AGRICULTURAL RISK MANAGEMENT DECISION MODELING FOR THE US PACIFIC NORTHWEST

By

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Chair

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Abstract

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The dissertation includes both empirical and theoretical studies in risk management for Pacific Northwest (PNW) farmers. Chapter one gives a brief introduction of the structure and contents of the following three studies.

Chapter two uses a mean-variance model to assess the risk management impact of cross hedging with alternative futures contracts (Chicago - CBOT, Kansas City - KCBT, or Minneapolis - MGE) for PNW soft white wheat hedgers. Since existing measures of liquidity costs are limited, a breakeven approach is developed to assess the risk management effect of the alternative futures markets. Results suggest KCBT is the best choice for risk protection in most cases. The MGE ranks the lowest and the CBOT is in the middle.

The goal of the chapter three is to develop a general mean-variance-skewness (MVS) model and compare it and the traditional mean-variance (MV) model against the expected utility (EU) model in the setting of an individual producer hedging in the futures market. Optimal solutions of optimal hedge ratios and comparative statics are derived. The optimal hedge ratios from MV and MVS models are numerically compared with that of EU model under alternative preference

parameters. Results show that: 1) the derived linear MVS model maintains the analytical convenience of MV model, 2) it can generate different results as MV, 3) it approximate EU better than MV, and 4) it is more flexible than MV.

Chapter four is to assess income risks of PNW apple growers and the effect of the apple crop insurance program. We have examined the income risks of conventional and organic production; and evaluate the roles of Grower Yield Certification (GYC) and a hypothesized Income Protection insurance for Red Delicious, Golden Delicious, Gala and Fuji. Results show organic apple growers earn higher expected revenue, incur higher production cost, make higher expected profit, but face higher income risks than conventional growers. Based on government investment in premium subsidies, revenue insurance is more cost effective. Organic apple production risks are higher than their conventional counterparts, causing the current GYC premium to be below the expected indemnity (except Gala).

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CHAPTER ONE

INTRODUCTION

In agricultural production, price risk and yield risk are the main risks faced by a farmer. Forward, futures and options are the three basic types of market driven risk management tools to protect a farmer from price risk. In addition, the United States government has provided pricing programs to help the farmer manage his price risk and crop insurance to manage the yield risk. This dissertation will concentrate on futures market and crop insurance. Each of the following three chapters focuses on a different set of issues. They are summarized in the rest of this chapter.

The Pacific Northwest (PNW) region produces about 80 to 90 percent of the soft white wheat in the US, and wheat is one of the region's major cash crops. Traditionally, the region's wheat producers have not used hedging extensively for price risk management. The lack of an inherent futures contract for soft white wheat is likely a major reason. Thus, the need to cross hedge PNW wheat using market classes with an inherent futures contract (hard red winter on Kansas City -KCBOT, soft red winter on Chicago - CBOT, or hard spring on Minneapolis - MGE) presents some unique basis issues. The idea of hedging a commodity for which no futures market exists (cross hedging) has become a common practice. Anderson and Danthine (1981) generally suggested cross hedging may be an appropriate risk management tool and such hedges can be evaluated just like a standard hedge. Although Wilson (1983) looked at cross hedging wheat in the US, an important class of wheat (soft white) was not included in the analysis.

The overall objective of chapter two is to determine which futures contract (CBOT, KCBOT, or MGE) maximizes utility of PNW soft white wheat hedgers. A standard mean-variance utility model is used to define the utility maximization equation, which includes the appropriate hedge ratios and a range of risk aversion coefficients. Results suggest that the KCBT may dominate the other two markets in terms of best protecting cross-hedging risk for soft white wheat in the Pacific Northwest, especially for large hedgers. This is generally true unless the true liquidity cost for the KCBT relative to Chicago is at or above currently available estimates. The MGE appears to be less effective given reasonable expectations of liquidity costs levels for the MGE, although precise estimates are not available. Results certainly suggest Kansas City should be given more attention as a hedging vehicle for soft white wheat in the Pacific Northwest region.

Chapter two is an applied study on futures market. Chapter three focuses more on theoretical aspect of futures and develops a general mean-variance-skewness (MVS) model based on the widely used mean-variance (MV) model. The linear mean-variance (MV) model has been widely used in finance and economic decision analysis as an approximation of Von Neumann-Morgenstern expected utility (EU) model. The MV model requires less information from decision makers' preference and random distributions than EU models in addition to its very convenient form for analytical work. Since conditions that guarantee the exact consistency between the MV and EU models are restrictive, many studies have expanded the model to incorporate higher moments.

The introduction of third or higher moments not only can improve the accuracy of the approximation, but is also suitable to represent investors' skewness preference (prudence) with the latter supported by empirical evidence. Literature of developing such MVS models or applying any form of three moment models to agricultural risk management is rarely found.

The goal of chapter three is to develop a general MVS model and compare it and the traditional MV model against the EU model in the setting of an individual producer hedging in the futures market. Kimball's absolute prudence which is isomorphic to Arrow-Pratt's risk aversion, is incorporated in the MVS model as well as the risk aversion level. The closed form solutions and comparative statics of OHR from both MV and MVS models are compared theoretically, which leads to important propositions.

Because closed form solutions from EU models are generally not available, the numerical analysis is used to benchmark MV and MVS against EU based on a field crop grower who faces uncertain price and yield and makes a decision on hedging in the futures market. Joint Gamma distributions of stochastic prices and yields are simulated with alternative set of parameters. Risk preference parameters are set around the commonly used constant relative risk aversion (CRRA) type of utility functions. Both sets of parameters are calibrated based on a US dryland wheat grower hedging in a wheat futures market. Numerical optimizations are obtained with sensitivity analysis, especially on prudence coefficient to reveal its impacts on hedging decision.

The OHRs derived from the MV and MVS models are identical only when: 1) the decision maker is "prudence neutral" or; 2) assuming unbiased futures market and perfect correlation at both second moment and third moment levels. Otherwise, the two models will yield different

OHRs. The OHR of MVS model changes in the same direction as that of the MV model when the initial futures price, covariance of cash and futures prices, and risk aversion coefficient changes one at a time. The signs on the comparative statics of the MVS OHR on the other parameters such as the prudence level, skewness of futures prices and coskewness of futures and cash prices are ambiguous unless further conditions are considered. For example, the MVS OHR will be “longer” so as to increase the benefit from increased profit skewness when the futures price is more skewed.

Numerical results show the OHRs from the MVS model is closer to those from EU model than MV model OHRs in all situations considered. This evidence suggests MVS model is superior to MV model. The farmer hedges more (or less) under the MVS model than the MV model when he/she is in a long (short) position.

The influences of risk aversion and prudence on OHRs for the MVS model are also examined by extending the ranges of relative risk aversion and prudence from the common CRRA utility preferences. The numerical results show the farmer full-hedges in the unbiased market and hedges less as risk aversion increases in the biased futures market. The hedging position decreases as the farmer becomes more prudent. Risk aversion has a greater influence on OHR than prudence in the case of biased futures market. The certainty equivalent consistently decreases as the risk aversion increases in both biased and unbiased market, but the certainty equivalent does not necessarily increase with prudence.

It has great potential to generate discussions. Although EU is widely used in risk analysis and numerical analysis can be easily carried when analytical results are not feasible, MVS as an approximation to EU is still meaningful because it can explicitly model and measure the decision maker's preference for the third moment. The model can be applied to other risk management instruments in agricultural markets, and can be extended to incorporate higher moments.

Chapter four discusses crop insurance for PNW apple growers to protect from yield risk. PNW, especially the state of Washington, is the leading region in both conventional and organic apple production. PNW apples are primarily grown for the high value fresh market due to their high quality. This higher quality also requires higher production costs, which in turn results in high profit risks for apple growers, when couple with adverse weather conditions, insects and plant diseases, and other factors.

Apple crop insurance is a major risk management tool for apple growers. However, the current apple crop insurance program only offers a yield based program. A frequent complaint made by PNW apple growers is that national insurance programs do not provide adequate coverage for high valued apples, which is more problematic for organic apples. The price selection level in GYC is set low compared to the fresh market price for PNW apples (4.65 \$/box for Red Delicious and Golden Delicious and 6.45 \$/box for Gala and Fuji). The yield coverage level is also low, ranges only to 75%. So far, no work has been found assessing the effect of the apple crop insurance program on either conventional or organic apple production.

The goal of chapter four is to assess income risks of PNW apple growers and the risk management effect of the apple crop insurance program by varieties (Red Delicious, Golden Delicious, Gala and Fuji). Income risks are represented by the distributions of growers' production income. The risk management effects of insurance programs are based on growers' expected utility models. We assume a representative apple grower chooses an insurance coverage level to maximize expected utility of wealth, composed of initial wealth, random production income and insurance transactions. Insurance can be GYC, and a hypothetical income protection insurance product. Insurance premiums are developed based on the actual premium structure.

Results show organic apple growers earn higher expected revenue, incur higher production cost (excluding establishment cost), make higher expected profit, but face higher income risks than conventional apple growers. In terms of certainty equivalent, that income insurance is not necessarily preferable than yield insurance by growers because the base price is set too low compared to its corresponding market cash price. However, from the point of view of the government investment in premium subsidies, revenue insurance is always more cost effective for all varieties and for both conventional and organic practices.

Organic apple production risks are higher than their conventional counterparts, causing the current GYC premium to be below the expected indemnity even before the subsidy and after the organic premium inflation factor (except Gala) based on our survey data. Gala apple production is less risky for both conventional and organic apple growers. Consequently, Galas benefit little from insurance and organic Gala becomes an exception from the other organic varieties, namely, the current GYC premium is above the expected indemnity. In the future insurance parameter setting, it would be good to separate at least Gala from the other varieties.

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CHAPTER TWO

CROSS HEDGING PNW SOFT WHITE WHEAT: CHICAGO, KANSAS CITY, OR MINNEAPOLIS

I. INTRODUCTION

The Pacific Northwest (PNW) region produces about 80 to 90 percent of the soft white wheat in the US, and wheat is one of the region's major cash crops. Traditionally, the region's wheat producers have not used hedging extensively for price risk management (Makus, et al., 1990). The lack of an inherent futures contract for soft white wheat is likely a major reason. Although the Minneapolis Grain Exchange (MGE) offered a white wheat futures contract for a number of years, the contract was thinly traded and has been discontinued. Thus, the need to cross hedge PNW soft white wheat using market classes with an inherent futures contract (hard red winter on the Kansas City Board of Trade -KCBT; soft red winter on the Chicago Board of Trade - CBOT; or hard red spring on the Minneapolis Grain Exchange - MGE) presents some unique challenges to hedging wheat in the PNW. Cross hedging is a process of hedging a cash commodity with the futures contract of a different but related commodity (Graff, et al., 1997). Simple price correlations between the Portland cash price (the principal cash market for PNW soft white wheat), and the three available futures contracts suggest that all three markets are potential candidates (Table 2.1).

There are studies (Wilson, 1983; Brorsen, et. al., 1998; Franken and Parcell, 2003) on the effectiveness of cross-hedging specific commodities in different futures markets, but none analyze the effect of cross-hedging PNW soft white wheat. The CBOT has been used as the futures market to investigate PNW growers' hedging behavior (Ke and Wang, 2002), but no work has been done to carefully evaluate all of the alternative futures contracts.

The goal of the paper is to determine which futures contract (CBOT, KCBT, or MGE) provides the best risk management effect for PNW soft white wheat hedgers. The specific objectives include: (1) to estimate regression hedge ratios for each market under the assumption of zero transaction costs; (2) to calculate the maximized mean-variance utility hedge ratios with non-zero transaction costs; and (3) to compare the three futures markets using a break-even method to determine the potential impact of liquidity costs.

II. METHODOLOGY

The classical mean-variance model has been applied frequently to hedging analyses (Benninga, et. al., 1984; Myers and Thompson, 1989; Brorsen, et al., 1998; Franken and Parcell, 2003) since being introduced by Markowitz in the 1950s (Steinbach, 2001). Under certain conditions, the mean-variance model generally provides results consistent with the more comprehensive and popular expected utility models (Meyer, 1987). In the context of hedging, Benniga, et. al. (1984) identify the set of specific conditions. The mean-variance utility maximization problem can be specified as:

(1) $$MaxE(U(R)) = \max[E(R) - \frac{\lambda}{2}\mathrm{var}(R)]$$

where *U( )* is the utility function; *R* is the return from any risky investment; λ is the decision maker's absolute risk aversion coefficient, and *E*() and *Var*() are the expected value and variance operators. Following Leuthold, et. al. (1989), a hedging return *R* is specified as:

$$R = X_s(S_1 - S_0) + X_f(F_1 - F_0) - TC\,|\,X_f\,|$$

where X_s is the cash market holding; X_f is the hedging level in the futures market; S_0 and F_0 are the known cash and futures prices at the beginning of a hedge period when the hedging decision is made; S_1 and F_1 are the uncertain cash and future prices at the end of the period; and *TC* is the total transaction cost per unit hedged. Denoting σ^2_s, σ^2_f, and σ_{sf} as the variances and covariance of the cash and futures prices respectively, and assuming the cash and futures markets to be unbiased[1], the expected value and variance of the return from hedging become:

$$\begin{aligned} E(R) &= X_s(E(S_1) - S_0) + X_f(E(F_1) - F_0) - TC\left|X_f\right| \\ &= -TC\left|X_f\right| \end{aligned}$$

$$Var(R) = X_s^2\sigma_s^2 + X_f^2\sigma_f^2 + 2X_f X_s \sigma_{sf}$$

Take the first derivative of equation (1) with respect to the hedging level (X_f) to obtain[2]:

(2) $$X_f^* = TC/(\lambda\,\sigma_f^2) - X_s\sigma_{sf}/\sigma_f^2$$

Assuming zero transaction cost, equation (2) yields:

(3) $$b^* \equiv X_f^*/(-X_s) = \sigma_{sf}/\sigma_f^2$$

The ratio of the futures hedging level to the cash market holdings (b^*) is equal to the slope coefficient when cash prices are regressed on futures prices, which is also called the regression hedge ratio. Although there is some debate about a price level versus price change approach (Brown, 1985; Witt, et. al., 1987), the price change approach can be used to remove the unit root problem from the time series data. Thus, the regression hedge ratio can be achieved by estimating the following regression:

(4) $$(S_t - S_{t-k}) = \beta_0 + \beta_1 (F_t - F_{t-k}) + \nu_t$$

where *k* indicates the hedge period and can be used to represent short versus long term hedging behaviors; S_t - S_{t-k} and F_t - F_{t-k} represent the cash and future price differences from day *t* to day *t-k* respectively; and ν_t is the error term. The regression hedge ratio β_1, although not considered optimal when transaction costs are included, can be used as an estimate of σ_{sf}/σ^2_f in the equation to calculate the optimal hedge level. The optimal hedge level X^*_f is equal to the negative of the optimal hedge ratio if we assume X_s = 1 (that is, a one unit cash position). The maximized utility (*MU*) is calculated by substituting the optimal hedge value into equation (1), namely:

(5) $$MU = TC X^*_f - (\lambda/2)[\sigma^2_s + (X^*_f)^2 \sigma^2_f + 2X^*_f \sigma_{sf}]$$

Transaction costs are never equal to zero and should include some measure of commission costs as well as liquidity costs as suggested by Brorsen, et al., 1998. Good measures of liquidity cost in commodity futures markets are limited. Thompson, Eales, and Seibold (1993) estimated the liquidity costs for the CBOT and KCBT futures markets using methods developed by Roll (1984) and Thompson and Waller (1988). No work was found focusing on liquidity costs for the MGE. Even Thompson, et al. (1883) caution that their estimation of CBOT and KCBT liquidity costs has its limitation due to the short time period analyzed. Brorsen, et al. (1998) also point out another potential limitation of the Thompson, et al. (1993) measure of liquidity costs. Their concern relates to whether or not large hedgers can influence the bid-ask spread. Therefore, a break-even method is employed to eliminate the need for using a specific measure of liquidity costs for all three markets. The break-even relationship can be expressed by equating (5) for the compared market to a market selected as the benchmark. That is:

$$MU^C(TC^C) = MU^B(TC^B) \tag{6}$$

where MU^C and MU^B are the maximized utility of the compared and benchmark futures markets respectively, expressed as functions of TC^C and TC^B; TC^B is the true transaction cost of a benchmark market which is known or specified; TC^C is the break-even transaction cost of the compared market to make equation (6) hold. Combining equation (2), (5) and (6) and solving for TC^C yields:

$$TC^C = \lambda\sigma_f^2 - \sqrt{\lambda\sigma_f^2(\lambda\sigma_f^2 + 2MU^B)} \tag{7}$$

The higher the break-even transaction cost for the compared market relative to the benchmark market, the more effective the compared market is in regard to its risk reducing effect. Hedging in the compared market can bring about the same expected utility level to the hedger as from the benchmark market, even though the transaction cost of the compared market is higher. Thus, a high break-even transaction cost suggests the compared market is more effective.

