AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Pacific Northwest Grain Growners' Income Risk Management

Bingfan Ke

H. Holly Wang[1]

Paper Presented at the Western Agricultural Economics Association Annual Meetings

Logan, Utah, July 2001

Copyright 2001 by Bingfan Ke and H. Holly Wang. All rights reserved. Readers may take verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

1. The authors are, respectively, a graduate research assistant and an assistant professor at the Department of Agricultural Economics, Washington State University. Contact information: ke@mail.wsu.edu (Bingfan Ke); wanghong@wsu.edu (H. Holly Wang).

Pacific Northwest Grain Growers' Income Risk Management

Introduction

Wheat is one of the major crops grown in the Pacific Northwest (PNW) area. In particular, this region holds the world's highest wheat yield for dry-land production (Young, Kwon and Young). Other crops included in rotations in this area are barley, dry beans, and lentils. Grain production in the PNW area is especially risky for two reasons. First, price fluctuations in the world grain market affect farmers' income directly because the majority of the wheat produced in this area is exported to the Asian market. Secondly, precipitation is limited and varies significantly even in small areas within the PNW region, thus causing cropping practices and yields to be heterogeneous. Winter wheat-summer fallow is the predominant cropping system in dry areas where annual rainfall is less than 15 inches. In intermediate rainfall areas (annual rainfall between 15 and 18 inches), winter wheat-spring barley-summer fallow is the common rotation. The rotation system is more complicated in high rainfall areas (annual rainfall more than 18 inches), usually with annual cropping including winter wheat, barley, and dry beans or lentils. For many PNW farms, revenue risk management is as important as seeking economic profit.

Farmers have several strategies available in their risk management portfolios. Among these strategies buying crop insurance and hedging in futures markets are the most important ones. In this paper, we will focus on the risk management effectiveness of several crop insurance programs and futures market instruments available to PNW farmers.

Two major types of crop insurance--yield insurance and revenue insurance--have been provided by the USDA Risk Management Agency (RMA) for most crops throughout the U.S., including wheat and barley in the PNW area. The yield insurance programs, Multiple Peril Crop Insurance (MPCI), have two versions. One is the individual-based version, the Actual Production History (APH) program. There is also a county-based version, Group Risk Plan (GRP). For APH, if a grower's own farm yield falls below the pre-selected coverage level, the difference (i.e., yield loss) will be paid to the farmer. In the county-based GRP, when the county average yield falls below the coverage level, farmers will be indemnified. GRP can deal with the moral hazard and adverse selection problems faced by the individual-based insurance programs. However, it has been shown that GRP is not an effective program since the indemnity is not perfectly correlated with the farmers' actual yield losses (Miranda, 1991; Wang, 2000). Several revenue insurance programs have been introduced in recent years. Income Protection (IP) program was initiated by RMA in 1997. The indemnity of IP is based on shortfalls below a crop revenue index. The index for IP coverage is the farm's APH yield times the average harvest futures price during a pre-planting period. Crop Revenue Coverage (CRC), also introduced in 1997, uses both base price and harvest price to indemnify the losses. The CRC revenue guarantee is the coverage level selected by the insured multiplied by the higher of either the APH yield multiplied by the base price times coverage level or, the APH yield multiplied by the harvest price times coverage level. Revenue Assurance (RA), developed by Farm Bureau Mutual Insurance Company, is available not only for a single crop, but also for multiple crops on a whole farm basis. The RA guarantee is calculated by multiplying the APH approved yield for the farm times the projected county price, times the coverage level selected by the insured. A new revenue insurance program, Adjusted Gross Revenue (AGR), is available in some selected pilot counties in Florida, Maine, Massachusetts, Michigan and New Hampshire for the 2001 crop year. AGR is a whole farm risk management tool. Apart from crops, it also covers livestock (RMA, 1999). All four of these revenue insurance programs (IP, CRC, RA, and AGR) are individual farm revenue based. Group Risk Income Protection (GRIP) was developed by the IGF insurance company. GRIP is similar to IP except that the indemnification is based on an area-revenue index instead of the farmer's individual-revenue index.

Among these insurance programs, APH and IP are available for wheat and barley in most of the counties in the PNW. In addition, CRC is available for wheat in most of the PNW region. PNW farmers can also use the hard winter wheat futures contracts to cross hedge the soft white winter wheat in Chicago Board of Trade (CBOT), Kansas City Board of Trade (KCBT), or Minneapolis Grain Exchange (MGEX). The objectives of this paper are to investigate the optimal strategy in using crop insurance (APH and IP for both wheat and barley, CRC for wheat) combined with hedging in futures market (for wheat) in revenue risk management for dry-land grain growers in the PNW region, and to evaluate the risk management effectiveness of alternative crop insurance programs. More specifically, we intend: (1) to find the optimal risk management strategies under different rotation systems (winter wheat-summer fallow in dry areas; winter wheat-spring barley-summer fallow in intermediate rainfall areas); (2) to evaluate the risk management effectiveness of each strategy; and (3) to estimate the substitute effect of the newly available revenue insurance programs on the combined market pricing instruments and yield insurance programs.

