Intertemporal Risk Management Decisions of Farmers under Preference, Market, and Policy Dynamics

Wen Du[*]

Ph. D.
School of Economic Sciences
Washington State University, USA
Pullman, WA 99164-6210
Phone: (509) 335-1490, Fax: (509) 335-1173
E-mail: duwenwsu@yahoo.com

H. Holly Wang

Associate Professor
School of Economic Sciences
Washington State University, USA
Pullman, WA 99164-6210
Phone: (509) 335-8521, Fax: (509) 335-1173
E-mail: wanghong@wsu.edu

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005

[*] Wen Du is former Graduate Research Assistant in School of Economic Sciences, Washington State University. The authors would like to thank Ron Mittelhammer and Larry Makus for useful comments.

Abstract

This paper adapts a generalized expected utility (GEU) maximization model (Epstein and Zin, 1989 and 1991) to examine the intertemporal risk management of wheat producers in the Pacific Northwest. Optimization results based on simulated data indicate the feasibility of the GEU optimization as a modeling framework. It further extends the GEU model by incorporating a welfare measure, the certainty equivalent, to investigate the impacts of U.S. government programs and market institutions on farmers' risk management decisions and welfare. A comparison between the GEU and other expected utility models further implies GEU has the advantage of specifying farmers' intertemporal preferences separately and completely. Impact analysis results imply that farmers' optimal hedging is sensitive to changes in the preferences and the effects of these preference changes are intertwined. Target price and loan rate levels, offered by certain government payment programs, can lead to the substitution of government programs for hedging. The evaluation of current risk management tools shows both crop insurance and government payments can improve farmers' welfare significantly. Government payment programs have a greater effect on farmers' welfare than crop insurance and crop insurance outperforms hedging.

Classification Code: Q14, D9, C61

Keywords: generalized expected utility, risk management, multi-period production, dynamic optimization, intertemporal preference, market institution, government payments

INTERTEMPORAL RISK MANAGEMENT DECISIONS OF FARMERS UNDER PREFERENCE, MARKET, AND POLICY DYNAMICS

I. Introduction

Agricultural production is a dynamic stochastic process greatly affected by unpredictable weather, technology advancement, individual farming practices, and price fluctuations in commodity markets. The risk management situation confronted by farmers is complicated with intra- and inter-temporal uncertainties in continuous multi-period production. Modeling farmers' risk management has been commonly based on a static approach, although a stochastic dynamic approach is more consistent with reality.

Expected utility maximization, commonly used as a standard framework in many studies including agricultural risk analysis, has been shown feasible in dynamic modeling. The standard specification allows a risk averse farmer to maximize a summarized discounted von Neumann-Morgenstern expected utility function of his or her stochastic income subject to a set of policy and resource constraints. Such a specification, however, assumes utility is additively separable and therefore implies the decision maker is intertemporally risk-neutral. A generalized expected utility (GEU) maximization model, developed by Epstein and Zin (1989, 1991), provides an alternative to study intertemporal decisions with further specification of the decision maker's preferences. The model utilizes a recursive constant elasticity of substitution (CES) expected utility function, which allows risk aversion to be disentangled from intertemporal substitutability of consumption.

Currently, U. S. farmers are able to use several risk management tools to manage risks, and make long term strategic plans accordingly. Hedging in the futures markets has a long history of being one of the most available and direct risk management tools for farmers. Crop insurance, currently facilitated and subsidized by the US federal government, is currently the most popular tool used by U.S. crop producers to manage yield and/or price risks. In recent years, the federal government increased its involvement in providing and facilitating risk protection instrument to farmers through various crop payment programs. The 2002 Farm Bill includes three major programs to farmers: a loan deficiency payment (LDP), a direct payment (DP), and a counter cyclical payment (CCP). These payment programs work as price insurance but without any premium charge. However, the programs are usually offered for a multi-year period. Provisions require that farmers make the decision on weather or not to participate in the programs at the beginning of the period.

As new policies and market institutions are constantly developed to improve risk protection for farmers, the risk management resources in the US changes over time. The aforementioned programs are revisited and adjusted every few years. In order to effectively utilize these risk protection programs, farmers need to adjust their expectations as well as risk management strategies throughout the production process.