III. DATA AND EMPIRICAL ANALYSIS

The analysis utilizes daily cash and futures prices from January 2, 1997 to June 30, 2003 (1,631 observations). Cash prices are daily prices provided by the USDA-Agricultural Marketing Service for soft white wheat delivered to Portland. Futures prices are daily settlement prices for the CBOT, KCBT, and MGE provided by the Commodity Research Bureau. Summary statistics for the price data are provided in table 2.1[3]. Hedging periods analyzed include 1, 21, 65, 130, and 260 days representing one day, one month, three months, six months, and one year hedges. The nearby futures contract is used for hedging, with the nearby being defined as the contract month closest to delivery without being in delivery when the hedge is lifted. A dummy variable is included in the regression model to capture the impact of the contract switching points.

Several diagnostic tests are conducted on the time series data to identify the appropriate specifications of the error terms for the regression model. The existence of a unit root in each time series is indicated by the Augmented Dickey-Fuller test. Thus, price changes rather than price levels are employed in the estimation as in equation (4). Conditional heteroscedasticity is also strongly indicated by the Q-test and Lagrange multiplier test (table 2.2). The sample autocorrelation function of residuals from simply regressing cash prices changes on futures prices changes shows spikes at lag 1 and *k*, where *k* corresponds to the different hedge periods. All of the above suggest a *k*th-order autoregressive error model with the GARCH variance model. Namely, the AR(*k*) - GARCH(1,1) regression model is the most appropriate. The Q test and Lagrange multiplier test are applied again to the suggested model and both support a good fit (Table 2.2). Equation (4) is now written as:

(4a) $$(S_t - S_{t-k}) = \beta_0 + \beta_1(F_t - F_{t-k}) + \beta_2 D - \rho_1 v_{t-1} - \rho_k v_{t-k} + \varepsilon_t$$

where *D* is the dummy variable with a value of 1 at the contract month switching point and 0 otherwise; ρ_1 and ρ_k are the first-order and *k*th-order autocorrelation parameters where *k* corresponds to the hedge period; v_{t-1} and v_{t-k} are the *1*st and *k*th-order autoregressive process which is:

$$v_{t-k} = (S_t - S_{t-k}) - \beta_0 - \beta_1 (F_t - F_{t-k});$$

and ε_t is the GARCH(1,1) variance model.

The absolute risk aversion level (λ) is allowed to vary from 0.2 to 1 as a way to observe how maximized utility responds to changes in the risk aversion level. The variances of cash prices and futures prices in the three markets are calculated directly from the data. The covariance of cash and futures prices is obtained by the multiplication of the regression hedge ratio and futures price variance.

Transaction costs include a commission cost and a liquidity cost. According to Brorsen, et al. (1998), the commission costs are 1.6 cents per bushel for small hedgers and 0.18 cents per bushel for large hedgers. Based on the Thompson, et al. (1993) estimation of liquidity cost at the CBOT and KCBT, two scenarios for liquidity costs are addressed. First, a liquidity cost of 0.25 cents per bushel is used for all three markets so that optimal hedge ratios and *MU* values can be compared. The lower range of the liquidity costs estimates from Thompson, et al. (1993) are 0.252 and 0.263 cents for the CBOT and KCBT, respectively. Second, 0.25 cents per bushel is used for the CBOT as the benchmark futures market, and break-even liquidity costs are calculated for the other two futures markets.

IV. RESULTS

The estimates of regression hedge ratios (no transaction cost) for the CBOT, KCBT, and

MGE futures markets are all significant at the 0.0001 level. Hedge ratios range from 0.30 to 0.36, indicating that about one-third of the cash position needs to be hedged in the futures market if there is no market transaction cost. These ratios for the three markets in five hedge periods are plotted in Figure 2.1, and the hedge ratios in the KCBT are higher than those in both the CBOT and MGE markets. Regression hedge ratios for the MGE futures market are generally between those for the KCBT and the CBOT. Without considering the transaction cost, the covariance between the futures and Portland cash prices relative to the variance of futures prices is highest for the KCBT, then the MGE, and lowest for the CBOT except the 1-day hedge period (CBOT is close to KCBT and higher than MGE). Or loosely speaking, the correlation between Portland cash and the futures prices accounting for the time series properties is highest for the KCBT and lowest for the CBOT with 1-day hedge period exception, quite different from the simple sample correlations reported in Table 2.1.

The hedging pattern is different when transaction costs are included. Table 2.3 shows the optimal hedge ratios for both small and large hedgers for the first scenario. Commission costs for small and large hedgers are set at 1.6 and 0.18 cents per bushel, respectively. Liquidity costs are 0.25 cents per bushel for all three futures markets. The optimal hedge ratios in the KCBT are still generally larger than those in the other two markets except that in the 1-day hedge period the optimal hedge ratios in the CBOT are the highest. However, the relative rank of the CBOT and MGE reflects some changes. Large hedgers generally have comparable optimum hedge ratios in the CBOT and MGE, with the CBOT being larger especially for the shorter term hedges. Small hedgers consistently have higher ratios in the CBOT than in the MGE regardless of risk aversion level. The optimal hedge ratio is higher in the CBOT in most cases when the commission cost is high (for small hedgers). The reason is that the optimal hedge ratio is monotonically increasing with regard to both the regression hedge ratio and variance of the futures prices with transaction costs as shown in equation (2). The regression hedge ratio is higher in the MGE, but the variance of the futures prices is higher in the CBOT. Thus, the relative rank between the CBOT and MGE is determined by a tradeoff between the regression hedge ratio effect and the futures price variance effect under the influence of risk aversion.

No hedging occurs for small hedgers facing a transaction cost when the risk aversion level is low (0.2). The optimal hedge ratios go up and converge toward the regression hedge ratios as the risk aversion level increases. This is because the more risk-averse hedgers are willing to discount the impact of any transaction cost.

The maximized utility values in Table 2.4, which are based on the equal liquidity cost scenario, show that the KCBT generally provides the highest utility values (smallest negative value).[4] The one-day hedge is the exception, where the CBOT has the highest utility value. The CBOT is the second best relative to maximized utility values, with the MGE ranking the lowest although optimal hedge ratios are about the same between the MGE and the CBOT in some cases. All the maximized utility values decrease as the risk aversion level increases, as expected. Larger hedgers always have higher maximized utility values because they pay lower transaction costs. Small hedgers (with high commission cost) have the same maximized utility values for all hedge periods when the risk aversion level is at 0.2 because they don’t hedge. Thus, only the variance of the cash price influences the utility value.

Since liquidity costs in the three markets are likely not equal, it is useful to use the break-even approach to assess the level of liquidity cost that provides the same level of utility (equation 7). Table 2.5 shows the break-even liquidity cost for the KCBT and MGE when the CBOT is selected as the benchmark market. The CBOT is assigned a liquidity cost equal to 0.25 cents per bushel based on Thompson, et al. (1993). The break-even liquidity costs are higher in the KCBT than those in the benchmark CBOT (except for the one day hedge) when the utilities in both markets are equated. In fact, trading on the KCBT is likely more expensive (higher liquidity costs) because of low trading volume (Brorsen, et al., 1998). From the Thompson, et al. (1993) estimation, KCBT liquidity costs range from 0.26 to 0.54 cents per bushel. The issue is how much more in liquidity costs can hedgers tolerate (relative to the CBOT), and still receive the same risk management effect.

If the highest estimated liquidity costs value for the KCBT is assumed (0.54 cents), any break-even liquidity cost value in table 2.5 for the KCBT above 0.54 cents suggests the compared futures market is superior to the benchmark market (the CBOT). The KCBT is generally superior at risk aversion levels above 0.60 and for the intermediate hedging periods (65 or 130 days). If the low range of the estimated liquidity cost for KCBT is assumed, (0.26 cents per bushel), the KCBT is superior for all hedge periods and risk aversion levels except for the one-day hedge period. This result is consistent for both small and large hedgers.

Results for the MGE are somewhat more problematic since no empirical estimates for liquidity costs are available. However, in order to achieve the same utility, liquidity costs for the MGE have to be very low or negative. Therefore, results suggest the CBOT is generally better than the MGE unless the liquidity costs for MGE are very low, which is unlikely given the low volume of the MGE relative to both the CBOT and KCBT.

V. SUMMARY AND CONCLUSION

A mean-variance version of the expected utility model is used to determine which futures contract (Chicago, Kansas city, or Minneapolis) provides the best risk management effect for Pacific Northwest soft white wheat hedgers. Regression hedge ratios are estimated first, as they provide a useful estimate needed to get the optimal hedge ratios. Transaction costs are included in the model, and both commission and liquidity costs are considered. Previous estimates of the liquidity cost for the KCBT cover a wide range, and such estimates are not available for the MGE wheat futures contract. Therefore, a break-even method is employed to compare risk management effects across the three futures markets. Five hedge periods (1, 21, 65, 130, and 260 days) with five risk aversion levels (0.20 to 1.00 in increments of 0.20) are analyzed.

The regression hedge ratios are different when compared to the optimal hedge ratios based on the mean-variance model when equal liquidity costs are assumed. Furthermore, the rank (based on size) of the hedge ratios changes in the three markets. The KCBT consistently has the largest regression hedge ratios, followed by the MGE and CBOT except the 1-day hedge period. When optimal hedge ratios are determined, the highest hedge ratios are still associated with the KCBT. Larger regression hedge ratios are associated with the CBOT relative to the MGE, although the two are close for the large hedge and longer hedge periods. All the optimal hedge ratios increase as the risk aversion level goes up, and they approach levels comparable to the regression hedge ratios.

Maximized utility values are consistently higher for the KCBT when the same level of liquidity cost (0.25 cents per bushel) is assumed for each exchange, except for the one-day hedge period. The CBOT ranks second, followed by the MGE. Maximized utility values are smaller with higher levels of risk aversion.

Since liquidity costs are likely different across exchanges, a break-even approach is used to assess the level of liquidity costs resulting in the same level of utility using the CBOT as the benchmark. Previous liquidity cost estimates for the CBOT are consistently around 0.25 cents per bushel, and the CBOT is more commonly used for hedging wheat in the Pacific Northwest. The KCBT can be superior to the CBOT for hedging effectiveness when the highest estimate (0.54 cents per bushel) of KCBT liquidity cost is used. However, results favor the CBOT for certain hedge periods and risk aversion levels. If the low range of KCBT liquidity costs estimates is assumed (0.26 cents per bushel), the KCBT is consistently superior with the one-day hedge still being the exception.

Although a liquidity cost estimate for the MGE is not available, break-even results suggest that the MGE should rank the lowest. The reason is that its liquidity cost has to be very low or negative in order to achieve the same utility as is available from the other two markets. Conceptually, the MGE's true liquidity cost should be higher given its volume relative to the CBOT and KCBT.

Results suggest that the KCBT may dominate the other two markets in terms of best protecting cross-hedging risk for soft white wheat in the Pacific Northwest, especially for large hedgers. This is generally true unless the true liquidity cost for the KCBT relative to Chicago is at or above currently available estimates. The MGE appears to be less effective given reasonable expectations of liquidity costs levels for the MGE, although precise estimates are not available. Results certainly suggest Kansas City should be given more attention as a hedging vehicle for soft white wheat in the Pacific Northwest region.

ENDNOTES

[1]The cash market is assumed unbiased when storage costs are included.

[2]It can be proved that X_f must have a non-positive value in an unbiased market for a hedger with a short cash position. Equation (2) is derived for a non-positive interior solution X_f when the exogenous variables on the right hand side satisfy the non-positive condition; otherwise a corner solution of $X_f = 0$ will be obtained which is of less interest.

[3]A few missing price values exist and are replaced with the price average from the two closest days.

[4]The maximized utility values are negative because unbiased futures and cash prices are assumed.

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Table 2.1. Summary Statistics for the Original Price Data (cents / bushel) and Correlation Coefficients

	Summary Statistics				Correlation Coefficients			
Variables	**Mean**	**Std. Dev.**	**Maximum**	**Minimum**	**Cash**	**CBOT**	**KCBT**	**MGE**
Cash	344.56	51.15	482.50	252.00	1.00	0.90	0.83	0.74
CBOT	297.97	45.13	441.75	230.75	0.90	1.00	0.94	0.88
KCBT	325.79	48.22	499.50	259.25	0.83	0.94	1.00	0.92
MGE	349.57	42.05	515.25	286.25	0.74	0.88	0.92	1.00

Table 2.2. The Q statistic (Q) test and Lagrange Multiplier (LM) Test for Identification of the Error Term

	Before AR (21)-GARCH (1, 1) model				After AR (21)-GARCH (1, 1) model			
Order	Q	Pr>Q	LM	Pr>LM	Q	Pr>Q	LM	Pr>LM
1	1352.73	<.0001	1349.87	<.0001	0.4459	0.5043	0.4511	0.5018
2	2467.87	<.0001	1350.37	<.0001	0.6095	0.7373	0.6117	0.7365
3	3343.53	<.0001	1353.52	<.0001	0.7100	0.8708	0.7121	0.8704
4	4048.77	<.0001	1354.56	<.0001	0.7106	0.9500	0.7142	0.9496
5	4603.84	<.0001	1354.89	<.0001	1.1065	0.9535	1.0801	0.9558
6	5017.84	<.0001	1357.25	<.0001	1.1935	0.9772	1.1871	0.9775
7	5320.71	<.0001	1357.25	<.0001	1.8452	0.9679	1.8303	0.9686
8	5547.59	<.0001	1357.91	<.0001	1.9796	0.9816	1.9523	0.9824
9	5717.69	<.0001	1357.93	<.0001	2.0085	0.9913	1.9677	0.9920
10	5860.24	<.0001	1360.32	<.0001	3.7725	0.9570	3.7156	0.9593
11	5982.23	<.0001	1360.44	<.0001	5.2864	0.9165	5.0536	0.9285
12	6094.09	<.0001	1360.66	<.0001	6.2677	0.9020	5.9156	0.9203

Note: The tests results are for the 21-day hedge period. Tests for the other hedge periods of 1, 65, 130, and 260 days are very similar to the 21-day hedge period, and are not presented.

Table 2.3. The Optimal Hedge Ratios for the Three Futures Markets with the Same Liquidity Cost at 0.25 cents / bushel for Five Hedge Periods and Alternative Risk Aversion Levels

	Alternative Risk Aversion Levels														
	0.200			0.400			0.600			0.800			1.000		
Hedge Period	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**
Small hedgers (commission cost = 1.6 cents per bushel)															
1 day	0	0	0	0.167	0.162	0.109	0.231	0.228	0.182	0.263	0.260	0.219	0.282	0.280	0.241
21 days	0	0	0	0.138	0.150	0.115	0.202	0.216	0.188	0.234	0.249	0.225	0.253	0.268	0.247
65 days	0	0	0	0.113	0.137	0.091	0.177	0.203	0.164	0.209	0.235	0.201	0.228	0.255	0.223
130 days	0	0	0	0.128	0.157	0.100	0.192	0.222	0.173	0.224	0.255	0.210	0.243	0.275	0.232
260 days	0	0	0	0.121	0.133	0.103	0.184	0.199	0.177	0.216	0.231	0.213	0.235	0.251	0.235
Large hedgers (commission cost = 0.18 cents per bushel)															
1 day	0.269	0.267	0.227	0.314	0.313	0.278	0.329	0.328	0.295	0.336	0.336	0.304	0.340	0.340	0.309
21 days	0.241	0.256	0.233	0.285	0.301	0.284	0.300	0.316	0.301	0.307	0.324	0.309	0.312	0.329	0.315
65 days	0.216	0.242	0.209	0.260	0.288	0.260	0.275	0.303	0.277	0.282	0.311	0.285	0.287	0.315	0.290
130 days	0.230	0.262	0.218	0.275	0.307	0.269	0.290	0.323	0.286	0.297	0.330	0.294	0.301	0.335	0.299
260 days	0.223	0.238	0.221	0.267	0.284	0.272	0.282	0.299	0.289	0.290	0.307	0.298	0.294	0.311	0.303

Note: All the hedge ratios should have negative signs representing a short hedge, so the negative sign is omitted from the table.