Previous Studies

Crop insurance and pricing instruments have long been studied in the context of farm risk management. It has been shown that crop insurance has a clear advantage over alternative institutional arrangements to protect farmers from yield risk (Ahsan, Ali, and Kurian, 1982).

Yield risk and crop insurance specifically associated with wheat production has also been studied. Marra and Schurle (1994) predicted farm level risk from county level yield using wheat yields in Kansas; Williams, et. al. (1993) applied stochastic dominance analysis on wheat and sorghum data in Kansas to compare the effectiveness of two crop insurance (individual MPCI and area MPCI) and two disaster assistance designs combined with government programs. They conclude that the individual crop insurance performs better than the area crop insurance.

Heifner and Coble (1998) use numerical methods to evaluate the performance of alternative insurance contract designs for representative corn, soybean and wheat farms at four locations across the US. Individual-index insurance contracts, including a form of individual-revenue insurance, are evaluated in several portfolios. Revenue insurance is found to outperform yield insurance when no pricing instrument is used; however, yield insurance becomes competitive when pricing instruments are included in the portfolio.

Wang, Hanson and Black (2000) examined the relative performance of alternative insurance contract designs (both individual-index insurance and area-index insurance) and the ability of revenue insurance to substitute for existing price and yield management instruments for a representative corn farmer, using numerical methods in the framework of expected utility maximization. The results show that yield insurance can perform as well as or better than revenue insurance when pricing instruments are included in the portfolio. Also, insurance contracts designed around area-based indices can outperform contracts designed around individual-firm indices after accounting for the transaction costs associated with moral hazard, adverse selection and administration.

Dhuyvetter and Kastens (1999) studied the linkage between crop insurance and hedging in futures market. Wheat yield data from 331 Kansas farms were used to examine the effects of no insurance, Catastrophic (CAT), APH, and CRC. They conclude that average revenue was similar across alternatives, but APH and CRC resulted in the least income variability. The risk reduction effects of hedging were small and the advantage of CRC over APH decreases as hedging increases.

There are also some other recent studies on revenue insurance from different perspective, such as the implications of price distributional assumptions, which are related directly to the measurement of price risk in revenue insurance (Goodwin, Roberts and Coble, 2000); an alternative CRC premium setting method--derivative security approach (Stokes, 2000); the actuarially fair premium rates for yield and revenue insurance for Georgia and South Carolina peaches (Miller, Kahl and Rathwell, 2000).

Most of these studies, however, include only one crop in the farm income model. Consequently, the risk management effect of diversification through planting multiple crops is ignored.

Although the insurance programs are heavily subsidized by the government, the participation rate for wheat is only 60% in PNW, which is much lower than other major wheat growing states such as Montana (87%) and Kansas (75%). The rate of use of futures market instruments is even lower. Previous risk analysis for this area has focused on the production side. No research in a risk management portfolio setting has been done for the PNW region where the natural conditions and cropping systems are unique to the US. Therefore, it is instructive to study the PNW farmers' risk management behavior in an integrated risk management system. In this paper, the desirable risk management portfolios for PNW farmers in two different rainfall zones (dry and intermediate) are identified under the framework of expected utility maximization, including available risk management instruments (APH, IP, CRC, and futures market for wheat; APH and IP for barley). The risk management effectiveness of each instrument is also evaluated. Due to the paucity of data for high rainfall area currently, it is not included in this paper.

The Decision Model

We assume that a representative farmer chooses a portfolio of risk management instruments before planting time each year based on the information available by then. The choice is made on the basis of maximizing expected utility of wealth at harvest.

(1) $$\underset{x}{Max}\ E[u(w_0 + p)]$$

where x is a vector which elements are the risk management instruments to be chosen by the farmer; u(.) is an increasing and concave utility function. The farmer is assumed to have constant relative risk aversion (CRRA) and the utility function takes the form $u(w) = (1-\theta)^{-1} w^{(1-\theta)}$, where θ is the relative risk aversion parameter and is set at $\theta = 2$, based on previous studies (Wang et. al., 1998). w_0 is the initial wealth level per acre, which is set at w_0 = \$550/acre for farms in Whitman County (This is calculated from sample farms of Whitman County that are reported in Agricultural and Food Policy Center working paper). π is the profit function.

(2) $$p\ (P, F, Y; x) = NP + FI + YI + RI$$

where:

$$NP = PY - C;$$

$$FI = x_1(F - F_0);$$

$$YI = P_b \max[0, x_2 E(Y) - Y] - PRE_y;$$

$$RI = \max[0, x_3 P_b E(Y) - FY] - PRE_r;$$

NP is the profit of selling crops without using any risk management instruments. P is the vector of wheat and barley cash prices at harvest, and Y is the corresponding realized yield. C is the total cost per acre. For model simplicity, we set C at a fixed value (\$230/acre for winter wheat-summer fallow two years rotation and \$465/acre for winter wheat-spring barley-summer fallow three years rotation, based on the production budgets report of Whitman County). FI is the net return of hedging in wheat futures market. F is the wheat futures price at harvest and F_0 is the initial futures price when the hedging is made. In our case, F_0 = \$2.99/bu., which is the September 1999 price of CBOT September 2000 wheat futures contract. The CBOT market is chosen because its price and PNW cash price are highly correlated. F is adjusted to be unbiased ($E(F)= F_0$) in order to avoid any speculating effect involved in the decision model. x_1 is the hedging quantity prior to planting time (sold if negative and purchased if positive). YI is the net return from yield insurance (APH, in our case, and for intermediate rainfall area YI is the summation of wheat and barley APH returns). P_b is the base price used to calculate the yield insurance indemnity when the realized yield is lower than the trigger yield. For wheat in the PNW area, CBOT September wheat futures price prior to planting level plus a "Portland Basis" is used as the base price. We choose P_b = \$3.49/bu., which is F_0 + \$0.5 "Portland Basis". For barley, the base price is 85% of CBOT September corn contract price in February, which is \$2.08/Bu. E(Y) is the projected yield at planting time, and Y is the realized yield. PRE_y is the insurance premium that is set at different levels in this study. x_2 is the APH insurance coverage level to be chosen. RI is the net return from revenue insurance (For intermediate rainfall area, RI is the summation of wheat and barley revenue insurance returns). For IP, P_b is defined the same as in the yield insurance. It is different for CRC, in which the base price is either the P_b defined above or, the futures price at harvest time, whichever is higher. PRE_r is the revenue insurance premium. x_3 is the revenue insurance coverage level to be chosen.

Joint Distribution of Price and Yield

A joint distribution of prices and yields at harvesting time of the 2000 crop year is simulated for each of the two rainfall areas, based on information available prior to planting time. For dry area with winter wheat--summer fallow rotation, the joint distribution includes the cash price and futures price of wheat, and the wheat yield of a representative farm in the area; for intermediate rainfall zone, where the typical rotation system is winter wheat-spring barley-summer fallow, the joint distribution includes five variables: cash prices for wheat and barley, futures price for wheat, and wheat and barley yields of a representative farm in the area. The joint distribution for each of the two areas is obtained in two steps: first a distribution of each of the variables is simulated independently (except for cash and futures prices of wheat, which are simulated jointly); then the correlations estimated from historical data are imposed among the variables to form the joint distribution, using Taylor's (1990) method.

ARCH/GARCH models have been commonly used for the analysis of prices (stock price, commodity cash price, and futures price). Engle (1982) introduced the ARCH (Autoregressive Conditional Heteroskedastic) process that allows the conditional variance to change over time as a function of past errors leaving the uncoditional variance constant. On the basis of ARCH model, Bollerslev (1986) developed Generalized ARCH model (GARCH). GARCH model assumes that both previous shocks and previous volatility affects current volatility. GARCH model allows for both a longer memory and a more flexible lag structure. In our study, wheat cash and futures prices are estimated jointly in a bivariate GARCH model, while barley cash price is modeled by a univariate GARCH model (Appendix). Since there is no closed form solution for the price distribution, numerical method is used to generate the distributions. Cash and futures prices of wheat in the first week of October 1999 are chosen as the initial values for simulating their joint distribution at harvesting time. Similarly, cash price of barley in the first week of April 2000 is chosen as the initial price. Based on the estimated models, 2000 samples of price are simulated for each of the three series. Data used in the price simulation are: weekly wheat futures price (September 1996-October 1999, CBOT); weekly wheat cash price (September 1996-October 1999, Portland Grain Market); and weekly barley cash price (September 1996-April 2000, Portland Grain Market). The Maximum Likelihood estimates are reported in **Table A1**.

A Beta density function is specified in this paper as the yield distribution (Appendix). In practice, both parametric and nonparametric methods have been used to estimate yield distributions. Parametric methods can provide more information and more efficient estimates than the nonparametric methods if the distributional assumptions are correct (Nelson and Preckel, 1989). Previous studies on agricultural production suggest that crop yield distributions are non-symmetric (skewed) and bell-shaped. These properties make the Beta density function a good candidate because a Beta density function is flexible enough to capture the skewness and the bell-shape. In addition, it is also very convenient for our simulation purposes. Beta distribution for yield has been used in risk management studies, such as Hennessy, Babcock, and Hayes (1997).

Historical yield data of wheat and barley in Whitman County, WA are used in our study. We choose Whitman County for two reasons: first, it is one of the prime grain production areas in the PNW; secondly and more importantly, its natural conditions and cropping systems can represent the general characteristics of the PNW region. Annual precipitation varies between 11 to 22 inches from western Whitman to eastern Whitman. Farmers in different rainfall zones have different rotation systems (Hall, Young, and Walker, 1999). As stated in the beginning of this paper, due to the availability of data for high rainfall zone, only two rotations are included in this study: winter wheat-summer fallow two years rotation in dry area and winter wheat-spring barley-summer fallow three years rotation in intermediate rainfall zone. The data available for the yield simulation include: 1990-1999 yield data of 301 farms in Whitman County, WA (159 farms in dry area growing wheat only; 142 farms in intermediate rainfall area growing both wheat and barley. From RMA); 1939-1999 wheat and barley yields of Whitman County (USDA).