Farmers' decision making and welfare are based on individual preferences in a given risk and policy environment. In the GEU specification, a decision maker's expected utility is subject to changes in three types of preferences: risk aversion, time discounting, and intertemporal substitutability. His or her intertemporal decisions are determined by the mutual effects of all these preferences. Uncertainty about consumption is resolved over time and preference orderings generally imply non-indifference to the way it resolves. The model provides a possibility to study farmers' intertemporal risk management decisions while considering their preferences toward risk, time, and inter-year substitution of consumption. It also allows us to examine the impacts of changing market institutions and U.S. agricultural policies on farmers' behavior at the same time.

The objectives of this paper are 1) apply the GEU model to farmers' intertemporal portfolio risk management decisions and compare it with other commonly used additive EU models as a framework in such decisions. Farmers' choose from hedging instruments, insurance products, and government payment programs to maximize utility. 2) investigate the impacts of intertemporal preferences towards risk, substitution, and time, as well as market institutions and policy alternatives, on farmers' risk management behavior based on the GEU model. We are interested in evaluating the different risk management tools and weighing their roles in risk management portfolios.

Specifically, the paper proceeds as follows: 1) Section II reviews literature in agricultural risk management modeling; 2) Section III discusses the model structure; 3) Section IV introduces the data and the simulation of yields and prices; 4) Section V discusses the optimization and model comparison results; 5) Section VI presents the impact analyzes of intertemporal preferences, market institutions, and policy alternatives on risk management decisions; and 6) Section VIII summarizes findings and draws conclusion.

II. Existing Literature

As a modeling framework, the expected utility (EU) maximization approach has been applied to producers' risk analysis in both static and dynamic situations since the 1970s. However, unlike its counterparts in economics and finance, a large amount of the existing work only use EU under static scenarios in agricultural economics (Nyambane et al., 2002).

In the standard specification of intertemporal EU maximization, it is common to assume an additive and homogeneous von Neumann-Morgenstern utility index. Such a specification, however, intertwines two distinct aspects of preference, intertemporal substitutability and relative risk aversion (Epstein and Zin, 1989). Additionally, these models did not perform well in empirical examinations (Hansen and Singleton, 1983; Mehra and Prescott, 1985). As a more general framework, the GEU model adds extra flexibility in identifying intertemporal substitution and is able to disentangle the intertemporal substitution from the risk aversion.

With the possible and testable separability for risk preference and intertemporal substitutability, it is possible to use the GEU model to estimate preference parameters separately and examine the form of the objective function. Continuing on from their theoretical paper, Epstein and Zin (1991) empirically investigated the parameter estimation and the testable restrictions. They got favorable and theoretically consistent estimates. Lence (2000) used 1936-1994 U.S. farm data to study the fitness of a GEU framework. He found the estimated farmers' utility parameters satisfy the theoretical restrictions of the GEU model. Furthermore, the EU model is rejected in favor of the GEU model. The empirical results from resource economics studies using the GEU model (Knapp and Olson,1996; Howitt et al. 2002) underscore the importance of using the more general specification of intertemporal preferences.

On the other hand, studies on agricultural risk management strategies have been extended from the earlier one-element models to portfolio models, and focus more on the interactions and relative impacts of the instruments within a portfolio. Among them are portfolios of crop yield insurance and futures contracts (Myers, 1988), futures market and government farm programs (Crain and Lee, 1996), crop yield insurance, futures, options and government programs (Wang, et al., 1998), and crop revenue insurance, futures and government programs (Zuniga, Coble, and Heifner, 2001; Wang, Makus, and Chen, 2004).

Studies on measuring farmers' welfare change are found in literature, but very few concentrate on farmers' welfare changes under different risk management portfolios. Wang, et al (1998) found Iowa corn farmers' willingness-to-pay decreases as the trigger yield level of crop insurance increases at a decreasing rate. Mahul (2003) found futures and options would improve French wheat producers' willingness-to-receive when hedging is used in the presence of crop insurance. Wang, Makus and Chen (2004) found U.S. farm program payments account for the primary value of all risk management portfolios for Pacific Northwest dryland grain producers.

Adaptation of the GEU framework specifically to agricultural risk management portfolio studies is rarely found in the literature. Other possible applications of GEU, like sensitivity analyses of dynamic optimization solutions with respect to a decision maker's preferences and other exogenous variables, have not been explored. No one has attempted developing a welfare measure in GEU models. This paper will make an effort to contribute to the literature from this perspective.

III. Model

Theoretical Framework

The foundation of the GEU model for intertemporal analysis builds on the independent works of Epstein and Zin (1989, 1991), and Weil (1990). In this study we focus on Epstein and Zin's approach.