Table 2.4. Maximized Utility Values for the Three Futures Markets with the Same Liquidity Cost at 0.25 cents / bushel for Five Hedge Periods and Alternative Risk Aversion Levels

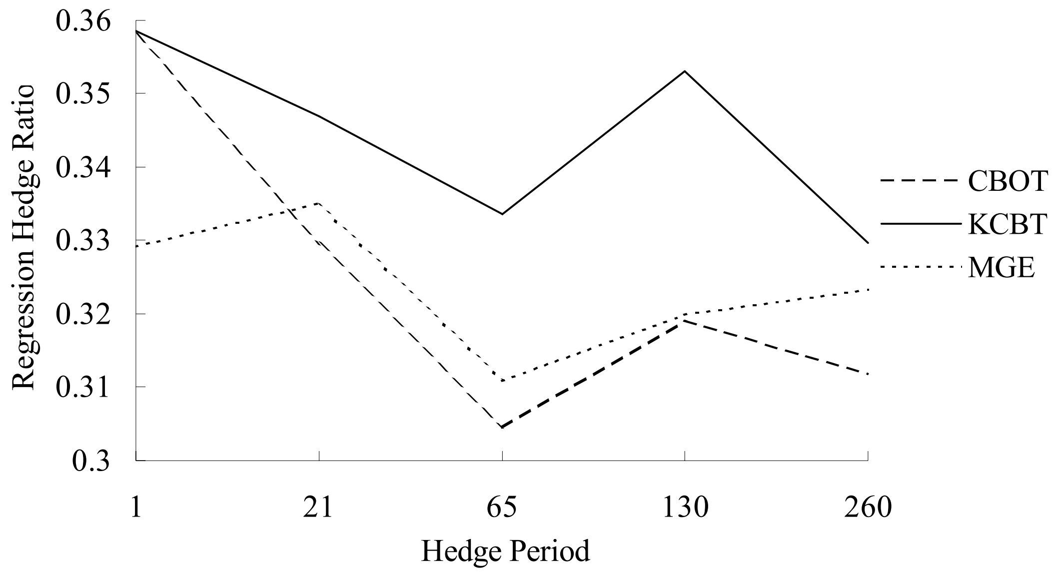
	Alternative Risk Aversion Levels														
	0.200			0.400			0.600			0.800			1.000		
Hedge Period	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**	**CBOT**	**KCBT**	**MGE**
Small hedgers (commission cost = 1.6 cents per bushel)															
1 day	-1.061	-1.061	-1.061	-1.988	-1.999	-2.073	-2.798	-2.819	-2.975	-3.579	-3.608	-3.842	-4.348	-4.385	-4.697
21 days	-1.061	-1.061	-1.061	-2.030	-2.016	-2.067	-2.888	-2.855	-2.961	-3.716	-3.664	-3.820	-4.532	-4.460	-4.666
65 days	-1.061	-1.061	-1.061	-2.061	-2.034	-2.088	-2.956	-2.895	-3.014	-3.823	-3.724	-3.907	-4.678	-4.542	-4.785
130 days	-1.061	-1.061	-1.061	-2.044	-2.008	-2.081	-2.918	-2.836	-2.995	-3.762	-3.634	-3.876	-4.595	-4.421	-4.742
260 days	-1.061	-1.061	-1.061	-2.053	-2.039	-2.078	-2.938	-2.906	-2.988	-3.794	-3.742	-3.863	-4.638	-4.565	-4.726
Large hedgers (commission cost = 0.18 cents per bushel)															
1 day	-0.886	-0.894	-0.953	-1.647	-1.662	-1.798	-2.401	-2.425	-2.636	-3.154	-3.185	-3.471	-3.906	-3.945	-4.306
21 days	-0.921	-0.908	-0.948	-1.729	-1.696	-1.784	-2.531	-2.477	-2.614	-3.331	-3.257	-3.441	-4.131	-4.036	-4.268
65 days	-0.949	-0.923	-0.970	-1.795	-1.733	-1.839	-2.635	-2.536	-2.701	-3.474	-3.337	-3.561	-4.312	-4.137	-4.421
130 days	-0.933	-0.900	-0.962	-1.758	-1.678	-1.819	-2.576	-2.449	-2.669	-3.393	-3.219	-3.518	-4.209	-3.988	-4.365
260 days	-0.941	-0.928	-0.959	-1.777	-1.743	-1.812	-2.607	-2.552	-2.657	-3.435	-3.359	-3.501	-4.262	-4.166	-4.344

Table 2.5. Break-even Liquidity Costs for KCBT and MGE with CBOT as the Benchmark Market Charging 0.25 cents / bushel in Liquidity Cost

	Alternative Risk Aversion Levels									
Hedge	**0.200**		**0.400**		**0.600**		**0.800**		**1.000**	
Period	**KCBT**	**MGE**	**KCBT**	**MGE**	**KCBT**	**MGE**	**KCBT**	**MGE**	**KCBT**	**MGE**
Small hedgers (commission cost = 1.6 cents per bushel)										
1 day	NA	NA	0.181	-0.339	0.160	-0.571	0.138	-0.803	0.117	-1.035
21 days	NA	NA	0.344	-0.033	0.404	-0.111	0.464	-0.190	0.523	-0.268
65 days	NA	NA	0.458	-0.010	0.574	-0.077	0.690	-0.144	0.807	-0.211
130 days	NA	NA	0.503	-0.065	0.642	-0.160	0.781	-0.254	0.920	-0.349
260 days	NA	NA	0.353	0.030	0.417	-0.017	0.481	-0.064	0.546	-0.110
Large hedgers (Commission cost = 0.18 cents per bushel)										
1 day	0.222	-0.011	0.202	-0.242	0.179	-0.475	0.158	-0.706	0.136	-0.938
21 days	0.303	0.142	0.363	0.063	0.423	-0.015	0.482	-0.094	0.544	-0.171
65 days	0.361	0.155	0.476	0.086	0.592	0.018	0.710	-0.047	0.827	-0.114
130 days	0.382	0.126	0.523	0.032	0.661	-0.063	0.801	-0.157	0.940	-0.251
260 days	0.307	0.173	0.372	0.126	0.438	0.081	0.502	0.034	0.565	-0.014

Note: When the risk aversion level is at 0.2, small hedgers don't hedge. The break-even transaction costs have no meaning at this level of risk aversion.

Figure 2.1. Comparison of Regression Hedge Ratios for the Three Futures Markets In Five Hedge Periods



CHAPTER THREE
RISK AVERSION, PRUDENCE, AND THE THREE-MOMENT DECISION MODEL FOR HEDGING

I. INTRODUCTION

A linear moment preference function has been widely used in decision analysis as an approximation of Von Neumann-Morgenstern expected utility (EU). The two-moment mean-variance model is the most popular. It was originated by Markowitz (1952) as a portfolio selection tool, extended by Tobin (1958) to include risk-free assets, and applied in equilibrium analysis by Sharpe (1964) and Lintner (1965) to the risk pricing of capital assets. It requires less information from decision makers and from random distributions than EU models. However, challenges (Borch, 1969; Feldstein, 1969) to the appropriateness of the approximation have caused the defenders of mean-variance to either modify the conditions or improve the model by adding more moments. Theoretically, the two-moment model can yield a consistent optimal decision with EU if 1) the decision maker's utility function is quadratic, or 2) the stochastic return is normally distributed (Tobin, 1958), or 3) the random variables satisfy the location-scale constraint (Meyer, 1987). However, Arrow and Hicks denounced a quadratic function as absurd because of its limited range of applicability and highly implausible implication of increasing absolute risk-aversion. On the other hand, the assumption of normal distribution of all risky outcomes is not realistic too since returns typically are not normally distributed.

Since all of these constraints are very restrictive, many studies have expanded the model to incorporate higher moments. Samuelson (1970) noted that higher than second moments improve the solution for any arbitrarily short, finite time interval. Tsiang

(1972) pointed out skewness preference may be prevalent in investor's behavior because modern financial institutions provided a number of devices for investors to increase the positive skewness of the returns of their investments. The skewness preference has received special attention in the asset pricing and portfolio theory (Kraus and Litzenberger, 1976; Friend and Westerfield, 1980; Sears and Wei, 1988; Lim 1989).

The three-moment model will be important for analytical studies on risk management decision modeling when the distribution is skewed. Poitras and Heaney (1999) compared the optimal demand for put options derived from the two moment and three moment models. It is shown theoretically the optimal demand for put options was reduced with positive skewness preference. However, they did not compare their results to the expected utility model, and their derived moment models require a specific utility form. Further development and application of three-moment model in agricultural risk management using derivatives are very limited.

In this paper, we will develop a general three-moment model and compare it and the traditional two-moment model to the expected utility in the setting of an individual producer hedging in the futures market. Specific objectives include (1) to theoretically develop the linear three-moment model analogue to the existing mean-variance model, (2) to apply it in the context of hedging and derive the optimal solution as well as comparative statics, and (3) to numerically compare the optimal hedge ratios (OHR) derived from the two-, three-moment models and the full expected utility model under alternative preference parameters. Only the second and third moments are concerned in this paper because higher moments add little, if any, information about the distribution's physical features (Arditti, 1967).

II. MODEL

A decision maker's preference can be represented by a Von Neumenn-Morgenstern utility function U(π). Using Taylor's expansion,

$$EU(\pi) = EU(\mu + \varepsilon)$$

$$\cong EU(\mu) + E[\varepsilon U'(\mu)] + E[\varepsilon^2 u''(\mu)]/2 + E[\varepsilon^3 u'''(\mu)]/3!$$

Where E() is the expected value operator, π is the random profit, μ is the expected profit, and ε is the error term with zero expected value. Because maximizing the utility function of the certainty equivalent is equivalent to maximizing the expected utility function (Robinson and Barry, 1987) and the utility function is monotonically increasing, the three-moment model in terms of mean, variance and skewness are derived as (Appendix A):

$$\text{(1)} \qquad Max\ \pi_{CE} = Max\ [E(\pi) - \frac{\lambda}{2}V(\pi) + \frac{\lambda\eta}{6}S(\pi)]$$

where π_{CE} is the certainty equivalent of profit; *E*(), *V*() and *S*() are the expectation, variance and skewness[1] operators; λ is Arrow-Pratt's absolute risk aversion coefficient, i.e., $-U''/U'$; η is Kimball (1990)'s absolute prudence level, i.e., $-U'''/U''$ which is isomorphic to Arrow-Pratt's absolute risk aversion. According to Kimball (1990), the absolute prudence measures the sensitivity of the optimal choice of a decision variable to risk. This term suggests the propensity to prepare and forearm oneself in the face of uncertainty while "risk aversion" measures how much one dislikes uncertainty and would turn away from uncertainty if possible. $\pi\eta$ is a measure of relative prudence, just as $\pi\lambda$ is a measure of relative risk aversion.

According to Arrow (1971), the essential properties for an investor's utility function are: (1) positive marginal utility for wealth, i.e., U'> 0, (2) decreasing marginal utility for wealth, i.e., U''< 0, and (3) non-increasing absolute risk aversion, i.e. U'''≥ 0. Thus both λ and η should be positive, i.e., the decision maker is risk averse and prudent. He/she would always desire positive skewness of return π when the mean and variance of the return remain constant. The two-moment model is equation (1) without the third term, or $\eta = 0$.

Assuming no transaction costs for trading futures contracts, the return π in the futures market for an individual farmer is specified as:

(2) $$\pi = \pi_0 + px - c + (f_0 - f)y$$

where π_0 is the initial wealth; p is the cash price at harvest; x is the nonstochastic production level; c is the cost of producing x; y is the hedging level in the futures market to be determined; f_0 is the price at planting time; f is the futures price at harvest. Denoting $\sigma_p^2, \sigma_f^2, \sigma_{pf}, s_p, s_f, \sigma_{p^2f}, \sigma_{pf^2}$ as the variances, covariance, skewnesses and coskewness of the cash and futures prices respectively[2], the expected value, variance and skewness of the return from hedging become:

(2.1) $$E(\pi) = \pi_0 + xE(p) - c + [f_0 - E(f)]y$$

(2.2) $$V(\pi) = x^2\sigma_p^2 + y^2\sigma_f^2 - 2xy\sigma_{pf}$$

(2.3) $$S(\pi) = x^3 s_p - y^3 s_f - 3x^2 y\sigma_{f^2p} + 3xy^2\sigma_{p^2f}$$

Substituting the specific expected value, variance and skewness of return in equation (1), the first order condition of the model yields:

(3) $$y^*_{MVS} = \frac{f_0 - E(f)}{\lambda\sigma_f^2} + \frac{\sigma_{pf}}{\sigma_f^2}x - \frac{\eta}{2\sigma_f^2}[s_f(y^*_{MVS})^2 + \sigma_{p^2f}x^2 - 2x\sigma_{f^2p}y^*_{MVS}]$$

where y^*_{MVS} is the optimal hedging levels for the three-moment models. The two-moment optimal hedge level y^*_{MV} equals the first two terms of equation (3). As expected, the optimal hedge levels from the two models are the same, or the three-moment model does not add any information upon the two-moment model, if the decision maker is "prudence neutral", i.e. $\eta = 0$.

The closed form solution for equation (3) is[3]:

$$y^*_{MVS} = \frac{x\sigma_{f^2p}}{s_f} + \frac{-\sigma_f^2 + \sqrt{\Delta}}{\eta s_f} \quad (4)$$

where $\Delta = (\sigma_f^2 - \eta x \sigma_{f^2p})^2 - \eta s_f[\eta x^2 \sigma_{f^2p} - 2x\sigma_{pf} - 2f_0/\lambda + 2E(f)/\lambda]$. It suggests that the solutions from the two models can be equal when the decision maker is not prudence neutral only if $\sigma_{fp} = \sigma_f^2, \sigma_{f^2p} = s_f$ and in the unbiased futures market ($f_0 = E(f)$). The farmer would fully hedge, namely, he or she will hedge the same amount as the production level in that case. Therefore, we have the following proposition.

Proposition 1: The optimal hedge levels of mean-variance and mean-variance-skewness models are equal if:

(i) the decision maker is "prudence neutral", i.e. $\eta = 0$ or;

(ii) $\sigma_{fp} = \sigma_f^2, \sigma_{f^2p} = s_f$ and the futures market is unbiased.

We refer $\sigma_{fp} = \sigma_f^2$ as cash and futures prices are perfectly correlated in the second moment, and $\sigma_{f^2p} = s_f$ as perfectly correlated in the third moment, assuming the variance and skewness of the two prices are the same for convenience. Only when the two prices are perfectly correlated, the mean-variance model yields a full hedge for risk averse farmers in the unbiased market. (ii) says if the two prices are furthermore perfectly correlated in the third moment, the mean-variance-skewness model yields a full hedge for risk averse and prudent farmers. The two cases are implied in a more strong condition when there is no basis risk, ie. $p = f$. Then a decision maker will always make a ful hedge in either model (and in the full expected utility model).

Corollary 1: The risk averse and prudent farmer will make a full hedge in an unbiased market if there is no basis risk.

The following comparative static propositions can be derived by partially differentiating the two optimal hedge levels with respect to each parameter.

Proposition 2: The short position will be increased (decreased) and the long position will be decreased (increased) if current futures price goes up (down) in both mean-variance and mean-variance-skewness models, while holding all other parameters constant.

Proof: Partially differentiate the two optimal hedge levels with the initial futures price:

(5) $$\frac{\partial y^*_{MV}}{\partial f_0} = \frac{1}{\lambda \sigma_f^2} > 0$$

(6) $$\frac{\partial y^*_{MVS}}{\partial f_0} = \frac{1}{\lambda \Delta^{1/2}} > 0$$

The values of the optimal hedge levels are monotonically increasing with the initial futures price. Higher optimal hedge level means "hedge more" for a short position hedger and "hedge less" for a long position hedger because the absolute value is decreased. This is a speculating effect because a higher current futures price means more expected profit gain (loss) for a short (long) hedger. For both models, the response is smaller for a more risk-averse hedger because the speculating position deviates from the optimal risk reducing position, and the more risk averse hedger chooses to deviate less.

Proposition 3: The short position will be increased (decreased) and the long position will be decreased (increased) if the covariance between the cash and futures prices increases (decreases) in both mean-variance and mean-variance-skewness models, while holding all other parameters constant.

Proof: The following are obtained by partially differentiating with the covariance of cash and futures prices.

(7)
$$\frac{\partial y^*_{MV}}{\partial \sigma_{pf}} = \frac{x}{\sigma^2_f} > 0$$

(8)
$$\frac{\partial y^*_{MVS}}{\partial \sigma_{pf}} = \frac{x}{\Delta^{1/2}} > 0$$

This is a risk reducing effect because a higher covariance means lower basis risk and risk reducing gives more incentive on short hedging but less incentive on long hedging. The responses from both models are proportional to the production level.

Proposition 4: The decision maker hedges more (less) if the current futures price is lower (higher) than the expected futures price as the decision maker becomes more risk averse in both mean-variance and mean-variance-skewness models, while holding all other parameters constant. The risk aversion coefficient will not affect the hedging position when the futures market is unbiased, when other parameters remain constant.

Proof: Differentiate with the risk aversion level and obtain:

$$(9) \qquad \frac{\partial y^*_{MV}}{\partial \lambda} = -\frac{f_0 - E(f)}{\lambda^2 \sigma_f^2}$$

$$(10) \qquad \frac{\partial y^*_{MVS}}{\partial \lambda} = -\frac{f_0 - E(f)}{\lambda^2 \Delta^{1/2}}$$

According to (9) and (10), the optimal hedge levels from the two models change in the same direction as risk aversion increases. Both equations have a positive sign as $f_0 < E(f)$ and a negative sign as $f_0 > E(f)$. Risk averters will make a full hedge when there is no basis risk in the unbiased futures market. This result will not change with the risk aversion level. The full hedge minimizes risk.