Since ten-year farm level yield data are not long enough to provide the degree of freedom we need for the distributional estimation, assumptions are made that farm yield follows the same distribution as county level yield but differs in mean and variance and that yields in county level and farm level have the same time trend. Since yield data for longer periods are easy to get at the county level, based on these assumptions we can first simulate a distribution for county level yield then the farm yield distribution can be obtained by transforming the county level yield distribution. The model estimates are reported in **Table A2**. Based on the estimated yield models, 2000 samples of county level yields of wheat and barley are simulated for the year 2000. The mean and variance differences between county level yield and farm level yield are estimated using the ten years' data available for both. The differences are then used to transform the simulated county level yield to farm level yield, using the mean preserving technique (Wang, 1996).

A practical method for simulating multivariate non-normal distributions is described in Taylor's paper (1990). This method is also used in our paper to simulate the joint distribution of price and yield by imposing correlations among the independently simulated distributions. A tri-variate distribution of wheat futures and cash prices and wheat yield of the representative farm is used for winter wheat-summer fallow rotation system in dry area. Since wheat futures and cash prices are already simulated jointly, it is only necessary to impose one correlation. Correlation between farm level wheat yield in dry area and wheat cash price is estimated using the historical data. The correlation (-0.147) is then imposed and the tri-variate joint distribution is obtained. The joint distribution in intermediate rainfall area should include five variables: wheat cash and futures prices, barley cash price, and the representative farm's yields of wheat and barley. Three correlations are imposed: wheat cash price and wheat yield (-0.159), wheat cash price and barley cash price (0.846), and wheat yield and barley yield (0.34). Other correlations are implied by these correlation impositions. The correlation matrices and the basic statistics of the simulated data are reported in **Table 1** and **Table 2** respectively.

Results

The optimization problems in the decision model (1) are solved numerically in Gauss. Certainty Equivalent (CE) is used as the welfare measurement to evaluate different risk management portfolios under certain conditions/restrictions. Intuitively, CE is the amount of money needed to give the farmer in order to keep him/her as well off as providing him/her with a risk management portfolio. CE can be calculated by solving equation (3):

$$E[u(w_0 + p^*)] = E[u(w_0 + p_0 + CE)] \quad (3)$$

where p^* is the net return of using a certain risk management portfolio at optimal levels; p_0 is the net return of selling crops at spot market without using any risk management instruments.

Optimal hedge ratios, optimal insurance coverage levels, and CE values are calculated for different risk management portfolios under various conditions/restrictions of coverage level and premium loading, with or without government subsidy. There are seven alternative portfolios for the representative farmer in dry area with winter wheat-summer fallow rotation: futures only; APH only; IP only; CRC only; APH with futures; IP with futures; and CRC with futures. There are fifteen alternatives for the representative farmer in intermediate rainfall area with winter wheat-spring barley-summer fallow rotation: wheat futures only; wheat APH and barley APH; wheat IP and barley IP; wheat CRC only; wheat CRC and barley APH; wheat CRC and barley IP; wheat APH and barley IP; wheat IP and barley APH; wheat CRC and futures; wheat APH and barley APH plus wheat futures; wheat IP and barley IP plus wheat futures; wheat CRC and barley APH plus futures; wheat CRC and barley IP plus wheat futures; wheat APH and barley IP plus wheat futures; wheat IP and barley APH plus wheat futures.

Dry Area

The optimization results for dry area are reported in **Table 3**. We first examined the performance of each portfolio under the situation of no coverage restriction, no premium loading and no government subsidy. As expected, both IP and CRC perform better than APH without futures: CE for APH is $1.24, while the values for IP and CRC are $1.99 and $1.72 respectively. This is because the revenue insurance can protect both yield and price risks. However, when hedging in futures is included in the portfolio, the combination of APH and futures (CE is $2.09) outperforms either IP or CRC (CE values are $2.02 and $1.96 respectively, with futures). For each of the portfolios, the farmer will choose an optimal coverage level higher than 100%. Theoretically, if the farmer choose a coverage level that equals its maximum possible yield/revenue he/she then can eliminate all the yield/revenue risk while maintains the same expected yield/revenue. However, for revenue insurance, this is true only if the price used to calculate the indemnity payment and the cash price at which the farmer sells crops are perfectly correlated. Since futures price and cash price are not perfectly correlated in our case, the farmer always faces certain price risk even under this "ideal" situation where there is no coverage restriction and actuarially fair premium is provided. Therefore, APH with futures are more flexible to use than the revenue insurance. This may explains why APH with futures outperforms IP or CRC with futures here. It implies that the revenue insurance is not a good substitute for yield insurance combined with futures when there is no coverage level restriction or premium loading imposed.

In reality, due to moral hazard, adverse selection problems and high administration cost, no insurance company can provide a crop insurance program at the actuarially fair rate and without coverage restrictions. The current crop insurance coverage in the PNW area is restricted between 50%-85%. Since the coverage restrictions are binding, 85% is the optimal level to choose. When this restriction is placed on the maximization problems, CRC with futures becomes the best choice, with a CE value of $1.43.

