent portfolios with the same variability. These elipses are equivalent to risk isoquants.

If $A = \sigma_{11}+\sigma_{33}-2\sigma_{13}$

$B = 2\sigma_{13}-2\sigma_{33}+2w_2(\sigma_{33}+\sigma_{12}-\sigma_{13}-\sigma_{23})$

$C = w_2^2(\sigma_{22}+\sigma_{33}-2\sigma_{23}) + w_2(2\sigma_{23}-2\sigma_{33}) + \sigma_{33} - Var(r_p$

$w_1 = -B +/- \sqrt{B^2-4AC}/2A$

Using the above procedure for graphing isovariance elipses, the following isovariance elipses represent the risk isoquants for unisured wheat, barley, and canola revenue.

The first order conditions of the Lagrangian objective function will be:

$\partial Z/\partial w1 = 2w_1\sigma_{11} + 2w_2\sigma_{12} + 2w_3\sigma_{13} + \lambda_1 E_1 + \lambda_2 = 0$

$\partial Z/\partial w2 = 2w_1\sigma_{21} + 2w_2\sigma_{22} + 2w_3\sigma_{23} + \lambda_1 E_2 + \lambda_2 = 0$

$\partial Z/\partial w3 = 2w_1\sigma_{31} + 2w_2\sigma_{32} + 2w_3\sigma_{33} + \lambda_1 E_3 + \lambda_2 = 0$

$\partial Z/\partial \lambda_2 = w_1 + w_2 + w_3 \ 1 = 0$

$\partial Z/\partial \lambda_1 = w_1 E_1 + w_2 E_2 + w_3 E_3 - E^* = 0$

matrix:

$$\underbrace{\begin{bmatrix} 2\sigma_{11} & 2\sigma_{12} & 2\sigma_{13} & E_1 & 1 \\ 2\sigma_{21} & 2\sigma_{22} & \sigma_{23} & E_2 & 1 \\ 2\sigma_{31} & 2\sigma_{32} & \sigma_{33} & E_3 & 1 \\ 1 & 1 & 1 & 0 & 0 \\ E_1 & E_2 & E_3 & 0 & 0 \end{bmatrix}}_{C} \underbrace{\begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \lambda_1 \\ \lambda_2 \end{bmatrix}}_{w} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \\ E^* \end{bmatrix}$$

The efficient frontier may be generated by inverting the matrix C representation and altering E^*. Note this analysis assumes full knowledge of costs, but has been included to illustrate the technical approach . By substituting information from the uninsured revenue covariances, the following graph resulted:

where $w_1 = -.0312 + .0038E^*$

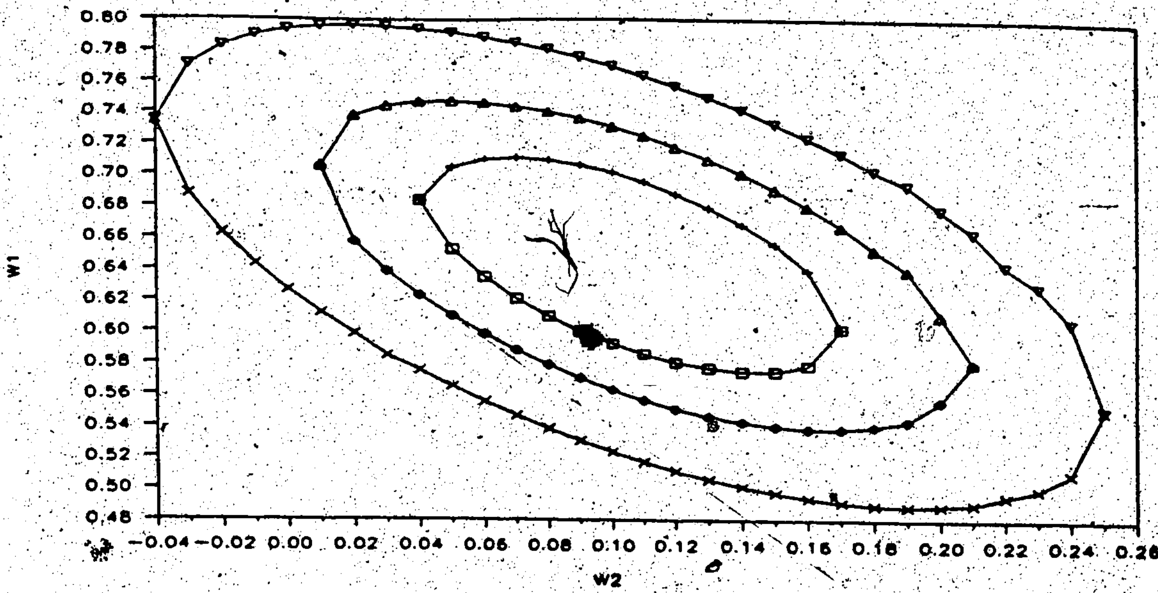
$w_2 = 5.86 - .0452E^*$

$w_3 = -4.833 + .0414E^*$

$\lambda_1 = 1428.285 - 11.508E^*$

$\lambda_2 = -176312.7 + 1405.9E^*$

Isovariance Elipses



Efficiency Frontier