The representation of the general preference for a decision maker under risk can be identified as:

(1) $$Max\,U_t = \left\{ \left(1-\beta\right) C_t^{\rho} + \beta \left[E_t\left(\tilde{U}_{t+1}^{\alpha} \right) \right]^{\frac{\rho}{\alpha}} \right\}^{\frac{1}{\rho}}$$

where $U_t(\cdot)$ is the von-Neumann Morgenstern utility function indexed by time t; E_t is the expectation operator at current period *t*; the "~" above *U* indicates the stochastic property of utility. β ($0 < \beta < 1$) is the discount factor per period and implicitly defines the decision maker's time preference. By consuming at $t+1$, he/she only consumes a fraction (β) of the utility that would have been consumed at t. α ($0 \neq \alpha < 1$) denotes the risk aversion parameter, and is equal to one minus the Arrow-Pratt constant relative risk aversion (CRRA) coefficient. A smaller α indicates greater risk aversion. ρ ($0 \neq \rho < 1$) denotes the intertemporal substitutability, equal to $(1-\sigma)^{-1}$ with σ denoting the elasticity of substitution. Early (late) resolution of risk would be preferred if $\alpha < (>) \rho$. C_t denotes the current consumption which is a function of the risky variables and the risk management choice variables. The decision maker's objective function is to maximize current utility, which comprehensively incorporates all of the lifetime expected future utilities.

The recursive GEU specification enables a separation of risk aversion from intertemporal substitution and the non-additive intertemporal preference relations. This feature is not usually shared by the EU specification. However, the GEU form nests the EU form as a special case. The recursive CES EU (CES-EU) preferences, widely used in finance, macroeconomics and intertemporal consumption analysis, are obtained when we impose the parametric restriction $\alpha = \rho$.

(2) $$Max\,U_t = \left\{ \left(1-\beta\right) C_t^{\alpha} + \beta \left[E_t\left(\tilde{U}_{t+1}^{\alpha} \right) \right] \right\}^{\frac{1}{\alpha}} \qquad \text{(CES-EU)}$$

Moreover, the standard multi-period recursive EU (MR-EU) preference is obtained when we further impose $\alpha = \rho = 1$. As indicated in equation (3), when the utility function is defined as a linear combination of current and future consumption levels, the optimization of MR-EU becomes a decision maker maximizing the summarized discounted expected consumption over a lifetime (finite or infinite time periods).

(3) $$Max\, U_t = (1 - \beta)\left[C_t + \sum_i \beta^i E_t\left(\tilde{C}_{t+i}\right)\right]$$ (MR-EU)

Here C_{t+i} denotes consumption for the i^{th} period in the future. With risk preference $\alpha = 1$, the decision maker is risk neutral. The additive specification due to $\rho = 1$ implicitly assumes preferences are homogeneous (perfectly substitutable) over time; each one of them carries the same weight when discounted to the current period. Such additivity is now well known to be too restrictive (Weil, 1990). Decision makers may have a clear preference for early resolution of risk compared to late resolution of risk (Kreps and Porteus, 1978).

Application of GEU to Farmers' Intertemporal Decisions in the PNW

When applying the GEU framework to our optimization problem, current consumption is further defined as net income from the farmer's wheat production and risk management. The farmer uses futures contract, yield insurance, and government programs to construct risk management portfolios. Hedge ratios and insurance coverage ratios are endogenous choice variables to be determined at the optimum, based on information available at *t-1*:

(4) $C_t = NC_t + CI_t + FI_t + GI_t$

where $NC_t = P_t Y_t - PC_t,$

$FI_t = \mathbf{x_{t-1}}[F_t - E_{t-1}(F_t)] - TC_t,$

$CI_t = P_b\, max[0, \mathbf{z_{t-1}}\, E_{t-1}(Y_t) - Y_t] - Pre_t$

$$GI_t = DP_t + LDP_t + CCP_t$$

$$Where\ DP_t = 0.85P_D \times 0.9E_{t-1}(Y_t),$$

$$LDP_t = E_{t-1}(Y_t)\ max(0,\ L_R - P_t),$$

$$CCP_t = 0.85 \times 0.935\ E_{t-1}(Y_t)\ max[0,\ P_T - P_D - max(P_t, L_R)]$$

where NC_t is the net income from producing and selling the crops in the cash market; CI_t is the net income from purchasing yield-based Multiple Peril Crop Insurance (MPCI); FI_t is the net income from hedging in the futures market; and GI_t is the net income from government programs.