When a 30% premium loading is charged, IP and CRC remain to be the better choice over APH. However, this premium loading lowers the optimal coverage level significantly, and the CE values for using crop insurance are all close to zero. This indicates that it is unlikely that the farmer will buy the insurance under this situation.

All the above results are based on the absence of government subsidy. The hedging ratios and CE values for each portfolio are then calculated under a scenario close to real world situation: 30% premium loading, 50%-80% coverage restrictions, and with government subsidy on insurance premium. The Agricultural Risk Protection Act of 2000 (2000 Act) was signed by President Clinton on June 20, 2000. The 2000 Act made significant increase in USDA's subsidy for each insurance policy beginning in crop year 2001 (RAM Spokane). Under the new policy, the percentage of premium paid by USDA is between 38% and 67%, depending on different coverage levels. Although our simulated data are for 2000, a year of past, our intention is to make references for current and the future. Therefore we include the new subsidy schedule in our analysis. The optimal coverage level for each portfolio is close to the upper bound of the restriction, 85%, under this schedule. While the government subsidy increases CE values significantly (almost $3 per acre), it does not change the most desirable portfolio: CRC (85% coverage) with futures (42% of mean yield) still performs the best.

Intermediate Rainfall Area

The optimization results for intermediate rainfall area are reported in **Table 4** (actuarially fair insurance premium) and **Table 5** (with 30% premium loading)**.** When there are no coverage restrictions, no premium loading, and no government subsidy, wheat APH with futures plus barley IP is the most desirable portfolio with a CE value of $8.45, 20 cents more than wheat CRC with futures plus barley IP (**Table 4**). The optimal insurance coverage level is always higher than mean yield/revenue for each of the portfolios.

When an upper bound of coverage level (85%) is imposed, wheat CRC (85%) with futures (53%, purchase) plus barley IP (85%) is the best choice (**Table 4**). The optimal coverage level is simply the upper bound (85%) for all the portfolios.

Again, a 30% premium loading decreases the CE values significantly. Wheat CRC with futures plus barley IP remains as the best portfolio with a CE value of $2.01. When the government subsidy schedule is applied, the optimal portfolio does not change. But the CE value is increased substantially: from $2.01 to $7.59 (**Table 5**).

Although we have no intention to analyze the effect of the rotation systems, we do find that the relative performance of each instrument and the most desirable portfolio are consistent for the two representative farmers in different rainfall zones. There is no obvious diversification effect when barley is included in the rotation system. This may be explained by the fact that cash prices and yields of wheat and barley are highly correlated. In addition to this, barley is only grown as an agronomic crop rather than an economic crop in the PNW area.

The results also show a complementary effect between yield insurance and futures and a substitute effect between revenue insurance and futures. For each of the risk management portfolios with futures involved, when the yield insurance (APH) coverage level decreases, the optimal hedging ratio always decreases also; while when the revenue insurance (IP or CRC) coverage level decreases, the farmer always increases his/her futures contract purchases.

The results also indicate that hedging in futures market still plays a role in reducing price risk even its substitutes--revenue insurance programs are used. Adding futures in a portfolio almost always increases its CE value.

Summary and Conclusion

In this paper, the most desirable farm income risk management strategies for two rotation systems in the Pacific Northwest are identified under a framework of expected utility maximization. Certainty equivalent is used as the welfare measurement. Insurance programs available to PNW farms and futures market are included in our risk management analysis. The risk management effectiveness of each instrument and the substitute effect of the revenue insurance programs on the combination of yield insurance and futures market are also evaluated. Numerical methods and simulation techniques are used to estimate the price and yield joint distributions, based on available historical data.

The results show that under current coverage restriction level and the new government subsidy schedule, CRC at an 85% coverage level combined with a futures hedge position of 42% is the most effective risk management portfolio for farms in dry area (winter wheat-summer fallow rotation); while for farms in intermediate rainfall area with winter wheat-spring barley-summer fallow rotation, wheat CRC (85% coverage) and barley IP (85% coverage) plus wheat futures market (with a hedging ratio of 53%) is the most desirable one. In general, revenue insurance is more effective than yield insurance. Either IP or CRC is a good but not perfect substitute for the combination of APH and futures hedging. However, adding futures to a portfolio of IP or CRC can still increase the risk management effectiveness. The results also indicate that a 30% premium loading is prohibitive without government subsidy.

The risk management analysis is conducted on a simulated “representative” farmer in each of the two rainfall areas. The farmers are assumed to face the “average risk” in this area and have a constant relative risk aversion. Further work need to be expanded to the analysis of farmers with different risk preferences and under different risk levels. The most desirable risk management portfolio for farmers in wet area is still left to be identified.

Reference

Agricultural and Food Policy Center Working Paper 01-1, January 2001, Texas A&M University.

Ahsan, S. M., A. A. G. Ali, and N. J. Kurian. "Toward a Theory of Agricultural Insurance." *American Journal of Agricultural Economics*, 65(1982):520-529.

Bollerslev,Tim. "Generalized Autoregressive Conditional Heteroskedasticity." *Journal of Econometrics*, 31(1986):307-327.