When the current futures price is lower than the expected maturity price, both models advise the decision maker to underhedge, namely, to sell less than their production level. As they become more risk averse they will increase their hedging levels toward the full level, because their risk reducing incentive increases relative to their loss reducing incentive. If the current future price is sufficiently low the decision maker would be likely to take a long position, namely, buy now and sell in the future from the futures market. In that case, the farmers would hedge less as they are more risk averse. On the other hand, when the current futures price is higher than the expected maturity price, both models recommend over hedging, and more risk-averse farmers will over hedge less so as to be closer to the full hedge level.

The comparative statics of the three-moment optimal hedge level on the other parameters are:

$$(11) \qquad \frac{\partial y^*_{MVS}}{\partial \eta} = \frac{\sigma_f^2}{\eta^2 s_f} + \frac{[\eta x \sigma_f^2 \sigma_{f^2 p} - \eta x s_f \sigma_{pf} - \sigma_f^4 - \eta s_f (f_0 - E(f)/\lambda)]\Delta^{-1/2}}{\eta^2 s_f}$$

(12) $$\frac{\partial y^*_{MVS}}{\partial s_f} = -\frac{x\sigma_{f^2p}}{s_f^2} + \frac{\sigma_f^2}{\eta s_f^2} -$$

$$\frac{\Delta^{-1/2}\{(\sigma_f^2 - \eta x\sigma_{f^2p})^2 + \eta s_f[\eta x^2\sigma_{f^2p} - 2x\sigma_{pf} - 2f_0/\lambda + 2E(f)/\lambda]/2\}}{\eta s_f^2}$$

(13) $$\frac{\partial y^*_{MVS}}{\partial \sigma_{f^2p}} = \frac{x}{s_f}[1 + \Delta^{-1/2}(-\sigma_f^2 + \eta x\sigma_{f^2p} - \tfrac{1}{2}\eta x s_f)]$$

The signs for equation (11), (12) and (13) are ambiguous. These signs will be examined for the following empirical example.

III. SIMULATION AND NUMERICAL RESULTS

Numerical analysis of an example examines the level of approximation of the two-moment and three-moment models to the expected utility model by comparison of the optimal hedge ratios (OHR). The hedge ratio is the ratio of hedging to the production level. Assume the hedger has the commonly used CRRA (constant relative risk aversion) utility function (Coble, et. al.; Mahul; Wang, et. al.):

(14) $$U(\pi) = (1-\theta)^{-1}\pi^{(1-\theta)}$$

where θ is the relative risk aversion coefficient. The optimal hedge ratio for the expected utility model is solved numerically. For two- and three-moment models, the optimal hedge ratios are obtained by (3) ignoring the third term and (4). The values of θ range from 1 to 4 following Dynan(1993). Six levels of relative risk aversion coefficient (θ), specifically 1.5, 2, 2.5, 3, 3.5, 4, are analyzed. The six levels of the absolute risk aversion coefficient λ and absolute prudence coefficient η are calculated based on the relative risk aversion levels ($\lambda = \theta/\pi$, $\eta = (1+\theta)/\pi$)[4].

The analysis assumes a representative farmer who grows wheat in U.S. Pacific

Northwest region. The initial wealth determined by average per acre is 550 \$/acre. Production cost is 230 \$/acre and production level is 68.94 bushels/acre. Bivariate gamma distribution is chosen to simulate the wheat cash and futures prices for the 2002 harvest period because (1) it's positively skewed; (2) gamma random variables (cash and futures prices in this case) are positive; (3) it facilitates including the skewness parameter in the simulation. The approach of Law and Kelton (1982) is used to simulate the correlated bivariate gamma distribution.

The correlation between the wheat cash and futures prices is 0.48. The scale and location parameters for the gamma distribution are calculated from the variances (0.37 and 0.56 for wheat cash and futures prices) and skewnesses (0.12 and 0.29 for wheat cash and futures prices)[5]. The mean values are adjusted to 3.7 and 3 \$/bushel respectively after the simulation. These parameter levels are determined based on the weekly Portland spot market cash price and CBOT futures price data from September 1998 to August 2001. The descriptive statistics for the simulated cash and futures prices are shown on Table 3.1. The skewness of the simulated cash and futures prices are significant, although they appear small[6]. The initial future price f_0 is set at three levels (3.20, 3.00 and 2.80 \$/bushel). The futures market is unbiased when f_0 equals 3.00 \$/bushel. The hedger is likely to take a short (or long) position if f_0 equals to 3.20 (or 2.80) \$/bushel.

Table 3.2 shows the optimal hedge ratios (OHR) from three models under six relative risk aversion levels and three levels of initial futures prices. The results show that the OHRs from three-moment model are closer to those from expected utility model than two-moment model OHRs in all situations. The evidence from this example strongly favors the three-moment model over the two-moment model.

Comparing the absolute OHR values, the farmer hedges more (less) in the MVS model than in the MV model when he is in a long (short) position. Based on equation (3), the optimal hedge level of the MVS model has one more term than that of MV model, which is due to skewness of profit. If a farmer with a short (long) position hedges more, the skewness of profit which he desires will be decreased (increased) according to the definition of skewness of profit. Thus compared to MV model, the farmer would hedge less (more) in a short (long) position.

When the initial futures price changes from 2.8 to 3 and to 3.2 $/bushel, the OHR values of both models increase, consistently with Proposition 2. The OHRs from the MV model increase at a constant rate for each relative risk aversion level. But the values from MVS do not have the same pattern with each level of initial futures price increase, which is also consistent to Proposition 2 as in equations 5 and 6.

The absolute values of OHRs from the MV model do not change in the unbiased futures market while they drop with the relative risk aversion in the biased futures market. This is consistent with Proposition 4 (equation 9). The absolute values of MVS OHRs decrease in biased and unbiased futures as relative risk aversion increases. This seeming inconsistency arises because the particular CRRA utility we choose is not constant in prudence. The prudence level is related to the risk aversion level. In order to compare the MVS results to the true utility maximization results, we allow the prudence to vary accordingly. Therefore, the conditions in Proposition 4, i.e., holding all other parameters constant, is violated, and the OHR changes for MVS model in Table 3.2 is a result of a joint increase in both risk aversion and prudence.

In both models, the farmer hedges more when he is in a short position than in a long one. This is because the minimum risk position is short. When the market goes biased for the same level in both directions, the short hedge is enhanced and the long hedge is only a residual after the short position has been fully reduced.

The comparative statics are also numerically checked so as to illustrate the ambiguous signs of equation (11) and (12). Equation (13) is not checked because the coskewness can not be controlled in the simulation since it changes with the skewness. First, we examine how the MVS OHR changes with the skewness of futures prices. The cash price skewness is fixed because it is not directly related to OHR (Equation 4). Three skewness levels (0.5, 1.0 and 1.5 times of the original skewness) are chosen for the futures prices so that the bivariate gamma distributed cash and futures prices could be simulated[7]. Two more bivariate gamma distributed cash and futures prices are simulated based on the change of skewness. According to the simulated data, the coskewness, $\sigma_{p^2 f}$ decreases and σ_{pf^2} increases as the skewness of futures goes up and vice versa.

The comparative static results of MVS OHRs on futures price skewness are demonstrated in table 3.3. Both unbiased and biased (long and short positions) are considered. The farmer takes a longer position when the futures price is more skewed. The intuition is that the farmer uses hedging to both reduce variance and increase skewness of the profit, and if futures price is more skewed the long position can amplify the profit skewness more effectively. The increasing skewness motivates the farmer to increase his long hedge position at a cost of decreased variance. The same reasoning can be used to explain the smaller short position when skewness increases in the biased futures market. The opposite behavior occurs under the unbiased market because the short positions are much smaller than in the other two cases. The variance reducing effect dominates the skewness increasing effect comparing the variance equation (2.2) and skewness equation (2.3) of profit. This causes the farmer to take a larger short position. Therefore, the comparative static on futures skewness cannot be simply determined in sign.

The influence of risk aversion and prudence on the OHRs in the MVS model is shown in Figure 3.1 (a) and (b), respectively. The relative risk aversion and prudence range from 1 to 5. Empirical research on prudence levels is not available. The range is chosen at the same as risk aversion because the two are often close in commonly used utility functions such as exponential (constant absolute risk aversion preference), log or power functions (constant relative risk aversion preference). The impact on OHR from relative risk aversion has consistent pattern as in proposition 4, when the relative prudence level is fixed at 2.

When relative risk aversion is fixed at 2, the hedging position decreases as the farmer becomes more prudent so that all three lines in Figure 3.1(b) are downward sloping. The downward slope in the unbiased market is so small that the line looks horizontal. The influence of the prudence on the market is trivial in this case. The decreasing position means hedging less in short and more in long. We have also set risk aversion at other levels, but the OHRs show the same pattern, i.e., decreasing with prudence. This means the sign of equation (11) is not sensitive to the preference parameters. Compared to Figure 3.1(a), risk aversion makes a big difference in OHR than prudence in the biased futures market.

Figure 3.2 demonstrates how relative risk aversion and prudence affect the certainty equivalent in the MVS model in an unbiased futures market. The certainty equivalent is the certain amount of money which leaves the decision maker equally well-off as the specified risky hedging opportunity. The higher certainty equivalent means higher utility achieved with hedging. The results show that changes of certainty equivalent brought by difference prudent levels are small relative to the changes brought by different risk aversion levels.

The certainty equivalent always decreases as the risk aversion increases in both biased and unbiased markets, because the farmer requires higher compensation for risk. For the same reason, one might expect the certainty equivalent to increase as prudence increases. However, it decreases as the prudence increases when in a short position (See Figure 3.2(b)). This occurs because the short position reduces the profit skewness enough to offset the increased prudence.

IV. SUMMARY AND CONCLUSION

A linear mean-variance-skewness (three-moment) model is developed and applied to hedging in the futures market. The optimal hedge ratio (OHR) and associated comparative statistics are derived and compared theoretically from both three-moment and two-moment models. The term “prudence” introduced by Kimball is included in the three-moment model. The OHRs from the two models are equal only when: 1) the decision maker is “prudence neutral” or; 2) with unbiased futures markets, assuming perfect correlation of cash and futures prices in both second and third moments. The OHR of the three-moment model changes in the same direction as that of the two-moment model when the initial futures price, covariance of cash and futures prices and risk aversion coefficient change respectively. Otherwise, effects on OHRs are not definite theoretically. The signs on the comparative statics of the three-moment OHR on the other parameters such as the prudence level, skewness of futures prices and coskewness of futures and cash prices are ambiguous.

The two and three moment models are also compared against the expected utility model for a numerical example so as to examine which model provides a closer approximation to expected utility. We assume the hedger is a typical farmer, with the common CRRA utility function, who grows wheat in the Pacific Northwest. The results show the OHRs from the MVS model is closer to those from expected utility model than those from MV model in all situations considered. This strong evidence suggests that the MVS model is superior to the MV model. The farmer hedges more (less) in the MVS model than in the MV model when he/she is in a long (short) position. This results from the additional term skewness of return in the MVS model. The comparative statics of MVS OHRs on futures price skewness indicates the farmer takes a longer position so as to increase the benefit from increased positive profit skewness when the futures price is more skewed. The opposite behavior for the unbiased market is primarily because the short positions are much smaller than in the other two cases, and the variance reducing effect dominates the skewness increasing effect. There's no clear pattern when the farmer is in a short position.

The influences of risk aversion and prudence on OHRs for the MVS model are also examined. The ranges of relative risk aversion and prudence are extended a little based on the common CRRA utility function. The numerical results show the farmer full-hedges in the unbiased market and hedges less as risk aversion increases in the biased futures market. The hedging position decreases as the farmer becomes more prudent. Risk aversion has a greater influence on OHR than prudence in the biased futures market.

The certainty equivalent consistently decreases as the risk aversion increases in both biased and unbiased market, because the farmer requires his/her certain compensation for the risky hedge. Similarly, the certainty equivalent should be expected to increase with prudence; however, it decreases in a very large short position. This is because the long position increases quickly which reduce the profit skewness thereby offsetting the effect of the increased prudence.

ENDNOTES

[1] "Skewness" refers to the third moment instead of standardized third moment in this paper.

[2] $\sigma_{fp^2} = E\{[f - E(f)][p - E(p)]^2\}$, $\sigma_{f^2p} = E\{[f - E(f)]^2[p - E(p)]\}$

[3] The first order condition equation has two roots and result in two closed forms of y^*_{MVS} actually. The sign operator before the square root could be 'add' or 'subtract'. The 'add' operator is chosen in order to achieve the maximum by the second order condition (SOC).

[4] For the particular CRRA preference, the relative prudence is determined once the relative risk aversion is set at a certain level.

$$\frac{\partial U}{\partial \pi} = \pi^{-\theta}, \ \frac{\partial^2 U}{\partial \pi^2} = -\theta \pi^{-(1+\theta)}, \ \frac{\partial^3 U}{\partial \pi^3} = \theta(1+\theta)\pi^{-(2+\theta)},$$

$$\lambda = -U''(\mu)/[U'(\mu)] = \theta/\mu, \ \ \eta = -U'''(\mu)/[U''(\mu)] = (1+\theta)/\mu$$

[5] Location parameter $\alpha = 4(\sigma^2)^3/S^2$ and scale parameter $\beta = S/2\sigma^2$.

[6] Formal hypothesis test is conducted. H_0: $S = 0$ vs. H_1 $S \neq 0$ where S is the skewness. Then the statistic z, $z = \hat{S}/\sqrt{6/n}$, where n =10,000 the number of observations, follows the standard normal distribution under the null hypothesis. Here, z is 5.031 and 11.424 for cash and futures prices, respectively, and both are larger than the critical value at 5%. Therefore, the null hypothesis of zero skewness is rejected for both.

[7] If the skewness is less than 0.5 times, the futures price would be almost normally distributed which is not the interest of this paper. If the skewness is larger than 1.5 times, the bivariate gamma distributed cash and futures prices would not be able to be simulated.

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Table 3.1. Descriptive Statistics for Simulated Cash and Futures Prices ($/bushel)

Variable	N	Mean	Skewness	StDev	Minimum	Median	Maximum
cash	10000	3.7	0.123	0.6104	2.052	3.653	6.672
future	10000	3	0.28	0.7418	1.267	2.914	7.048

Table 3.2. Optimal Hedge Ratios Comparison under Six Relative Risk Aversion Levels and Three Levels of Initial Futures Prices

θ	1.5	2	2.5	3	3.5	4
unbiased futures market (f_0 = Ef = 3 $/bushel)						
Mean-Variance Model	0.392	0.392	0.392	0.392	0.392	0.392
Mean-Variance-Skewness Model	0.385	0.384	0.382	0.381	0.38	0.378
Expected Utility Model	0.385	0.383	0.382	0.38	0.379	0.378
f_0 = 3.2 $/bushel						
Mean-Variance Model	2.325	1.842	1.552	1.358	1.22	1.117
Mean-Variance-Skewness Model	2.089	1.676	1.424	1.253	1.13	1.037
Expected Utility Model	2.046	1.673	1.43	1.261	1.138	1.043
f_0 = 2.8 $/bushel						
Mean-Variance Model	-1.541	-1.058	-0.768	-0.575	-0.437	-0.333
Mean-Variance-Skewness Model	-2.008	-1.361	-0.992	-0.754	-0.588	-0.465
Expected Utility Model	-1.86	-1.295	-0.954	-0.727	-0.566	-0.446

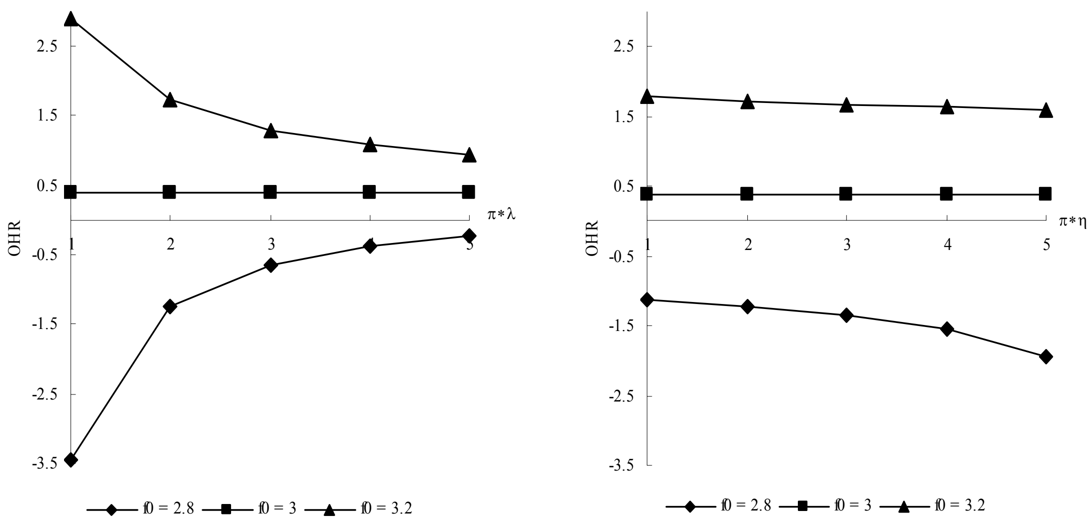
Note: The negative hedge ratios mean the hedger takes a long position for f_0 = 2.8 $/bushel.