P_t and Y_t represent cash prices[1] and yields for winter wheat at harvest time respectively, with PC_t as the production cost. F_t is the futures price at time t and the futures market is treated as unbiased. $\boldsymbol{x_{t-1}}$ is the hedging amount determined at a previous time period which is positive for a long position and negative for a short position. $\boldsymbol{x_{t-1}}$ is in bold face to indicate its status as a choice variable. TC_t is the transaction cost of trading futures. P_b is the base price used to calculate the indemnity from crop insurance with Pre_t as the premium[2]. $\boldsymbol{z_{t-1}}$ is the coverage selection of the insurance and is also in bold face to indicate a choice variable. *DP* is the direct payment program which gives a constant payment to farmers, *LDP* is the loan deficiency payment, and *CCP* is the counter cyclical payment. P_D is the direct payment rate, L_R is the loan rate, and P_T is the target price. The formulation of DP, LDP, and CCP is specified according to the 2002 Farm Bill and calibrated to PNW wheat growers, the chosen area for the empirical analysis.

Due to the nonlinearity in the objective function and the random interrelationships among variables, closed-form optimal solutions are unavailable in the dynamic optimization. Therefore empirical solutions are obtained by numerical methods. For the dynamic optimization,

---

[1] Cash price is a farm gate price after transportation cost is deducted from the spot market cash price.
[2] The premium of the current year's crop insurance is paid at harvest time.

we simulate yields and prices for the next five years. Optimal levels of crop insurance coverage and hedge ratios are determined simultaneously and intertemporally in the presence of government programs.

Evaluation of Risk Management Portfolios

To further measure the risk management value and the income transfer value of alternative risk management instruments to the farmer, we reconstruct the consumption in the GEU model by introducing a certainty equivalent (CE) variable. We choose CE to evaluate alternative risk management portfolios relative to cash sales, under certain specified preference sets. Here CE is the certain amount of money that would be offered to the farmer in every period to keep him or her as well off as providing the farmer with the specified risk management portfolio. CE can be calculated by solving:

(5) $$U_t(C_t, E_t(C^*_{t+1}, C^*_{t+2}, ..., C^*_{t+i})) = U_t(C^0_t, E_t(C^0_{t+1} + CE, C^0_{t+2} + CE, ..., C^0_{t+i} + CE))$$

where $C^*_{t+i},\ i = 1,2,...,$ is the optimal consumption (net income) under a specific portfolio in the next i^{th} period, and $C^0_{t+i},\ i = 1,2,...,$ is the net income from selling in the cash market which is defined as the NC_t for that period.

IV. Data, Simulation and Model Calibration

Data Source

The risk management situation in the Pacific Northwest (PNW) provides us with an interesting case to explore farmers' risk management decisions in this area. The PNW, covering Washington, Idaho, California, and Oregon, is one of the major wheat production areas in the US. There is a large acreage of non-irrigated farms in this region. Soft white winter wheat has been the dominant cash crop and is primarily exported to the Asian market. This region, however, has historically been an area with low utilization rates of risk management instruments like futures (Makus, *et al.*, 1990) and some acreage-based crop insurance (Vandeveer and Young, 2000).

We select a representative farmer from each of the two counties, Whitman County and Grant County, in Washington State. Although both represent dryland soft white wheat farming region in the Pacific Northwest (PNW), these two counties have different levels of precipitation. Whitman County sits on the east central border of Washington and is part of the highest yield area for soft white wheat in the state. Whitman County has an average annual precipitation of around 14 inches. In comparison, Grant County is located in the center of the state and does not border Whitman County. Grant County is much dryer with an average annual rainfall of 5 inches in 2002. Accordingly, wheat production is riskier in Grant County. However, since there is some irrigation in Grant County, the yield is not much lower than that in Whitman County (Figure 1).

Historical data for soft white wheat yield, cash price and futures price for Whitman County and Grant County are collected and examined to identify time series patterns for simulation. The yield data for Whitman County and Grant County in Washington State are obtained from the U.S. Department of Agricultural National Agricultural Statistics Service (http://www.usda.gov/nass/) and Risk Management Agency (RMA) at annual basis for 1939-2003 and 1972-2003, respectively.

Annual September wheat cash and futures prices from 1973 to 2003 are selected to represent harvest prices. September is the time when the farmer makes decisions on the following year's hedging and insurance participation, and prepares for the planting of next year's winter wheat crop. For cash price, we use the monthly average of daily September prices at the Portland spot market. The data are from the USDA-ERS Wheat Yearbook (http://www.ers.usda.gov/publications/so/view.asp?f=field/whs-bb/). Since the PNW region grows soft white wheat which has no actively traded futures contract, the Chicago Board of Trade (CBOT) September wheat futures contact is chosen by the farmer for hedging. We pick the mid-week price of the first week (Wednesday or Thursday) of September to develop our dataset.