Dhuyvetter, Kevin C. and Terry L. Kastens. "Linkage Between Crop Insurance and Pre-Harvest Hedging." *Journal of Agricultural and Applied Economics,* 31(April 1999):41-56.

Engle, Robert F. "Autoregressive Conditional Heteroskedasticity with Estimation of the Variance of U.K. Inflation." *Econometrica,* 50(1982):987-1008.

Goodwin, B. K., Matthew C. Roberts, and Keith H. Coble. "Measurement of Price Risk in Revenue Insurance: Implications of Distributional Assumptions." *Journal of Agricultural and Resource Economics*, 25(July 2000):195-214.

Hall, Mike, Douglas L. Young, and David J. Walker. *Agriculture in the Palouse: A Portrait of Diversity*. College of Agriculture, University of Idaho. Bul. 794, February 1999.

Heifner, R., and K. Coble. "The Revenue-Reducing Performance of Alternative types of Crop Yield and revenue Insurance with Forward Pricing." Report to Risk Management Agency. Economics Research Service/USDA, Washington DC, Dec. 1998.

Hennessy, D. A., B. A. Babcock, and D. J. Hayes. "Budgetary and Producer Welfare Effects of Revenue Insurance." *American Journal of Agricultural Economics*, 79 (1997):1024-1034.

Marra, M. C. and B. W. Schurle. "Kansas Wheat Yield Risk Measures and Aggregation: A Meta-analysis Approach." *Journal of Agricultural and Resource Economics,* 19(July 1994):69-77.

Miller, Stephen E., Kandice H. Kahl and P. James Rathwell. “Revenue Insurance for Georgia and South Carolina Peaches.” *Journal of Agricultural and Applied Economics*, 32(April 2000): 123-132.

Miranda, M. J. “Area-Yield Crop Insurance Reconsidered.” *American Journal of Agricultural Economics*. 73(1991):233-242.

Nelson, Carl H. and Paul V. Preckel. “The Conditional Beta Distribution as a Stochastic Production Function.” *American Journal of Agricultural Economics,* May 1989: 370-378.

RMA *2000 Revenue Crop Insurance Plans*, USDA, December 1999.

RMA Spokane Regional Office. *Risk Management Agency Presentation*, Washington State University, August 2000.

Stokes, J. R. “A Derivative Security Approach to Setting Crop Revenue Coverage Insurance Premiums.” *Journal of Agricultural and Resource Economics,* 25(July 2000):159-176.

Taylor, C. Robert. “Two Practical Procedures for Estimating Multivariate Nonnormal Probability Density Functions.” *American Journal of Agricultural Economics*, 72(Feb. 1990):210-217.

Wang, H. Holly. “Zone-Based Group Risk Insurance.” *Journal of Agricultural and Resource Economics*, 25(2000):411-431.

Wang, H. Holly, Steven D. Hanson and J. Roy Black. “Can Revenue Insurance Substitute for Yield and Price Risk Management Instruments?” Working paper, the Department of Agricultural Economics, Washington State University, 2000.

Wang, H. Holly. “Farmer Risk Management Behavior and Welfare under Alternative Portfolios of Risk Instruments.” Ph.D Dissertation, Michigan State University, East Lansing, Michigan, 1996.

Wang, H., S. D. Hanson, R. J. Myers, and J. R. Black. “The Effects of Alternative Crop Insurance

Designs on Farmer Participation and Welfare." *American Journal of Agricultural Economics*, 80(1998): 806-820.

Williams, J. R., G. L. Carriker, G. A. Barnaby, and J. K. Harper. "Crop Insurance and Disaster Assistance Designs for Wheat and Grain Sorghum." *American Journal of Agricultural Economics*, 75(1993):435-447.

Young, D. L., T.-J. Kwon and F. L. Young. "Profit and Risk for Integrated Conservation Farming Systems in the Palouse." *The Journal of Soil and Water Conservation*, 49(1994):601-606.

Appendix

Price Model and Estimates

The univariate GARCH(1,1) model for barley cash price:

$$\text{(A1)} \qquad 1000\Delta P_t^B = m_{C0} + m_1 1000\Delta P_{t-1}^B + e_t$$

$$e_t \left| \Omega_{t-1}^B \right. \sim N(0, s_t^2)$$

$$s_t^2 = c_1 + a_{11} e_{t-1}^2 + b_{11} s_{t-1}^2$$

where ΔP_t^B is the first difference of the logarithm of barley cash price at time t. A lag term ΔP_{t-1}^B is included in the mean equation since the first order autocorrelation is detected.