Table 3.3. Impacts of Futures Price Skewness on Three-Moment Optimal Hedge Ratios

theta	1.5	2	2.5	3	3.5	4
unbiased futures market (f_0 = Ef = 3 \$/bushel)						
0.5*Sf	0.364	0.362	0.359	0.357	0.354	0.351
Sf	0.385	0.383	0.382	0.38	0.379	0.378
1.5*Sf	0.39	0.39	0.39	0.39	0.39	0.39
f_0 = 3.2 \$/bushel						
0.5*Sf	2.15	1.71	1.442	1.261	1.131	1.033
Sf	2.089	1.676	1.424	1.253	1.13	1.037
1.5*Sf	1.98	1.599	1.366	1.208	1.094	1.008
f_0 = 2.8 \$/bushel						
0.5*Sf	-1.71	-1.18	-0.868	-0.663	-0.518	-0.411
Sf	-2.008	-1.361	-0.992	-0.754	-0.588	-0.465
1.5*Sf	-2.569	-1.619	-1.148	-0.859	-0.663	-0.52

Note: The negative hedge ratios mean the hedger takes a long position for f_0 = 2.8 \$/bushel.

Figure 3.1. Comparative Statics of Optimal Hedge Ratio (OHR) by Relative Risk Aversion Level and Relative Prudence level

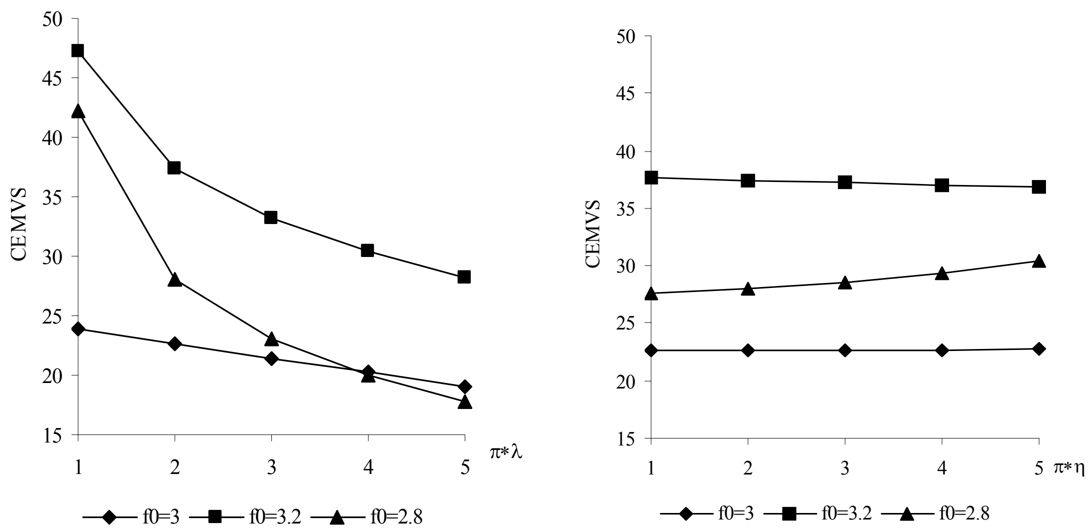


(a) (b)

Note: (1) The negative hedge ratios mean the hedger takes a long position for f_0 = 2.8 \$/bushel.

(2) $\pi^*\lambda$ is relative risk aversion and $\pi * \eta$ is relative prudence.

Figure 3.2. Certainty Equivalent Changes with Relative Risk Aversion Level and Relative Prudence Level respectively



(a) (b)

Note: $\pi^*\lambda$ is relative risk aversion and $\pi * \eta$ is relative prudence.

CHAPTER FOUR

PRODUCTION RISK AND CROP INSURANCE EFFECTIVENESS: ORGANIC VERSUS CONVENTIONAL APPLES

I. INTRODUCTION

Apples are a major crop in the Pacific Northwest (PNW) states (Washington, Idaho, and Oregon). As the leading state of apple production since 1920s, Washington (WA) accounts for 58.8% of total US apple production in 2005. The value of apple production is $1.23 billion, representing 19 percent of total agricultural value produced in WA. Oregon is also a major producer of apples, and it generates $26 million value of production accounting for 11 percent total value of production in Oregon State (NASS, 2006). The value of apples production in Idaho was $12.5 million in 2005, ranking No.11 in the United States (US) apples production. The nutrient-rich soil, arid climate, plentiful water and advanced growing practices provide the right ingredients for producing top-quality apples in PNW region.

Due to health and environment concerns, a significant interest in organic apples production has developed over the last 10 to 15 years. WA orchards produce about 35 percent of the organic apples in the U.S. and about 20 percent of the organic apples in the world (Schotzko and Granatstein). The dry climate and ideal temperatures in central Washington reduce the number of disease and pest problems that can impact fruit and therefore reduces the need for applications to control insects and pests. Certified Washington State organic apple acreage increased from well below 500 total acres in the late 1980s to 9,861 acres in 2002[1]. Most of the PNW organic acreage is planted in Red Delicious followed by Granny Smith, Gala, Golden Delicious, Fuji and so on.

PNW apples are primarily grown for the fresh market with a higher quality and higher value. PNW especially Washington's quality standards for all apples are more stringent than grading standards used in any other growing region in the world. This higher quality also requires higher production costs, which in turn results in high profit risks for apple growers, when couple with adverse weather conditions, insects and plant diseases, and other factors. Apple crop insurance is a major risk management tool for apple growers. However, compared with major field grain crops, the current apple crop insurance program is quite limited with only yield based contracts. The basic choices include catastrophic coverage, higher coverage under Grower Yield Certification (GYC) which is a type of Multi Peril Crop Insurance (MPCI) policy, and optional coverage for fresh fruit quality.

A frequent complaint made by PNW apple growers is that national insurance programs do not provide adequate coverage for high valued PNW fresh apples, and are even less adequate for organic apples. The price selection level in GYC is set low compared to the fresh market price for PNW apples (4.65 $/box for Varietal B and 6.45 $/box for Varietal A). The yield coverage level is also low, ranges only to 75%. In 2000, USDA's Risk Management Agency (RMA) introduced a pilot coverage enhancement option (CEO) which was an option of increasing the coverage to 85%, but it was terminated recently.

An extensive amount of production-based research has been done on risk management of organic farms. Duram reported organic farmers were exposed in both production and price risks during the three-year transition period from conventional to organic production. Hanson et. al. (1990) compared conventional and organic grain rotation during the first nine years of production and found that the average annual profits of the conventional rotation were higher than the organic rotation without organic price premiums. Reganold et. al. compared conventional, integrated pest management, and organic apple production systems. Numerous studies have also been found on insurance programs for field crops such as wheat and barley (Ke and Wang; Wang, et. al.), corn and soybean (Sherrick, et. al.; Miranda and Glauber), and other field crops. However, little work has been done specifically assessing both production and price risks for organic fruit growers. Hansen et. al. (2004) indicated that most fruit and vegetable producers had little knowledge of crop insurance. No other work has been found assessing the crop insurance program for tree fruits.

Apples have many varieties for which production and price can differ markedly. Currently, GYC insurance groups all apples only into two groups, varietal A and B. Fuji, Gala and other newer varieties are in varietal A. Red delicious, golden delicious and other traditional varieties are in varietal B. This could limit the risk reducing effectiveness of the insurance.

The goal of this paper is to assess income risks of WA apple growers and the risk management effectiveness of apple crop insurance programs. Specifically, we will: (1) examine the income risks associated with conventional and organic production; (2) evaluate the roles of GYC for conventional and organic apples by variety; (3) evaluate presumed income based insurance (IP) and compare it with GYC.

II. METHODOLOGY

Income risks are represented by the distributions of growers' income from production.

(1) $$\pi_0 = PY - C$$

where π_0 is the profit function from producing apples; P is the farm gate price after harvest[2], Y is the corresponding realized production level, and C is the deterministic cost of producing Y.

When growers have insurance, their profit function is specified as revenue generated from sales, yield or revenue insurance indemnities less production costs and subsidized insurance premiums:

(2) $$\pi = \pi_0 + INS - PRE + SUB$$

the insurance income, INS, represents indemnity from GYC and the hypothetical IP as in the following:

(3) $$INS_{GYC} = x_1 p_b \max(0, x_2 \bar{y} - Y)$$

(4) $$INS_{IP} = \max(0, x_1 p_b x_2 \bar{y} - PY)$$

where p_b is the base price; x_1 is the price selection level of the grower; and x_2 is the GYC coverage level selected. The setting for INS_{GYC} is based on the actual GYC policy that growers can select a price level and a yield coverage level as a percentage of the established base price and Actual Production History (APH). The APH is established as the projected yield at planting time, and here we use mean yield for APH. The setting for INS_{IP} is based on the current IP program for field crops, except that the base price level is set at the same level as GYC instead of futures market price. PRE is the premium, calculated as both the actual premium currently set by RMA and the actuarially fair level for GYC, but only for the actuarially fair level for the IP;

SUB is the RMA premium subsidy based on the current policy.

The risk management decision is presumed made based on growers' expected utilities. We assume a representative apple grower chooses an insurance coverage level to maximize his or her expected utility of wealth, composed of a deterministic initial wealth, random production income and insurance transactions.

(5) $$\underset{x_1, x_2}{Max}\, E[U(w)], \text{ and } \quad w = w_0 + \pi$$

where *E*( ) is an expectation operator; *U*( ) is a von Neumann-Morgenstern utility function representing the risk attitude of the decision maker; *w* is the stochastic terminal wealth; and w_0 is an initial wealth level.

Welfare effects of the insurance programs are evaluated by the Certainty Equivalent (CE) of the insurance, i.e., the certain amount of income paid to the grower for him to achieve the same expected utility without using the insurance as using the insurance.

(6) $$MaxEU(w) = EU(w_0 + \pi_0 + CE)$$

The grower is assumed to have constant relative risk aversion, with the utility function as:

(7) $$U(w) = (1-\theta)^{-1} w^{(1-\theta)}$$

where θ is the Arrow-Pratt relative risk aversion coefficient. This utility function, representing constant relative risk aversion, is justified by Wang, et. al. and has been commonly used in a similar focus (Coble, et. al.; Mahul).

III. DATA AND SIMULTIONS

The empirical analysis is based on simulated risks faced by PNW apple production in crop year of 2006. Historical data are used to estimate random price and yield distributions used in the simulations. Data sources are: (1) WA Growers Clearing House (WAGCH) price data by variety, for both conventional and organic apples; (2) National Agricultural Statistics Service (NASS) aggregated state conventional yield data, long term but not by variety; (3) RMA farm level conventional APH records, not variety specific; (4) WAGCH conventional production data by variety; (5) Washington Fruit Survey (1993, 2001, 2002) acreage data by variety; and (6) farm-level data from our own survey for organic apple growers in the Pacific Northwest including yield from 2000 to 2005 and production cost by variety. The information from each source is combined together with reasonable assumptions to obtain farm level yields and prices by variety for both conventional and organic apple data.

To be able to capture the weather-related yield risks, a long time series of historical yields is needed while accounting for time trends. Several functional forms of time trends (linear, piecewise linear, quadratic, and loglinear) for the mean yield of conventional varietal apples are considered. The analysis showed no trend for Red Delicious and Golden Delicious and a piecewise trend for Gala and Fuji. For the organic varietal yields, no trend was considered based on limited recent six years data.

The proper crop-yield distributions have been debated in the agricultural economics literature since the early 1970's. Several studies have agreed that crop yields are skewed (Babcock and Hennessy; Coble et al.; Borges and Thurman; Nelson and Preckel). Some studies support positive skewness (Day) while others support negative skewness (Swinton and King; Ramirez). A few non-normal distributions are proposed such as Beta (Borges and Thurman;

Nelson and Preckel), Gamma (Gallagher), and log-normal (Jung and Ramezani). Just and Weninger identify three common methodological problems in yield distribution analyses: use of aggregate yield data, inflexible trend modeling, and inappropriate interpretation of the Normality test results. They shed doubt on the validity of previous findings of yield nonnormality and renew support for the normal distribution of crop yields. Unfortunately, a consensus specification for crop yield distributions has not been reached in the agricultural economics literature. Thus this paper will use normal distribution to simulate the yields because: (1) the normality test of the residuals after time detrending can not be rejected; (2) there is no former work questioning the normality of apple yields; and (3) the multivariate joint normal distribution is well defined, which is convenient to simulate joint yield and price distribution with a correlation imposed.

Both conventional and organic varietal prices are obtained from WAGCH. Trends are identified and lognormal distributions are chosen to simulate the prices for 2006 against a few other candidate distributions. An empirical distribution with 10,000 samples is simulated for each variety's price and yield (See Appendix B for details of the data process).

The independently simulated yield and price distributions are converted into joint distributions using a linear transformation to impose the correlation structure estimated from the data. The conventional yield-price correlation is about -0.6 for all varieties, and the organic correlations are about -0.7 with the exceptions for Fuji at -0.2.

Per acre production cost for conventional apples for established trees are obtained from Schotzko and Granatstein. The organic varietal costs are calculated as the average of the surveyed growers' costs for each variety.[3] Production cost ranges from 4,000 to 5,000 \$/acre for conventional and 4,500 to 7000 \$/acre for organic apples. The costs are assumed deterministic.

In accordance with current GYC options, the maximum price selections are 4.65 \$/box for Red Delicious and Golden Delicious and 6.45 \$/box for Gala and Fuji. The price selection level can be chosen from 67% to 100%. The yield selection level ranges from 50% up to 75% with 5% increment. The current policy provides an aggressive base premium rate and a regressive subsidy rate based on the growers' choice of yield coverage levels. The rates for base premium are 3.2%, 3.7%, 4.5%, 5.4%, 6.5% and 7.7% of liabilities and subsidy rates are 67%, 64%, 64%, 59%, 59%, 55% corresponding to coverage levels of 50%, 55%, 60%, 65%, 70% and 75%, respectively. The organic apple premium is inflated by an optional organic factor of 1.05.

The value of the relative risk aversion coefficient is set at $\theta = 2$, which is based on previous research (Wang, Hanson and Black; Coble, Heifner and Zuniga; Pope and Just). Thus the initial wealth (farm equity) for organic and conventional Red Delicious and Golden Delicious growers is 6,685 \$/acre based on the debt/asset ratio for Washington farmers (17%, WASS) and the average WA apple orchard asset, 8,066 \$/acre, including land value, the cost of irrigation system and tree value (Glover, et. al.). The initial wealth for Gala and Fuji is 8,803 \$/acre since the trees value for those two is much higher than traditional varieties.

IV. RESULTS

The descriptive statistics of simulated varietal yields, prices and profits for both conventional and organic apples are shown in Table 4.1. Organic apple growers have higher expected revenue and higher risk than conventional apple growers. Among conventional apples, the newer Gala and Fuji varieties have higher expected revenue and lower risk than Red Delicious and Golden Delicious. This may explain why Gala and Fuji have increased their market shares dramatically in recent years. Organic Fuji has the highest expected revenue and risk among all the organic varieties. Different from conventional Gala apples, organic Gala has lower risk (standard deviation) and also lower expected revenue than both organic Fuji and organic Golden Delicious.

Besides the benchmark case of no insurance, six other scenarios are investigated for each of conventional and organic varieties. GYC under current policy premium rates, GYC under actuarially fair premium rates, and hypothesized IP under actuarially fair premium rates, all of which have two cases of with and without subsidies. These scenarios allow us to compare the welfare values of GYC and IP at a similar basis (actuarially fairness), can also to reveal the premium loading effect of current GYC.

Red Delicious

The optimization results (Table 4.2) for Red Delicious show that both GYC and hypothesized IP protect the farmer from risk as shown by reductions in the standard deviation of profit for most insurance options Both conventional and organic growers choose full coverage in all cases except GYC without the subsidy for conventional apples. In this case, the grower does not choose insurance because the current premium is too high relative to his/her risks and no subsidy is provided. As expected, the grower has a higher welfare as measured by certainty equivalent (CE) and pays lower premium with subsidy than without subsidy for both GYC and hypothesized IP programs.

The conventional grower is better off (higher CE and less premium) when the insurance is actuarially fair than when the premium is set as in the current policy. This implies a loading exists in the current premium rates. The hypothesized IP gives the conventional grower higher protection (less risk as measured by standard deviation of profit) and higher welfare (CE) than GYC program, although the grower pays more premium. This is because both their production and marketing risks are protected with IP which results in receiving a higher indemnity and a higher government subsidy.

The standard deviation reduction of profit ranges from 0 (GYC without subsidy) to 239.07 (IP) for the conventional grower and from 288.27 (IP) to 662.87 (GYC) for the organic grower when insurance is used. Thus the organic apple grower's income risk is reduced more dramatically by insurance than conventional grower. Consequently, the organic apple grower's welfare gain from insurance is higher than that of the conventional grower although he has to pay much higher premium for GYC than the conventional grower so as to reduce more risk. Different from conventional apples, the income protection gives less risk protection for organic Red Delicious grower than GYC. This is because that price selection (4.65 $/box) in the current GYC programs is too low compared to the organic Red Delicious market cash price (9.27 $/box). It's easier to get indemnity from GYC than IP program based on Equation (3) and (4).