Deterministic Trend vs. Stochastic Trend

Because of the multiple time dimensions involved in GEU specification and dynamic programming, simulation of yield data could affect the final optimization results to a large extent. Specifying a pattern that is consistent with real processes is critical in this study.

From the time series plots of Whitman County and Grant County yield (Figure 1) for 1972 to 2003, an upward trend is visible for the last 32 years. There are possibly two sources of randomness that influence the county yield time series. One is the stochastic technology changes that will determine the "mean" yield in any given year, and the other is the random weather that moves the yield around the "mean". For multi-period analysis, we need to model the long-run inter-year randomness from technology changes as well as the short-run random effects brought by weather. A stochastic trend model would be more appropriate than any deterministic trend models in that it incorporates both types of randomness.

Moss and Shonkwiler (1993) developed a single time-dependent stochastic trend model. Their model transforms the error term rather than the dependent variable to incorporate the possibility of both non-stationary data and non-normal errors in corn yield variation. The model is also general enough to include both the standard deterministic time trend and normal errors as special cases. This model is adopted for our analysis.

Similarly for wheat cash and futures prices (Figure 2), the long-run unpredictable balance of supply and demand determines the annual price trend, and short-run information at the market and other factors add more price variability around the trend. Therefore, this stochastic trend model is also fitted to price data.

The model consists of one measurement equation and two transition equations:

(6)
$$y_t = \mu_t + \varepsilon_t$$
$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t$$
$$\beta_t = \beta_{t-1} + \varsigma_t$$

where y_t is the independent variable indexed by time t; $\begin{pmatrix} \mu_t \\ \beta_t \end{pmatrix}$ is the state vector; ε_t is the random error describing the short run randomness with mean zero and variance σ_ε^2;[3] and $\begin{pmatrix} \eta_t \\ \varsigma_t \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\eta^2 & 0 \\ 0 & \sigma_\varsigma^2 \end{pmatrix} \right)$ is the error vector describing the long run randomness in the transition equation that governs the evolution of the state vector. Both of the errors in the measurement equation follow normal distributions and are independent of each other.

In the basic specification, μ_t, the mean component of the dependent variable, is shown as a random walk with a drift. Therefore the final generalization shows that the mean of the dependent variable grows at a random rate.

---

[3] The model also allows for a non-normal errors when ε_t is assumed to be generated by an inverse hyperbolic sine transformation from normality: $e_t = (\tau_t - \delta) \sim N(0,1)$, and $\tau_t = \theta^{-1} \ln\left(\theta\varepsilon_t + \left\{ (\theta\varepsilon_t)^2 + 1 \right\}^{\frac{1}{2}} \right)$ where δ is the non-centrality parameter; $\delta > 0 (< 0)$ denotes the distribution is skewed to the right (left) and if $\delta = 0$ the distribution is symmetric. θ is associated with the degree of kurtosis with $\theta \neq 0$ denoting a kurtotic distribution. Thus, the error term can be expressed as $\varepsilon_t = \dfrac{e^{\theta\tau_t} - e^{-\theta\tau_t}}{2\theta}$.

The stochastic trend model reduces to a deterministic time trend model if $\beta_0 \neq 0$ and $\sigma_\eta^2 = \sigma_\varsigma^2 = 0$. If $\beta_0 = 0$, then it reduces to a constant mean regression model.

Estimation and Simulation for Yields and Prices

Applying the stochastic trend model to our yield and price data using maximum likelihood estimation programmed in GAUSS, we find there is no stochastic trend in the yield for Whitman County but there is one for Grant County. The stochastic trend also exists in the Portland cash prices and CBOT futures prices (Table 1).

For Grant County yield, cash price and futures price, the significance of estimated σ_η confirms the existence of a random walk in the mean component. However, the insignificance of estimated σ_ς shows such stochastic variation doesn't exist within the mean of the trend. For Whitman County yield, however, the trend is generally a deterministic time trend and there is no significant randomness in the slope of the time trend. The simple linear regression model with a deterministic time trend appears to be a good model for Whitman County yield[4].

The plots of predicted values versus actual values show that in general the stochastic trend models fit the data well by capturing the long-run variation in the trend for wheat yield in Grant County (Figure 3) and cash prices (Figure 4)[5]. The 95 percent confidence intervals include nearly all of the realizations.