The bivariate GARCH(1,1) model for wheat cash and futures prices:

$$\text{(A2)} \quad 1000\begin{bmatrix} \Delta P_{Ft} \\ \Delta P_{Ct} \end{bmatrix} = \begin{bmatrix} m_{F0} \\ m_{C0} \end{bmatrix} + \begin{bmatrix} e_{Ft} \\ e_{Ct} \end{bmatrix}, \qquad \begin{bmatrix} e_{Ft} \\ e_{Ct} \end{bmatrix} \left| \Omega_{t-1}^W \right. \sim N(0, H_t^2)$$

$$vech(H_t^2) = \begin{bmatrix} s_{Ft}^2 \\ s_{FCt} \\ s_{Ct}^2 \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{12} & 0 \\ 0 & 0 & a_{22} \end{bmatrix} \begin{bmatrix} e_{Ft}^2 \\ e_{Ft-1} e_{Ct-1} \\ e_{Ct-1}^2 \end{bmatrix} + \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{12} & 0 \\ 0 & 0 & b_{22} \end{bmatrix} \begin{bmatrix} s_{Ft-1}^2 \\ s_{Ft-1} s_{Ct-1} \\ s_{Ct-1}^2 \end{bmatrix}$$

where ΔP_{Ft} and ΔP_{Ct} are the first difference of the logarithm of wheat futures price and cash price respectively.

Table A1 Estimates for the GARCH Models

	m_{F0}	m_{C0}	m_1	c_1	c_2	c_3	a_{11}	a_{12}	a_{22}	b_{11}	b_{12}	b_{22}
Wheat	-3.20 (1.87)	-5.11 (2.69)	N/A	37.14 (28.52)	186.76 (251.71)	146.59 (1552.17)	0.08 (0.03)	0.05 (0.04)	0.004 (0.03)	0.86 (0.06)	0.58 (0.49)	0.84 (1.67)
Barley	N/A	-2.19 (1.55)	0.26 (0.08)	32.08 (21.42)	N/A	N/A	0.16 (0.06)	N/A	N/A	0.78 (0.07)	N/A	N/A

Note: Values in (.) are standard deviations.

Yield Model and Estimates

The probability function of the Beta distribution is:

(A3) $$f(Y) = \frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)} \frac{(Y-Y_l)^{a-1}(Y_u-Y)^{b-1}}{(Y_u-Y_l)^{a+b-1}}$$

where Y_l is the lower bound of yield and Y_u is the upper bound of yield; α and β are the parameters of the Beta distribution; Γ(.) is the Gamma function.

For wheat yield:

(A4) $$Y_{wt} = g_0 + g_1 T + g_2 Y_{wt-1} + e_{wt}$$

where Y_{wt} is the wheat yield at time t, T=1, 2, … 61, e_{wt} s are the stochastic yield residuals and follow a Beta distribution with parameters α_w, β_w, e^l_{wt} (lower bound), and e^u_{wt} (upper bound).

For barley yield:

(A5) $$Y_{bt} = g_0 + g_1 T + e_{bt}$$

where Y_{bt} is the barley yield at time t, T=1, 2, … 61, e_{bt} s are the stochastic yield residuals and follow a Beta distribution with parameters α_b, β_b, e^l_{bt} (lower bound), and e^u_{bt} (upper bound).

Table A2 Parameter Estimates for the Yield Models

Parameters	?$_0$	?$_1$	?$_2$	R^2	α	β	e^l_t	e^u_t
Wheat	19.06 (3.66)	0.50 (0.10)	0.31 (0.13)	0.81	2.74 (0.48)	3.62 (0.65)	Min(e_{wt})	Max(e_{wt})
Barley	31.72 (1.74)	0.63 (0.06)	N/A	0.65	4.02 (0.72)	2.30 (0.39)	Min(e_{bt})	Max(e_{bt})

Note: Values in (.) are standard deviations.

Table 1 Correlation Matrix of the Simulated Data

	Dry Area			Intermediate Rainfall Area				
	P_W	F_W	Y_W	P_W	F_W	Y_W	P_B	Y_B
P_W[1]	1			1				
F_W[2]	0.651	1		0.651	1			
Y_W[3]	-0.141	-0.091	1	-0.149	-0.097	1		
P_B[4]				0.839	0.560	-0.027	1	
Y_B[5]				-0.033	-0.007	0.340	0.015	1

Note: 1. Cash price of wheat.
2. Futures price of wheat.
3. Wheat yield of the representative farm.
4. Cash price of barley.
5. Barley yield of the representative farm.

Table 2 Basic Statistics of the Simulated Data

Variables	P_B($/CWT)	P_W ($/Bu.)	F_W($/Bu.)	Dry Y_Wheat	Int. Y_Wheat	Y_Barley
Mean	4.30	2.79	2.41	67.20	69.30	64.83
Coef. Of Var.	0.10	0.18	0.22	0.17	0.16	0.24
M3[1]	0.39	0.70	0.74	0.15	0.15	-0.39
M4[2]	3.72	4.21	4.23	2.41	2.41	2.57

Note: 1. Sample skewness (3rd Moment).
2. Sample kurtosis (4th Moment).