However, from the point of view of the premium paid by the grower and government investment in premium subsidy, hypothesized revenue insurance (IP) is more cost effective for both conventional and organic practices. For example, the per dollar subsidy investment will bring a $4.21 welfare gain by GYC and $9.34 welfare gain by IP under actuarially fair premium structures for organic Red Delicious. The per dollar grower investment in insurance (premium paid) will gain $5.14 welfare by GYC and $11.41 by IP under the same scenario. Notice, the $0.61 welfare gain brought by each dollar of government subsidy in conventional GYC suggests that it would be more economic for the government to give the $1 directly to growers instead of subsidizing the GYC program.

The organic grower pays higher premium and is less willing to pay for GYC when the premium is actuarially fair than set by current policy. The reason is that the organic apple production risks are so high based on our survey, that the current GYC premium is set below the expected indemnity even after the organic premium is inflated by 5 percent by policy. This is also why in our scenario of current GYC without subsidy the grower still chooses the highest coverage level. Although the insurance price is quite low compared to the market organic apple prices, organic growers still benefit more than their conventional counterpart from the GYC. The organic inflation factor needs to be increased so as to make the insurance actuarially fair.

Sensitivity analysis of risk aversion level is also conducted. We examine the risk aversion levels from 1.5 to 3 with 0.5 increments. The rankings of insurance programs in all the comparisons do not change except the values of CE increase as the risk aversion level goes up.

Golden Delicious

Similar to Red Delicious, both GYC and hypothesized IP protect the Golden Delicious grower from risk (Table 4.3), but the hypothesized IP is not better than GYC in absolute values for either conventional or organic growers. Again, hypothesized revenue insurance (IP) is more cost effective for both conventional and organic practices in terms of the premium paid by the grower and government investment in premium subsidy. The grower chooses full coverage in all cases except that GYC premium is set by policy with the subsidy removed case for conventional apples.

When the premium is higher than the actuarially fair level and no subsidy, the grower chooses not to buy insurance. When subsidy is added, the grower chooses full yield coverage and a reduced price selection level at 92%. The conventional grower's welfare gain is higher and he pays less premium when actually fair or with subsidy. The risk is reduced greatly after insurance for organic apples. The organic grower is less willing to pay for insurance and has to pay more premiums when actuarially fair for the same reason as organic Red Delicious apple. The 0.13 CE/Subsidy ratio indicates the current GYC is more cost ineffective for Golden Delicious growers than Red Delicious growers.

Gala

As for Gala, the conventional grower is not interested in current GYC or hypothesized IP either with or without subsidies. The conventional grower chooses insurance only for actuarially fair GYC, but this plan does not provide much value to him either. Thus both GYC and IP are not effective in reducing the risk for conventional Gala growers. The price selection and yield coverage are too low to provide significant protection. Or, this grower's risk is not high enough for him/her to benefit from the insurance as shown by the coefficients of variation

(CV) in Table 4.1.

GYC and hypothesized IP can protect organic Gala growers from risk. The grower chooses full coverage in all cases except when current premium is high without subsidy for GYC. The organic grower has a higher welfare gain from insurance because of the higher risk of growing organic Gala. If the subsidy is removed from the current GYC, the organic grower will reduce their coverage level from maximum to minimum. The GYC is preferable to the hypothesized IP for the organic Gala grower for the same reason as Red Delicious. However, hypothesized revenue insurance (IP) is much more cost effective for both conventional and organic practices in terms of the premium paid by grower and government investment in premium subsidy.

Different from other organic varieties, the organic Gala grower pays less premium and is more willing to pay for GYC when the premium is actuarially fair than set by current policy. This means the GYC premium for organic Gala is set above the expected indemnity, which is a normal practice. The reason that organic Gala is an exception is that Gala production risk is much lower than the other organic apples and thus reduces the expected indemnity.

Fuji

Table 4.5 demonstrates the optimization results for Fuji apples. The current GYC is not beneficial to the grower with or without subsidy because the premium is set too high relative to the grower's risk. The conventional grower chooses full coverage in all other cases. However, the conventional grower does not receive much protection from insurance in any of these cases. GYC is preferable to IP under same situations. Like all the other varieties, hypothesized revenue insurance (IP) is more cost effective for both conventional and organic Fuji practices in terms of the premium paid by grower and government investment in premium subsidy.

The organic Fuji grower is much more willing to pay for insurance since it exhibits the highest profit risk of all varieties (Table 4.1). Although the yield risk is lower than for both Red Delicious and Golden Delicious, the low price and yield correlation for organic Fuji apples makes its income highly risky. This makes the insurance value for organic growers the second highest following Red Delicious among all varieties.

V. SUMMARY AND CONCLUSIONS

PNW, especially the state of Washington, is the leading region in both conventional and organic apple production. PNW apples are primarily grown for the high value fresh market due to their high quality. Multiple perils (production cost) and market fluctuation (price risk) results in revenue risk. Crop insurance is a major risk management tool for apple growers. The current apple insurance program offers only a yield based program. Both price selection and coverage level are set too low to provide adequate protection. In this paper, we examined the income risks associated with conventional and organic production and evaluated the roles of GYC and hypothesized IP insurance schemes for conventional and organic apples by variety.

Results show organic apple growers earn higher expected revenue, incur higher production cost (excluding establishment cost), make higher expected profit, but face higher income risks than conventional apple growers.

We assume the apple grower makes decisions on insurance coverage and price election levels to maximize expected utility of after harvest wealth, composed of initial wealth, random production income and insurance transactions. Results show, in terms of certainty equivalent, that income insurance is not necessarily preferable than yield insurance by growers because price selection in the current GYC programs is too low compared to the market cash price. Only conventional Red Delicious growers will benefit from IP more than GYC under comparable premium subsidy structures since the base selection is very close to Red Delicious market price. From the point of view of the government investment in premium subsidies, revenue insurance is always more cost effective for all varieties and for both conventional and organic practices.

The conventional apple growers' welfare gain from the current insurance is less than the organic growers because their income risk is lower. Organic apple production risks are higher than their conventional counterparts, causing the current GYC premium to be below the expected indemnity even before the subsidy and after the organic premium inflation factor (except Gala) based on our survey data. Although the insured price is quite low compared to the organic market prices, organic growers still benefit more than their conventional counterparts from the GYC. Gala apple production is less risky for both conventional and organic apple growers. Consequently, Galas benefit little from insurance and organic Gala becomes an exception from the other organic varieties, namely, the current GYC premium is above the expected indemnity. In the future insurance parameter setting, it would be good to separate at least Gala from the other varieties. This implies that the current Varietal A and B categorization is not accurate enough to assess a fair premium structure for apple growers which may cause adverse selection problems.

The results depend heavily on the simulated distribution. Our organic grower survey sample is small, and the organic results can be more reliable only when more grower production records are available in the future.

ENDNOTES

[1]2002 estimated figures from Washington State University Center for Sustaining Agriculture and Natural Resources.

[2]Apples are sent to packing house after harvested, and then sorted, stored, packed and marketed to retailers year round. The growers usually receive the payment from the packing house based on the average price over the crop year less a packing house cost. Therefore, the price is stochastic until way after the harvesting time.

[3]Both costs do not include establishment cost. There is a large amount of establishment cost in the first few years of new trees. These costs are usually amortized into later years when the trees get matured, so that the profit levels would be greatly reduced. However, we don’t find this information by variety and by conventional/organic practice.

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Table 4.1. Descriptive Statistics of the Simulated Varietal Conventional and Organic Yields, Prices and Revenues

	Conventional						Organic					
Variable	Mean	StDev	CV	Min	Max	Skewness	Mean	StDev	CV	Min	Max	Skewness
Yield												
Red Delicious	902.23	278.32	0.31	0	1958.21	0.04	1139.8	518.6	0.45	0	3224.4	0.12
Golden Delicious	1032.9	269.7	0.26	48.5	2050.7	0.06	1067.3	449.2	0.42	0	2845.3	0.07
Gala	929.52	103.7	0.11	523.76	1364.67	0.03	744.24	209.67	0.28	0	1615.47	-0.01
Fuji	832.16	200.74	0.24	83.87	1640.3	0	1000.7	404.8	0.4	0	2431.6	0.03
Price												
Red Delicious	4.37	1.57	0.36	1.1	16.74	1.09	9.27	2.32	0.25	3.75	22.83	0.76
Golden Delicious	6.22	2.04	0.33	1.82	20.04	0.99	11.77	3.94	0.33	3.5	37.77	0.96
Gala	9.25	1.71	0.18	4.5	18.04	0.52	13.55	2.94	0.22	5.84	27.9	0.66
Fuji	10	2.56	0.26	3.69	25.08	0.8	13.58	3.25	0.24	4.61	38.53	0.76
Revenue												
Red Delicious	3712	1232.9	0.33	0	10378.5	0.74	9645.8	3404.2	0.35	0	21261.9	-0.45
Golden Delicious	6112.5	1756.6	0.29	727	18181.3	0.74	11237	3624	0.32	0	26093	-0.16
Gala	8501.3	1292.7	0.15	5042.5	14087.5	0.43	9704.6	2311.8	0.24	0	21247.5	0.09
Fuji	7890.2	1124.1	0.14	1753.7	12910.7	0.12	13319	5889	0.44	0	43335	0.5

Note: Yield unit is boxes per acre. Price unit is dollars per box. Profit unit is dollars per acre.

Table 4.2. Optimization Results for Red Delicious Apple

	Profit								
	Mean	Std Dev	CE	Price Election	Optimal Coverage	Premium	CE / Premium	Subsidy	CE / Subsidy
<u>Conventional</u>									
No insurance	6487.00	1232.85							
GYC	6529.21	1135.70	81.77	1.00	0.75	109.03	0.75	133.26	0.61
GYC (W/O subsidy)	6487.00	1232.85	0.00	0.00	0.00	0.00	N/A	0.00	N/A
GYC (Actuarially fair,W subsidy)	6570.18	1135.70	122.43	1.00	0.75	68.06	1.80	83.18	1.47
GYC (Actuarially fair,W/O subsidy)	6487.00	1135.70	39.87	1.00	0.75	151.24	0.26	0.00	N/A
IP (Actuarially fair,W subsidy)	6610.23	993.78	213.99	1.00	0.75	100.83	2.12	123.23	1.74
IP (Actuarially fair,W/O subsidy)	6487.00	993.78	92.80	1.00	0.75	224.06	0.41	0.00	N/A
<u>Organic</u>									
No insurance	11373.68	3404.19							
GYC	11669.21	2741.32	1064.03	1.00	0.75	144.62	7.36	176.75	6.02
GYC (W/O subsidy)	11492.45	2741.32	915.33	1.00	0.75	321.37	2.85	0.00	N/A
GYC (Actuarially fair,W subsidy)	11615.76	2741.32	1018.86	1.00	0.75	198.06	5.14	242.08	4.21
GYC (Actuarially fair,W/O subsidy)	11373.68	2741.32	816.56	1.00	0.75	440.14	1.86	0.00	N/A
IP (Actuarially fair,W subsidy)	11444.87	3115.92	664.76	1.00	0.75	58.25	11.41	71.19	9.34
IP (Actuarially fair,W/O subsidy)	11373.68	3115.92	605.28	1.00	0.75	129.44	4.68	0.00	N/A

Table 4.3. Optimization Results for Golden Delicious Apple

	Profit								
	Mean	Std Dev	CE	Price Election	Optimal Coverage	Premium	CE / Premium	Subsidy	CE / Subsidy
Conventional									
No insurance	8697.47	1756.58							
GYC	8683.43	1687.57	18.20	0.92	0.75	114.83	0.16	140.35	0.13
GYC (W/O subsidy)	8697.47	1756.58	0.00	0.00	0.00	0.00	N/A	0.00	N/A
GYC (Actuarially fair,W subsidy)	8757.72	1684.09	93.24	1.00	0.75	49.30	1.89	60.25	1.55
GYC (Actuarially fair,W/O subsidy)	8697.47	1684.09	33.28	1.00	0.75	109.55	0.30	0.00	N/A
IP (Actuarially fair,W subsidy)	8710.16	1717.20	37.89	1.00	0.75	10.38	3.65	12.69	2.99
IP (Actuarially fair,W/O subsidy)	8697.47	1717.20	25.26	1.00	0.75	23.08	1.09	0.00	N/A
Organic									
No insurance	13334.29	3623.67							
GYC	13556.31	3137.56	800.41	1.00	0.75	135.42	5.91	165.52	4.84
GYC (W/O subsidy)	13390.79	3137.56	655.25	1.00	0.75	300.94	2.18	0.00	N/A
GYC (Actuarially fair,W subsidy)	13530.88	3137.56	778.02	1.00	0.75	160.85	4.84	196.59	3.96
GYC (Actuarially fair,W/O subsidy)	13334.29	3137.56	606.04	1.00	0.75	357.44	1.70	0.00	N/A
IP (Actuarially fair,W subsidy)	13366.75	3473.45	423.96	1.00	0.75	26.56	15.96	32.46	13.06
IP (Actuarially fair,W/O subsidy)	13334.29	3473.45	395.42	1.00	0.75	59.02	6.70	0.00	N/A

Table 4.4. Optimization Results for Gala Apple

	Profit		CE	Price Election	Optimal Coverage	Premium	CE / Premium	Subsidy	CE / Subsidy
	Mean	Std Dev							
<u>Conventional</u>									
No insurance	10156.33	1292.74							
GYC	10156.33	1292.74	0.00	0.00	0.00	0.00	N/A	0.00	N/A
GYC (W/O subsidy)	10156.33	1292.74	0.00	0.00	0.00	0.00	N/A	0.00	N/A
GYC (Actuarially fair,W subsidy)	10157.82	1291.52	1.81	1.00	0.75	1.22	1.48	1.49	1.21
GYC (Actuarially fair,W/O subsidy)	10156.33	1291.52	0.32	1.00	0.75	2.72	0.12	0.00	N/A
IP (Actuarially fair,W subsidy)	10156.33	1292.74	0.00	0.00	0.00	0.00	N/A	0.00	N/A
IP (Actuarially fair,W/O subsidy)	10156.33	1292.74	0.00	0.00	0.00	0.00	N/A	0.00	N/A
<u>Organic</u>									
No insurance	11738.63	2311.77							
GYC	11747.36	2112.44	142.52	1.00	0.75	130.99	1.09	160.09	0.89
GYC (W/O subsidy)	11692.17	2263.74	7.28	0.67	0.55	68.72	0.11	0.00	N/A
GYC (Actuarially fair,W subsidy)	11815.48	2112.44	208.90	1.00	0.75	62.87	3.32	76.85	2.72
GYC (Actuarially fair,W/O subsidy)	11738.63	2112.44	134.01	1.00	0.75	139.72	0.96	0.00	N/A
IP (Actuarially fair,W subsidy)	11742.10	2292.07	40.04	1.00	0.75	2.84	14.09	3.47	11.52
IP (Actuarially fair,W/O subsidy)	11738.63	2292.07	36.61	1.00	0.75	6.32	5.80	0.00	N/A

Table 4.5. Optimization Results for Fuji Apple

	Profit									
	Mean	Std Dev	CE	Price Election	Optimal Coverage	Premium	CE / Premium	Subsidy	CE / Subsidy
<u>Conventional</u>									
No insurance	9790.18	1124.14							
GYC	9790.18	1124.14	0.00	0.00	0.00	0.00	N/A	0.00	N/A
GYC (W/O subsidy)	9790.18	1124.14	0.00	0.00	0.00	0.00	N/A	0.00	N/A
GYC (Actuarially fair,W subsidy)	9845.31	1037.71	78.93	1.00	0.75	45.10	1.75	55.12	1.43
GYC (Actuarially fair,W/O subsidy)	9790.18	1037.71	23.99	1.00	0.75	100.23	0.24	0.00	N/A
IP (Actuarially fair,W subsidy)	9790.63	1120.80	2.51	1.00	0.75	0.37	6.77	0.45	5.54
IP (Actuarially fair,W/O subsidy)	9790.18	1120.80	2.05	1.00	0.75	0.82	2.49	0.00	N/A
<u>Organic</u>									
No insurance	15110.17	5889.15							
GYC	15294.42	5479.92	909.20	1.00	0.75	126.97	7.16	155.18	5.86
GYC (W/O subsidy)	15139.24	5479.92	775.65	1.00	0.75	282.15	2.75	0.00	N/A
GYC (Actuarially fair,W subsidy)	15281.34	5479.92	897.89	1.00	0.75	140.05	6.41	171.17	5.25
GYC (Actuarially fair,W/O subsidy)	15110.17	5479.92	750.79	1.00	0.75	311.22	2.41	0.00	N/A
IP (Actuarially fair,W subsidy)	15177.85	5673.25	676.69	1.00	0.75	55.38	12.22	67.68	10.00
IP (Actuarially fair,W/O subsidy)	15110.17	5673.25	618.95	1.00	0.75	123.06	5.03	0.00	N/A

APPENDIX A: DERIVATION OF THE THREE-MOMENT MODEL IN TERMS OF MEAN, VARIANCE AND SKEWNESS

$$U(\pi_{CE}) = U(\mu - m) = EU(\mu + \varepsilon)$$

where μ is the expected profit return, m is premium and ε is the error term with zero expected value. The profit return π is a random variable which is equal to $\mu + \varepsilon$.

$$U(\mu - m) \cong U(\mu) - mU'(\mu)$$

$$EU(\mu + \varepsilon) \cong EU(\mu) + E[\varepsilon U'(\mu)] + E[\varepsilon^2 u''(\mu)]/2 + E[\varepsilon^3 u'''(\mu)]/3!$$

$$= U(\mu) + \sigma^2 U''(\mu)/2 + S_k U'''(\mu)]/3!$$

$$m = \sigma^2 U''(\mu)/[2U'(\mu)] + S_k U'''(\mu)/[3!U'(\mu)]$$

$$\pi_{CE} = \mu - m$$

$$= \mu - \lambda\sigma^2/2 + S_k U'''(\mu)/[6U'(\mu)]$$

$$= \mu - \lambda\sigma^2/2 + S_k \lambda\eta/6$$

where $\lambda = -U''(\mu)/[U'(\mu)]$, $\eta = -U'''(\mu)/[U''(\mu)]$

APPENDIX B: YIELD, PRICE AND INCOME RISK SIMULATION FOR PNW APPLE GROWERS

We have explored four sources of data available for the apple risk research. First is the NASS published data. Second is APH RMA records. Third is the WA Clearing House data. The last one will be from our own survey. They each have advantages and disadvantages in terms of representing the risks as listed in the following table.