For the distributions of yield and prices, we conduct normality tests first on the detrended data. Results fail to reject the null hypothesis of normality. We also estimate the stochastic trend model including non-normal errors. The estimates of the non-normal parameters are not statistically different from zero, confirming that the data follow a normal distribution.

---

[4] We further tested for autocorrelation within the series before applying the time trend and found no evidence.
[5] Similar pattern is also shown for wheat futures prices.

We use the fitted linear time trend model to simulate annual wheat yields in Whitman County, and use the fitted stochastic trend models to simulate Grant County yield, Portland Cash price, and CBOT futures price. An empirical distribution with 2000 samples is simulated for each of the next five years and for each series. All the series are first simulated independently without autocorrelations or contemporaneous correlations. For the cash and futures prices, we then impose a correlation of 0.871 based on historical data. Table 2 gives the descriptive statistics of the simulated data.

Parameter Calibration

Identification of farmers' risk preferences and time preferences has been attempted in previous studies using different models (Saha, Shumway and Talpaz, 1994; Chavaz and Holt, 1996; Epstein and Zin, 1990; Lence, 2000). Among them, Lence used a similar dynamic GEU model to estimate US farmers' preference parameters based on aggregated consumption and asset return data from 1966-1994. We implement those estimates, $\alpha = -0.13$, $\beta = 0.89$ and $\rho = 0.9493$, as the base for our representative farmers and assume they stay fixed over time.

In the determination of current consumption (or net income) level, transportation cost between the Portland spot market and the two counties is set at \$0.50 per bushel for Whitman County and \$0.47 for Grant County; production cost is determined as \$203 per acre for Whitman County (Hinman and Baldree, 2004) and \$195 for Grant County[6]; transaction cost associated with hedging is set at \$0.017/bushel. The price used to indemnify crop loss in the insurance programs is the CBOT September wheat futures price plus a Portland basis of \$0.45 per bushel. The insurance coverage levels are restricted to be either zero or from 50% to 85% with an increment of 5%. The insurance premium is computed as the product of the expected indemnity

[6] Production cost for Grant County is derived based on budgeting report for Lincoln County, a similarly dry county in Washington State. Reference: Esser, Hinman, and Platt (2003).

(actuarially fair premium level) and 1 minus the regressive subsidy rate specified in current policies[7].

For government programs, the direct payment rate P_D is set at \$0.52 per bushel. The base yield used to calculate a per acre payment is set at 90 percent of the expected yield. The loan rate (L_R) for the *LDP* is \$2.86 per bushel for soft white wheat in Whitman County and \$2.91 per bushel in Grant County. The target price (P_T) for CCP is \$3.92 per bushel. These parameters are based on current US farm policies.

V. GEU Maximization and Comparison with EU maximization

We implement the stochastic dynamic optimization programming using GAUSS and numerically solve for the optimal hedge ratios and crop insurance coverage ratios for our representative farmers in the two Washington State counties (Whitman and Grant). Results are shown in Table 3. Note that all the hedge ratios are reported without the negative sign, which indicates hedging is in short position in all cases.

As we can see, the specification of the GEU model gives us extra flexibility in the parameterization of the objective function. We are able to explore the feasibility of the GEU model as well as to compare the results from GEU optimization with those from other widely used expected utility optimization models. The first scenario GEU full ($\alpha = -0.13$, $\beta = 0.89$ and $\rho = 0.9493$) is our base scenario. It represents the farmer who is risk averse ($\alpha < 1$), has high intertemporal substitutability of consumption (ρ close to 1), and prefers an early resolution of the risk to a late resolution ($\alpha < \rho$). The farmer discounts future consumption by a factor of 89% and makes a decision for the next five years based on all available information as of today.

[7] The subsidy rate corresponding to the coverage levels of 50, 55, 60, 65, 70, 75, 80, and 85 percent are respectively, 67, 64, 64, 59, 59, 55, 48, and 38 percent.

Other scenarios of interest in our study include the two special cases of the GEU base model, CES-EU optimization with $\alpha = \rho = -1$ and $\beta = 0.89$, and MR-EU optimization with $\alpha = \rho = 1$ and $\beta = 0.89$. The former refers to the case where the farmer is more risk averse and has smaller intertemporal substitution preference in consumption, while the latter refers to the case when he/she is risk neutral and has perfect intertemporal substitution preference.