Table 3 Optimization Results for Winter Wheat-Summer Fallow Rotation in Dry Areas

	Unrestricted Coverage			85% Coverage		
	Fut.	Insur.	CE ($)	Fut.	Insur.	CE ($)
Actuarially Fair						
Futures Only	-0.5	N/A	0.56	N/A	N/A	N/A
APH Only	N/A	1.12	1.24	N/A	0.85	0.47
IP Only	N/A	1.23	1.99	N/A	0.85	0.97
CRC Only	N/A	1.08	1.72	N/A	0.85	1.04
APH with Fut.	**-0.6**	**1.15**	**2.09**	-0.53	0.85	1.16
IP with Fut.	0.23	1.32	2.02	-0.34	0.85	1.1
CRC with Fut.	-0.34	1.07	1.96	**-0.42**	**0.85**	**1.43**
30% Premium Loading						
	No Subsidy			*With Subsidy, 50%-85% Coverage*		
APH Only	N/A	0.62	0	N/A	0.85	1.32
IP Only	N/A	0.55	0.06	N/A	0.84	2.19
CRC Only	N/A	0.53	0.06	N/A	0.85	2.58
APH with Fut.	-0.5	0.63	0.59	-0.53	0.85	2.1
IP with Fut.	**-0.5**	**0.48**	**0.65**	-0.36	0.84	2.47
CRC with Fut.	**-0.5**	**0.58**	**0.65**	**-0.42**	**0.85**	**2.97**

Note: The hedging level is reported as a ratio to expected yield.

Table 4 Optimization Results for Winter Wheat-Spring Barley-Summer Fallow Rotation
Intermediate Rainfall Areas, Actuarially Fair

	Unrestricted Coverage				85% Coverage			
	Fut.	Insur_W	Insur_B	CE ($)	Fut.	Insur_W	Insur_B	CE ($)
Futures Only	-0.67	N/A	N/A	1.48	N/A	N/A	N/A	N/A
APH Only	N/A	1.07	Max	5.36	N/A	0.85	0.85	2.61
IP Only	N/A	1.21	Max	8.2	N/A	0.85	0.85	4.01
CRC_W Only	N/A	1.17	N/A	4.04	N/A	0.85	N/A	1.88
CRC_W+APH_B	N/A	1.07	Max	6.29	N/A	0.85	0.85	3.55
CRC_W+IP_B	N/A	1.06	Max	7.95	N/A	0.85	0.85	4.1
APH_W+IP_B	N/A	Max	Max	7.16	N/A	0.85	0.85	3.26
IP_W+APH_B	N/A	1.29	1.35	7.15	N/A	0.85	0.85	3.47
CRC_W with Fut.	-0.52	1.24	N/A	4.77	-0.56	0.85	N/A	2.87
APH with Fut.	-0.78	1.13	Max	7.21	-0.69	0.85	0.85	4.13
IP with Fut.	0	1.21	Max	8.2	-0.47	0.85	0.85	4.66
CRC_W+APH_B+Fut.	-0.52	1.05	Max	7.05	-0.57	0.85	0.85	4.55
CRC_W+IP_B+Fut.	-0.33	1.05	Max	8.25	**-0.53**	**0.85**	**0.85**	**4.92**
APH_W+IP_B+Fut.	**-0.59**	**1.13**	**Max**	**8.45**	-0.64	0.85	0.85	4.54
IP_W+APH_B+Fut.	0	1.29	1.35	7.15	-0.51	0.85	0.85	4.28

Table 5 Optimization Results for Winter Wheat-Spring Barley-Summer Fallow Rotation
Intermediate Rainfall Areas, 30% Loading

	Unrestricted Coverage, No Subsidy				50%-85% Coverage, Subsidy			
	Fut.	Insur_W	Insur_B	WTP ($)	Fut.	Insur_W	Insur_B	WTP ($)
Futures Only	-0.67	N/A	N/A	1.48	N/A	N/A	N/A	N/A
APH Only	N/A	0.75	0.7	0.43	N/A	0.85	0.85	4.37
IP Only	N/A	0.76	0.75	0.77	N/A	0.85	0.83	6.4
CRC_W Only	N/A	0.77	N/A	0.23	N/A	0.85	N/A	3.23
CRC_W+APH_B	N/A	0.76	0.69	0.52	N/A	0.85	0.82	6.08
CRC_W+IP_B	N/A	0.75	0.76	0.83	N/A	0.85	0.83	6.76
APH_W+IP_B	N/A	0.75	0.77	0.7	N/A	0.85	0.85	5.16
IP_W+APH_B	N/A	0.78	0.69	0.55	N/A	0.85	0.83	5.74
CRC_W with Fut.	-0.62	0.73	N/A	1.5	-0.56	0.85	N/A	4.21
APH with Fut.	-0.67	0.78	0.7	1.88	-0.69	0.85	0.85	5.87
IP with Fut.	-0.62	0.62	0.75	1.92	-0.47	0.85	0.83	7.06
CRC_W+APH_B+Fut.	-0.64	0.68	0.72	1.77	-0.57	0.85	0.83	7.06
CRC_W+IP_B+Fut.	**-0.63**	**0.62**	**0.75**	**2.01**	**-0.53**	**0.85**	**0.83**	**7.59**
APH_W+IP_B+Fut.	-0.65	0.77	0.74	1.96	-0.64	0.85	0.85	6.43
IP_W+APH_B+Fut.	-0.65	0.66	0.72	1.77	-0.51	0.85	0.83	6.52