	NASS	RMA	Clearing House	Survey
Period	>30 years	24 years	4 years	5 year
By variety	No	No	Yes	Yes
Aggregation	State level	Farm level	State level	Farm level
Organic/Conventional	mixed	mixed	Separated	Organic only

Ideally, to analyze the income risks of an apple grower, we will need farm level data, by variety, by grade/size category because they are sold at different prices, by conventional or organic practice, and longer period so as to represent the production risk caused by weather. Some bad weather might have not appeared in recent four or five years. However, from the above table we see that there is no one source that can satisfy all the research needs. The information from each source is combined together with reasonable assumptions to obtain farm level yields and prices by variety for both conventional and organic apple data.

I. Yield, Price and Income Simulation for Conventional Apples

We first need to estimate the model parameters, and simulation can be easily carried in computer software based on the parameters. We first identify the long term trend using NASS data, and examine the detrended residual yield distribution. The test statistic of Shapiro-Wilk normality test for the residuals is 0.96, which means we cannot reject that the residual of the yield following a normal distribution. Because we will need the farm yield which may have a higher risk than the state level, we turn to RMA data. Assuming they follow the same trend because of the same technical development, we can measure the farm level yield distribution and calculate the farm level variance.

Clearing House data is the only source with output quantity by variety. We use these data as a proxy to the total WA state output of each variety excluding cull. Based on an average state cull rate, we converted the packed output into total output including culls. Then based on the two Washington Fruit Surveys in January 1993 and 2001, and the by variety acreages changes for the years after, we estimated the acreage for each year for each variety, and use them to divide the total output to get yield by variety. These yields by variety are estimated based on many assumptions, with about ten years of data, and are at state level. With these yields, we can estimate the trends of each variety, detrend them, and estimate the distributions. We then convert the state level by variety distributions into farm level by simply enlarging their variances while maintain all other distributional parameters at the state level. We follow the same variance ratios between state and farm from the above all variety samples in this conversion of by variety samples. These farm level yield distribution by variety estimations can be used in simulation.

It is relatively easier to estimate the price distribution because prices are at the state level and individual farms face the same prices. First, the Clearing House website provides the average by variety FOB data for over ten years. Specifically, Reds and Goldens: 1980-2004, Granny Smith: 1984-2004, and Gala and Fuji: 1991-2004. The FOB prices are then converted into farm gate prices by subtracting the warehouse cost. Again, trends are identified and lognormal distributions are adopted after refutable tests.

The correlations between the yield of all varietal apples and their prices are estimated from the historical data. A negative correlation is identified for the established varieties because of the market supply demand relationships. The correlation is then imposed in the joint price-yield simulation. The growers per acre revenue distribution can be calculated by the price times the yields, under the assumption of all apples are sold at an average market price.

II. Yield, Price and Income Simulation for Organic Apples

A survey on organic apple growers in the PNW was conducted by Washington State University and University of Idaho. We have Red Delicious, Golden Delicious, Fuji, Gala, Braeburn, and Granny Smith apples in our survey with a total of 118 observations for 33 farms for 6 years (2000-2005). Although the number of farms is not large, it has a good representability given the whole population of PNW growers with no less than five acres of organic apples is very small. We only keep the first four varieties because the others have only one or two farms with multiple years of yield records which are not enough for risk analysis purposes.

No trend is modeled because we believe that the conventional long term trend does not represent the organic technology, and the six years of farm data is not long enough to model the trend. As a result, we average the annual yields to represent the expected yield for each variety by farm, and the sample standard deviations is also used to represent the yield risks for each variety by farm. Then, the averages and standard deviations of all the farm yield are used as the representative farm's expected yield and standard deviation. Following the same normal distributions of conventional yields, 10,000 random yields are simulated for each variety representing the upcoming crop year 2006.

The organic FOB price data (1998-2004) is found from the WA Growers Clearing House (WAGCH) website, the same place as conventional apple. Following the same procedure as in the conventional price estimations, a lognormal model is used and 10,000 random prices are simulated for each variety.

The price-yield correlations are calculated based on the WAGCH and survey data over years 2000 through 2004, during which both price and yield have observations. A joint price-yield distribution is then obtained from a linear transformation of the independently simulated price and yield distributions. The revenue distribution from growing each variety of apples is obtained by multiplying the prices and yields in the joint distribution.

APPENDIX C: COMPUTER PROGRAM CODES FOR CHAPTER 2

Appendix C.1. Identify the Specification of Error Terms for the Regression Model (SAS)

```
proc import datafile="c:\data\hedge.xls" out=one replace;
run;

proc corr data=one;
run;

data one1;  set one;
    if dummy=1 then D2=0;
    else D2=1;
    *D2 is dummy variable where 1 is contract switching point and 0 not;
    cash1 = dif1( cash );
    c1 = dif1( c );
    k1 = dif1(k);
    m1 = dif1(m);
    run;


PROC AUTOREG DATA=one1;
    MODEL Cash1 = c1 d2/ NLAG=1 GARCH=(Q=1,P=1) /*ARCHTEST*/ METHOD=ML;
    OUTPUT OUT=OUT6 CEV=V R=R;
    run;

data one21;  set one;
     cash21 = dif21( cash );
     c21 = dif21( c );
  run;

PROC AUTOREG DATA=one21;
    MODEL CASH21 = c21 dummy/ NLAG=(1 21) GARCH=(Q=1,P=1) ARCHTEST METHOD=ML;
    OUTPUT OUT=OUT211 CEV=V R=R;
run;

data one65;  set one;
    cash65 = dif65( cash );
    c65 = dif65( c );
  run;

PROC AUTOREG DATA=one65;
    MODEL CASH65 = c65 dummy/ NLAG=(1 65) GARCH=(Q=1,P=1) /*ARCHTEST*/
METHOD=ML;
    /*MODEL CASH65 = c65 / NLAG=(65) GARCH=(Q=1,P=1) ARCHTEST METHOD=ML;*/
    OUTPUT OUT=OUT651 CEV=V R=R;
    run;

data one130;  set one;
    cash130 = dif130( cash );
    c130 = dif130( c );

PROC AUTOREG DATA=one130;
    MODEL CASH130 = c130 dummy / NLAG=(1 130) GARCH=(Q=1,P=1) /*ARCHTEST*/
METHOD=ML;
    /*MODEL CASH130 = c130 / NLAG=(130) GARCH=(Q=1,P=1) ARCHTEST
METHOD=ML;*/
    OUTPUT OUT=OUT1301 CEV=V R=R;
```

```
    run;

/*260 days hedge period*/
data one260;  set one;
    cash260 = dif260( cash );
    c260 = dif260( c );
  run;

PROC AUTOREG DATA=one260;
    MODEL CASH260 = c260 dummy/ NLAG=(1 260) GARCH=(Q=1,P=1) /*ARCHTEST*/
METHOD=ML;
    /*MODEL CASH260 = c260 / NLAG=(260) GARCH=(Q=1,P=1) ARCHTEST
METHOD=ML;*/
    OUTPUT OUT=OUT2601 CEV=V R=R;
    run;
```

Appendix C.2. Calculate the Utility Maximized Hedge Ratio (GAUSS)

```
new;
cls;

format /rd 16,4;

load z[] =    C:\data\dif.txt;

/*The variables are Cash dif, Chifuture dif, KCBT dif, MBT dif*/

n = rows(z)/4;
z = reshape(z,n,4);
@
CTC = 1.6;              /*commission cost for small hedgers*/
@
CTC = 0.18;             /*commission cost for Large hedgers*/
@
TC0 = 0.26 + CTC;
@
TC0 = 0.25 + CTC;

Let V[4,5] =
3.2579138    19.5727942  37.3549684  51.1045413  62.2345384
/*cash variance for 5 hedging periods*/
4.9185891    21.0261394  33.9674329  43.0818195  51.4391643
/*CBOT futures variance for 5 hedging periods*/
4.8509113    23.2267014  43.2922457  56.8513911  59.6205502
/*KCBT futures variance for 5 hedging periods*/
4.5838074    21.4092174  41.7183450  52.4063269  52.4790609
/*MGE futures variance for 5 hedging periods*/
;
vs0 = v[1,.]^2;
vf0=V[2:4,.]^2;

let b[5,3] = 0.3581     0.3585   0.3291
                  0.3296     0.3469   0.335
                  0.3046     0.3336   0.3109
                  0.3191     0.3531   0.3199
                  0.3117     0.3297   0.3233;
/*Regression hedge ratios with dummy variable*/
Vsf0 = b'.*Vf0;

xfhold = zeros(5,15);
maxEUhold = zeros(5,15);
```

```
lamda1 = {0.2, 0.4, 0.6, 0.8, 1};

i=1;
    do until i > 5;                  /* 5 risk aversion levels */
    lamda = lamda1[i];    /* a scalor */

    j=1;                             /* 3 markets with corresponding TC */
        do until j>3;
        tc = tc0;

        k=1;
            do until k >5;        /* 5 hedging periods */
            vf = vf0[j,k];        /* variance of futures */
            vsf = vsf0[j,k];      /* covariance of cash and futures */
            vs = vs0[k];

            Xf0 = tc/(lamda*vf)-vsf/vf;
            if xf0 < 0;
            Xf = xf0;
            else;
            xf = 0;
            endif;

            {f} = maxeu(xf);
            xfhold[k,(3*i+j-3)] = xf;
            maxEuhold[k,(3*i+j-3)] = f;

            k=k+1;
            endo;
        j=j+1;
        endo;

    i = i+1;
    endo;

print "xfhold" -xfhold;
print "maxeuhold" maxeuhold;

end;

proc maxeu(xf);
     local eu;
     EU = -abs(xf)*TC -lamda/2*(Vs + (xf^2)*vf+ 2*xf*Vsf);
     retp (eu);
     endp;
```

APPENDIX D: COMPUTER PROGRAM CODES FOR CHAPTER 3

Appendix D.1. Simulating Bivariate Gamma Distribution for Futures and Cash Prices (GAUSS)

```
new;
cls;
format /rd 6,3;

r = 10000;
MC = 3.7;
Mf = 3;
k = 1;
Vc = k*0.37;
Vf = k*0.56;
j = 0.5;
Sc = 0.12;
Sf = j*0.29;
/*These are nonstandardized third moments which are recalulated from the data
(meanc(c-Ec)^3. */
rho = 0.48;
/*The above data are mean, variance and skewness correlation of futures and
  cash prices and dry area wheat yield*/

a1 = 4*Vc^3/(Sc^2);
b1 = Sc/(2*vc);
a2 = 4*vf^3/(Sf^2);
b2 = sf/(2*vf);
/*The calculation is based on the 2nd and 3rd moments with alpha and beta
sigma^2 = alpha*beta^2, skewness = 2*alpha*beta^3*/

z = rho*(a1*a2)^0.5;

y1 = rndgam(r,1,a1-z);
y2 = rndgam(r,1,a2-z);
y3 = rndgam(r,1,z);
x1 = b1*(y1+y3);
x2 = b2*(y2+y3);

/*Correlated bivariate gamma simulation. The approach is based on
Averill M. Law and W.David Kelton "simulation Modeling and Analysis" P270*/

xc = x1 + MC - meanc(x1);
xf = x2 + Mf - meanc(x2); /*Adjusted mean*/
xx = xc~xf;

NC = xc-meanc(xc);
NF = xf-meanc(xf);              /*W/O standardized*/
```

```
SC1 = sumc(NC^3)/(r-1);        /*sample Skewness of Cash*/
Sf1 = sumc(NF^3)/(r-1);        /*sample Skewness of futures*/

vc2f = sumc((NC^2).*NF)/(r-1);        /*sigma of cash^2 and futures*/
vcf2 = sumc(NC.*(NF^2))/(r-1);        /*sigma of cash and futures^2*/

x=68.94;
g = xc.*x;
ohr = 0.35;
/*0.38 0.35 0.35 0.35 for j=1,2,3,4*/
h = (3-xf).*ohr*x;
pi0 = 550 - 230 +g+h;

NP = pi0-meanc(pi0);                  /*W/O standardized*/
Spi = sumc(Np^3)/(r-1);        /*sample Skewness of Cash*/

print "mean" meanc(xc) meanc(xf);
print "skew" SC1 Sf1 vc2f vcf2;
print "cov" vcx(xx);
print "corre" corrx(xx);
print "a1 b1 " a1 b1;

output file = Bgammasimuv05.txt reset;

print xx;
```

Appendix D.2. Calculating the Optimal Hedge Ration for Two-moment, Three-moment and Expected Utility Model (GAUSS)

```
new;
cls;
format /rd 6,3;

r = 10000;
load xx[r,2] = bgammasimu.txt;

xc = xx[.,1];
xf = xx[.,2];

NC = xc-meanc(xc);
NF = xf-meanc(xf);              /*W/O standardized*/
SC1 = sumc(NC^3)/(r-1);        /*sample Skewness of Cash*/
Sf1 = sumc(NF^3)/(r-1);        /*sample Skewness of futures*/

vc2f = sumc((NC^2).*NF)/(r-1);      /*sigma of cash^2 and futures*/
vcf2 = sumc(NC.*(NF^2))/(r-1);      /*sigma of cash and futures^2*/

print "mean" meanc(xc) meanc(xf);
print "skew" SC1 Sf1 vc2f vcf2;
print "cov" vcx(xx);
print "corre" corrx(xx);

/*Test the null hypothesis H0: skewness=0 vs.H1 skewness=/0*/
z1 = sc1/sqrt(6/r);
z2 = sf1/sqrt(6/r);
z = cdfni(0.975);    /*critical value*/
/*Reject the null hypothesis since z1 and z2 both greater than z*/

f0 = 2.8;
/*wheat price for the first week of September 2001 as the initial future price*/
@f0 = meanc(xf);    /*unbiased futures market*/
@Y = 68.94;      /*bushel/acre*/
C = 230; /*two year rotation*/
/*The above data are from the PNW crop insurance paper*/

ymv = zeros(1,6);
ymvs = zeros(1,6);
CEmv = zeros(1,6);
CEmvs = zeros(1,6);
UCEmv = zeros(1,6);
UCEmvs = zeros(1,6);
```

```
W0 = 550;    /*Intial wealth for whitman County is 550 $/acre(Wang,2003)*/
W = W0;
/*Average Profit from hedging is around $25 under biased futures market*/

lamda0 = (seqa(1.5,0.5,6))/W;
eta0 = (seqa(2.5,0.5,6))/W;
theta0 = seqa(1.5,0.5,6);

EF1 = meanc(xf);
cov = vcx(xx);

i = 1;
     do until i > 6;
     lamda = lamda0[i];      /*6 risk aversion levels*/
     eta = eta0[i];    /*6 absolute prudence levels*/
     theta = theta0[i];

    /*Two moments model*/
     ymv[i] = (f0-EF1)/(lamda*cov[2,2])+cov[1,2]*y/cov[2,2]; /*OHR*/

     CEmv[i] = y*meanc(xc)-c+(f0-EF1)*ymv[i] - lamda*(y^2*cov[1,1] +
                 ymv[i]^2*cov[2,2] - 2*y*ymv[i]*cov[1,2])/2;
                 /*Certainty Equivalent*/
     UCEmv[i] = ((1-theta)^(-1))*CEmv[i]^(1-theta);      /*U(CE)*/

     /*Three moments model*/
     sf = sf1;    /*1 skewness levels*/
     delta = (lamda^2)*(cov[2,2]-eta*y*vcf2)^2 - lamda*eta*sf*(lamda*eta*y^2*vc2f-
             2*lamda*y*cov[1,2]-2*f0+2*EF1);

     ymvs[i] = y*vcf2/sf+(-lamda*cov[2,2]+sqrt(delta))/(lamda*eta*sf); /*OHR*/

     CEmvs[i] = y*meanc(xc)-c+(f0-EF1)*ymvs[i] - lamda*(y^2*cov[1,1] +
                 ymvs[i]^2*cov[2,2] -2*y*ymvs[i]*cov[1,2])/2 + lamda*eta*(y^3*sc1 –
                 ymvs[i]^3*sf - 3*y^2*ymvs[i]*vc2f+3*y*ymvs[i]^2*vcf2)/6;
                 /*Certainty Equivalent*/

     UCEmvs[i] = ((1-theta)^(-1))*CEmvs[i]^(1-theta);      /*U(CE)*/
i = i+1;
endo;

/***MAXIMIZING EXPECTED UTILITY***/
    sqpSolveSet;
     x0 = {0.3};
     MIP = 0;
     {x,f,lagr,ret} = sqpSolve(&EU,X0);
```

```
  F = -F;

 proc EU(X0);
      local EU,profit,mpi,vpi,theta;
      Profit = xc*y - c + (f0 - xf)*x0 + W0;
      MPI = MEANC(Profit);
      VPI = VCX(PROFit);
      theta = 1.5;
      EU = -meanc((profit^(1-theta))/(1-theta));
 retp(EU);
 endp;


print "Two-momentOHR " ymv./y;
print "Three-MomentOHR " ymvs./y;
print;
print "UCEmv " ucemv;
print "UCEmvs " ucemvs;
print;
print "CEmv " cemv;
print "CEmvs " cemvs;
print "maximized expected utility " f;
print "optimal hedge ratio " x/y;

end;
```