Besides the CES-EU and MR-EU, a multi-period additive EU (MA-EU) optimization is also examined. The utility function in this case is the standard constant relative risk aversion utility function $U_t = \frac{C_t^\alpha}{\alpha}$ where $\alpha = -1$, which implies a relative risk aversion coefficient equal to 2. This utility function has been widely used in static single-period risk analyses (Mahul, 2003; Wang, Makus, and Chen, 2004; Coble, Heifner, and Zuniga, 2000). It is also easy to extend the model from single-period to multi-period as in equation (7), but note that this multi-period version has a static nature.

$$\text{(7)} \qquad Max\, U_t = \left[\sum_i \beta^i E_t \left(\frac{\tilde{C}_{t+i}^\alpha}{\alpha} \right) \right] \qquad \text{(MA-EU)}$$

Table 3 lists results of the Whitman County and Grant County farmers' optimal choice on risk management portfolios using the four different models. In general, we see that parameterization of intertemporal preferences determines the model specification, and the model specification is very important in modeling farmer's risk management behavior and finding the optimal portfolios for farmers' intertemporal decision.

For the optimal choice of crop insurance, the highest coverage of 85% is favored in all cases. This result is consistent with the model setting since the insurance is subsidized by the government and no premium loading is charged. The farmer purchases the highest available level so as to enjoy the most protection against yield risk and receive the highest subsidy. Also, the government commodity programs provide free price protection with a sizable expected income transfer. The farmer will always participate, which reduces the need for futures hedging.

From the hedge ratios, we can see the hedging levels are always below 32%. This is because first there is a transaction cost charged for hedging. Second, the government LDP and CCP programs also have price risk reduction features, which leads to a crowding out effect on hedging. Similar results are reported in Wang, Makus, and Chen (2004). The pattern of the hedge ratio is different in the GEU base model relative to the other models, and the level of hedging is slightly higher in the GEU full optimization. With risk aversion, time preference, and intertemporal substitution separately specified, the GEU full model shows the farmer's optimal hedge ratios is increasing over the first four years. The generally higher level of hedging, compared with results from other alternative models, implies he/she prefers to resolve the risk earlier rather than later. Although the farmer prefers an early resolution of risk, his or her relatively high intertemporal substitutability of consumption may balance the preference in a way that hedging would be kept at a nondecreasing rate to meet the relative volatility changes. In the fifth and final year, the farmer would reduce spending on hedging and accept more risk.

In the CES-EU model, the farmer's risk aversion and intertemporal substitution of consumption is integrated as one preference. The optimal hedge ratio is higher in the first year and then becomes lower in the second through the fifth years compared to the corresponding ratios in the GEU full model. The CES-EU model also displays a decreasing pattern over the five years. The higher level of hedging in the first year is consistent with the farmer's higher risk aversion. The pattern switches for the second year, however. Since the risk aversion and substitution preference are mixed together in this case, the effects of the two preferences are hard to differentiate in a cross-year setting. They may be competing against or reconciling with each other, which, neither of which is observable.

The CES-EU results are comparable to the MA-EU results in that they both share the same risk aversion. Interestingly, these two models yield nearly the same optimal hedge ratios. We have further checked with other risk aversion values including $\alpha = -2$ and $\alpha = 0.5$, and get similar results. The comparison gives the impression that these two models work very similarly in modeling the optimization behavior for the decision maker's risk management. This result indicates that although the GEU does not include the popular additive EU models for risk averters, its CES-EU component is equivalent. So, GEU is perhaps more general than it appears.

As a very special case of the GEU model, the MR-EU model applies to a farmer who is risk neutral and has perfect intertemporal substitutability in consumption. Consistent with these preferences, the optimal hedging ratio is zero for each year, reinforcing that the decision maker does not care about risks and has no specific concerns regarding consumption across years.

Optimal choices for the representative farmer in Grant County are very similar to Whitman County. The farmer prefers slightly less hedging than the Whitman farmer but still buys the same coverage of crop insurance. Although the production is riskier in Grant County because yield is a bit more stochastic, there is no huge gap between the yield levels as shown in the historical data (Figure 2.1). Also we assume farmers in both counties face the same prices, so they are exposed to the same price risks. The hedge ratios are very close to those in Whitman County under the same preference set.

In summary, the comparisons between the four models for Whitman County and Grant County in Washington State show that the GEU model is feasible by yielding reasonable results on optimal risk management portfolios. For a farm planning on multi-period management, GEU shows an optimal strategy that is more consistent with reality on hedging and crop insurance for the decision maker, who wants to maximize utility over the whole time span. The GEU model framework is also flexible enough to account for separate risk, time, and substitution preferences, and is able to incorporate other commonly used EU models that have either ignored intertemporal substitution preference or integrated such substitution with risk preference.