Appendix D.3. Certainty Equivalent Changes with Lamda and Eta (GAUSS)

```
new;
cls;
format /rd 6,3;

r = 10000;
load xx[r,2] = bgammasimu.txt;

xc = xx[.,1];
xf = xx[.,2];
NC = xc-meanc(xc);
NF = xf-meanc(xf);              /*W/O standardized*/
SC1 = sumc(NC^3)/(r-1);         /*sample Skewness of Cash*/
Sf1 = sumc(NF^3)/(r-1);         /*sample Skewness of futures*/
vc2f = sumc((NC^2).*NF)/(r-1);          /*sigma of cash^2 and futures*/
vcf2 = sumc(NC.*(NF^2))/(r-1);          /*sigma of cash and futures^2*/

print "mean" meanc(xc) meanc(xf);
print "skew" SC1 Sf1 vc2f vcf2;
print "cov" vcx(xx);
print "corre" corrx(xx);

/*Test the null hypothesis H0: skewness=0 vs.H1 skewness=/0*/
z1 = sc1/sqrt(6/r);
z2 = sf1/sqrt(6/r);
z = cdfni(0.975);   /*critical value*/
/*Reject the null hypothesis since z1 and z2 both greater than z*/

f0 = 3.2;
/*wheat price for the first week of September 2001 as the initial future price*/
@f0 = meanc(xf);   /*unbiased futures market*/
@Y = 68.94;     /*bushel/acre*/
C = 230; /*two year rotation*/
/*The above data are from the PNW crop insurance paper*/

ymv = zeros(1,6);
ymvs = zeros(1,6);
CEmv = zeros(1,6);
CEmvs = zeros(1,6);
UCEmv = zeros(1,6);
UCEmvs = zeros(1,6);

W0 = 550;   /*Intial wealth for whitman County is 550 $/acre(Wang,2003)*/
W = W0;
/*Average Profit from hedging is around $25 under biased futures market*/
```

```
lamda0 = (seqa(6,0,6))/W;
eta0 = (seqa(1,1,6))/W;
theta0 = seqa(1.5,0.5,6);
EF1 = meanc(xf);
cov = vcx(xx);

i = 1;
    do until i > 6;
    lamda = lamda0[i];    /*6 risk aversion levels*/
    eta = eta0[i];   /*6 absolute prudence levels*/
    theta = theta0[i];

   /*Two moments model*/
    ymv[i] = (f0-EF1)/(lamda*cov[2,2])+cov[1,2]*y/cov[2,2]; /*OHR*/

    CEmv[i] = y*meanc(xc)-c+(f0-EF1)*ymv[i] - lamda*(y^2*cov[1,1] +
              ymv[i]^2*cov[2,2] - 2*y*ymv[i]*cov[1,2])/2;
              /*Certainty Equivalent*/

    UCEmv[i] = ((1-theta)^(-1))*CEmv[i]^(1-theta);    /*U(CE)*/

    /*Three moments model*/
    sf = sf1;   /*1 skewness levels*/
    delta = (lamda^2)*(cov[2,2]-eta*y*vcf2)^2 - lamda*eta*sf*(lamda*eta*y^2*vc2f-
               2*lamda*y*cov[1,2]-2*f0+2*EF1);

    ymvs[i] = y*vcf2/sf+(-lamda*cov[2,2]+sqrt(delta))/(lamda*eta*sf); /*OHR*/

    CEmvs[i] = y*meanc(xc)-c+(f0-EF1)*ymvs[i] - lamda*(y^2*cov[1,1] +
               ymvs[i]^2*cov[2,2] - 2*y*ymvs[i]*cov[1,2])/2 + lamda*eta*(y^3*sc1 –
               ymvs[i]^3*sf - 3*y^2*ymvs[i]*vc2f+3*y*ymvs[i]^2*vcf2)/6;
                /*Certainty Equivalent*/

    UCEmvs[i] = ((1-theta)^(-1))*CEmvs[i]^(1-theta);    /*U(CE)*/
i = i+1;
endo;

print "Two-momentOHR " ymv./y;
print "Three-MomentOHR " ymvs./y;
print "UCEmv " ucemv;
print "UCEmvs " ucemvs;
print;
print "CEmv " cemv;
print "CEmvs " cemvs;
end;
```

Appendix D.4. Comparative Statics of the Optimal Hedge Ratio for Two-moment and Three-moment Models (GAUSS)

```
new;
cls;
format /rd 6,3;

r = 10000;
load xx[r,2] = bgammasimu.txt;
xc = xx[.,1];
xf = xx[.,2];
NC = xc-meanc(xc);
NF = xf-meanc(xf);              /*W/O standardized*/
SC1 = sumc(NC^3)/(r-1);         /*sample Skewness of Cash*/
Sf1 = sumc(NF^3)/(r-1);         /*sample Skewness of futures*/

vc2f = sumc((NC^2).*NF)/(r-1);       /*sigma of cash^2 and futures*/
vcf2 = sumc(NC.*(NF^2))/(r-1);       /*sigma of cash and futures^2*/

print "mean" meanc(xc) meanc(xf);
print "skew" SC1 Sf1 vc2f vcf2;
print "cov" vcx(xx);
print "corre" corrx(xx);


f0 = 3.2;/*wheat price for the first week of September 2001 as the initial future price*/
Y = 68.94;     /*bushel/acre*/
C = 230; /*cost for the two year rotation*/
/*The above data are from the PNW crop insurance paper*/

ymv = zeros(1,5);
ymvs = zeros(5,7);

W0 = 550;   /*Intial wealth for whitman County is 550 $/acre(Wang,2003)*/
W = W0; /*Average Profit from hedging is around $25*/

lamda0 = (seqa(1,1,7))/W;
eta0 = (seqa(1,1,7))/W;
theta0 = seqa(1.5,0.5,5);
@
lamda0 = seqa(0.2,0.2,5);
eta0 = seqa(0.2,0.2,5);
@
EF1 = meanc(xf);
cov = vcx(xx);
```

```
i = 1;
    do until i > 7;
    lamda = lamda0[i];      /*5 risk aversion levels*/
    j = 1;
        do until j > 7;
        eta = eta0[j];    /*5 absolute prudence levels*/
        /*Two moments model*/
        ymv[i] = (f0-EF1)/(lamda*cov[2,2])+cov[1,2]*y/cov[2,2]; /*OHR*/

        /*Three moments model*/
        sf = sf1;    /*1 skewness levels*/
        delta = (lamda^2)*(cov[2,2] - eta*y*vcf2)^2 –
                lamda*eta*sf*(lamda*eta*y^2*vc2f - 2*lamda*y*cov[1,2] –
                2*f0+2*EF1);
        ymvs[i,j] = y*vcf2/sf+(-lamda*cov[2,2]+sqrt(delta))/(lamda*eta*sf); /*OHR*/
     j = j+1;
     endo;
i = i+1;
endo;


print "Two-momentOHR " ymv./y;
print;
print "Three-MomentOHR " ymvs./y;

end;
```

APPENDIX E: COMPUTER PROGRAM CODES FOR CHAPTER 4

Appendix E.1. Simulating Price and Yield for Each Variety (GAUSS)

```
new;
cls;
y = zeros(10000,2);
p = zeros(10000,1);
xx = rndn(10000,2);

r = -0.5586; /*reds*/
@
r = -0.571; /*goldens*/

r = -0.564; /*gala*/

r = -0.861; /*fuji*/
@
/*correlation between the residuals from the price and yield trend*/
M = zeros(2,2);
M[1,1] = 1;
M[2,1] = r;
M[2,2] = sqrt(1-r^2);

yy = M*xx';

/*red trend*/
my = 902.91; /*yield prediction for 2006 as mean*/
mp = 1.416;      /*price prediction for 2006 as mean*/
Ysdv = {276.49,0.346}; /*standard deviation of yield and price*/
@
/*Goldens*/
my = 1032.09;
mp = 1.777;
Ysdv = {270.59, 0.3194};

/*Gala*/
my = 929.95;
mp = 2.209;
Ysdv = {103.89,0.1816};

/*Fuji*/
my = 832.23;
mp = 2.269;
Ysdv = {200.07,0.2514};
@
Y = Ysdv.*yy;
Y = y';
```

```
pp = Y[.,2]+mp;
lnp = exp(pp);
yield = my + y[.,1];

/*defnie all negative yields as 0*/
i = 1;
	do until i>10000;
	if yield[i] < 0;
	yield[i] = 0;
	else;
	endif;
	i=i+1;
endo;

py = lnp.*yield;
z = yield~pp;
zz = yield~lnp~py;

print "correlation between yield and lnprice" corrx(z);
print "standard deviation" stdc(z);
print "mean" meanc(z);
```

Appendix E.2. Modeling GYC Insurance for Red Delicious Grower (GAUSS)

```
new;
cls;
library pgraph;
format /rd 10,3;
n = 10000;

load xx[n,3] = pyreds.txt;
y = xx[.,1];
p = xx[.,2];
y0 = meanc(xx[.,1]);
p0 = meanc(xx[.,2]);
MP = 0;
VP = 0;
w0 = 6695;
cost = 3920;
m = 205;
load z0[m,4] = pricecoverage.txt;

EU0 = zeros(1,1);
prof = zeros(n,1);
sub0 = zeros(1,1);
prem0 = zeros(1,1);

i = 1;
   do until i>m;
   z = z0[i,.];
   MPCI = 4.37*z[1]*maxc(((z[2]*y0-y)~zeros(n,1))');
/*we use varietal apple B's price selection 4.65, fresh apple 6.9 and its mean 4.37 for red
delicious apples*/
@
   Prem = 4.37*z[1]*z[2]*y0*Z[3];
   sub = Prem*z[4];
   Total = MPCI-Prem+sub;
@
   Prem = meanc(MPCI);    /*Actuarially fair*/
   sub = prem*z[4];
   Total = MPCI-Prem+sub;    /*no subsidy*/

   w = w0 + p.*y + total - cost;    /*Only MPCI*/
   theta = 2;    /*Risk aversion coefficient*/
   U = w^(1-theta)/(1-theta);
   EU = meanc(U);
   prof = prof~w;
   Eu0 = EU0|eu;
```

```
   sub0 = sub0|sub;
   prem0 = prem0|prem;
i=i+1;
endo;

t = seqa(1,1,m); /*create an index to find which is the max coverage level*/
Eu0 = 10000.*eu0[2:m+1];
sub0 = sub0[2:m+1];
prem0 = prem0[2:m+1];
EUnew = t~EU0~sub0~prem0~z0;
E = sortc(eunew,2);
MaxEU = E[m,2];

g = E[m,1];
profit = prof[.,g+1];         /*the maximized profit*/
profit0 = w0+p.*y-cost;      /*Calculate the profit w/o insurance*/
Mp = meanc(profit);
stdp = stdc(profit);
Mp0 = meanc(profit0);
stdp0 = stdc(profit0);

/***WILLINGNESS TO PAY FOR THE FUTURES***/

WT0 = {100};
sqpSolveSet;
{WT,FW, GW, RTCW} = sqpSolve(&SSE,WT0);

print "price election, MPCI coverage";
print z0[g,.];
print "WILLINGNESS TO PAY FOR THE INSURANCE,Maximized expected utility" ;
print WT maxeu;
print "mean and stdc of original and maximized profit";
print mp0 stdp0 mp stdp;
print "Optimal subsidy and premium" E[m,3:4];

{ b,m,f } = hist(profit,20);

/***Procedure to CALCULATE THE WILLINGNESS TO PAY***/
proc SSE(WT0);
local EU0,UPI0,SSE;
        UPI0 = (profit0+wt0)^(1-theta)/(1-theta);
        EU0 =    10000 * MEANC(UPI0);
        SSE =    (maxeu - EU0)^2;

    retp(SSE);
    endp;
```

Appendix E.3. Modeling Hypothetical IP Insurance for Red Delicious Apple Grower (GAUSS)

```
new;
cls;
library pgraph;
format /rd 10,4;
n = 10000;

load xx[n,3] = pyreds.txt;    /*bivariate normal distributed price and yield*/
y = xx[.,1];
p = xx[.,2];
y0 = meanc(xx[.,1]);
p0 = meanc(xx[.,2]);
MP = 0;
VP = 0;
w0 = 6695;
cost = 3920;
m = 205;
load z0[m,4] = pricecoverage.txt;
/*Create a Z0 matrix which include the base price selection,the MPCI coverage
(50%-75%), and corresponding base premium rate and premium subsidy factor*/

EU0 = zeros(1,1);
prof = zeros(n,1);
sub0 = zeros(1,1);
prem0 = zeros(1,1);

i = 1;
   do until i>m;
   z = z0[i,.];
   IP = maxc(((6.9@4.65,p0@*z[1]*z[2]*y0-p.*y)~zeros(n,1))');
/*set price election as the MPCI level (4.65) or mean of cash prices*/

   Prem = 6.9@4.65,p0@*z[1]*z[2]*y0*Z[3];
   sub = Prem*z[4];
   Total = IP-Prem+sub;
@
/*ONly consider actuarially fair case for IP*/
   Prem = meanc(IP);    /*Actuarially fair*/
   sub = prem*z[4];
   Total = IP-Prem;    /*no subsidy*/
@
   w = w0 + p.*y + total - cost;    /*Only MPCI*/
   theta = 2;    /*Risk aversion coefficient*/
   U = w^(1-theta)/(1-theta);
```

```
    EU = meanc(U);
    prof = prof~w;
    Eu0 = EU0|eu;
    sub0 = sub0|sub;
    prem0 = prem0|prem;
i=i+1;
endo;

t = seqa(1,1,m); /*create an index to find which is the max coverage level*/
Eu0 = 10000.*eu0[2:m+1];
sub0 = sub0[2:m+1];
prem0 = prem0[2:m+1];
EUnew = t~EU0~sub0~prem0~z0;
E = sortc(eunew,2);
MaxEU = E[m,2];

g = E[m,1];
profit = prof[.,g+1];          /*the maximized profit*/
profit0 = w0+p.*y-cost;      /*Calculate the profit w/o insurance*/
Mp = meanc(profit);
stdp = stdc(profit);
Mp0 = meanc(profit0);
stdp0 = stdc(profit0);

/***WILLINGNESS TO PAY FOR THE FUTURES***/
WT0 = {100};
sqpSolveSet;
{WT,FW, GW, RTCW} = sqpSolve(&SSE,WT0);

print "price election, MPCI coverage";
print z0[g,.];
print "WILLINGNESS TO PAY FOR THE INSURANCE, Maximized expected utility" ;
print WT maxeu;
print "mean and stdc of original and maximized profit";
print mp0 stdp0 mp stdp;
print "Optimal subsidy and premium" E[m,3:4];

/***Procedure to CALCULATE THE WILLINGNESS TO PAY***/
      proc SSE(WT0);
      local EU0,UPI0,SSE;
          UPI0 = (profit0+wt0)^(1-theta)/(1-theta);
          EU0 = 10000 * MEANC(UPI0);
          SSE =    (maxeu - EU0)^2;

      retp(SSE);
      endp;
```