VI. The Impacts of Preference, Market, and Policy Dynamics

For this part of analysis, we only focus on Whitman County wheat growers. Based on the GEU maximization, we examine the impacts of risk aversion, time preference, and intertemporal substitutability on farmers' optimal choice of hedging and crop insurance participation through parameterization of the preferences. By setting the price instruments with futures contracts, insurance policies, and government payments at different levels, we examine the impacts of market institutions. In addition, we investigate the relative impacts of each of the major risk management tools through various ways of constructing a risk management portfolio. These impacts are not only reflected in the optimal level of hedge ratios, but also in the cash value associated with the choice.

In order to differentiate the impacts of intertemporal preferences from those of market and policy alternatives, we consider two steps. First, assume the set of policy and market risk management tools stays the same while farmer's preferences vary, with the preferences changing one at a time. Second, change the parameters related with hedging, crop insurance, and government programs, for one tool at a time, when preferences are set at the base level.

Impacts of Preferences: Risk Aversion, Time Preference, and Intertemporal Substitutability

We solve the GEU optimization problem by dynamic programming using GAUSS for risk aversion parameter ranging from -5 to 1 (Arrow-Pratt CRRA coefficient from 0 to 6), time discount factor from 0.1 to 0.9, and substitution preference from -5 to 1. The examinations are conducted separately for each of the preferences. We change only one preference parameter at a time, while holding the other two preferences at the same level as in the base scenario. Theoretical restrictions on the parameters have been considered so that only feasible values were assigned within each range.

At this time, the farmer can choose from hedging in the commodity futures market and a no-load MPCI yield insurance. He or she is also able to receive government payments through DP, LDP, and CCP. The parameterization for these risk management instruments is at the base level. Results show that differences in the optimal portfolio are only in hedge ratios, the crop insurance purchase ratios are always at 85% level. Therefore, we focus on the variation in hedge ratios in the following discussion.

Risk Aversion

Figure 3.1 displays how hedge ratios in the next five years respond to risk aversion (α) changes[8]. In general, the farmer's optimal hedge ratios[9] are sensitive to variations in α. In the first year, which is the most responsive, a 1% increase in α (from around -3 to close to 1) results in a 0.74% decrease in the hedge ratio (from 35% to close to 0). Regarding the evolution of hedge ratios for each year, it shows a similar pattern throughout the five years. All ratios first increase very slowly when the farmer's risk aversion varies at higher levels (α from -3 to -1 or CRRA from 4 to 2). Then the ratios switch one by one to decrease as risk aversion gets smaller.

[8] We only select some "typical" values of risk aversion to display in the graph for space consideration. We did the same in the graphs of time preference and intertemporal substitutability. Complete results are available upon request.

[9] Here all hedge ratios are in short positions. When referring to hedge ratios, we usually mean the magnitude rather than the sign unless specifically stated.

Specifically, the turning points are at α equal to -3, -2, -0.8, 0.2, and 0.4 for the first until fifth year, respectively. After the turning point, hedge ratios generally decrease at a faster rate. This decreasing pattern seems more consistent with the intuition that less risk averse people would tend to hedge less. However, the increasing pattern before the turning point is still possible to happen. Similar patterns have been seen in empirical dynamic hedging research (Martinez and Zering, 1992).

At a specific risk aversion level, the optimal hedging level appears to decrease over the five years if the farmer is highly risk averse (α less than -2). The pattern is almost reversed if the farmer is not very risk averse (α greater than 0.2). For farmers who have mild risk aversion, the pattern is mixed. Depending on the specific point he or she is at, the farmer may hedge more either in the early stages or in the later stages. Theoretically, $\alpha < (>) \rho$ indicates the decision maker prefers early (late) resolution. Therefore when the farmer is very risk averse, he or she would want to resolve risk as early as possible by hedging more in early years, and vice versa. However, hedging reduces risks but also costs the farmers some certain income because of the futures transaction cost. As α and ρ get close, although $\alpha < \rho$ holds for the entire range in Figure 5, the preference of early resolution gets weak and the time discount of fixed transaction cost makes the farmer want to hedge less earlier and more later. Similar observations also exist in the sensitivities of time preference and intertemporal substitution.

Time Preference

From Figure 6 we notice that the hedge ratios are responsive to time preference changes but not as much as to risk aversion. The most responsive ratio is for the first year, but it only varies between 32% and 25%. Ratios for the second to fourth year only change from 30% to 32%, and ratio for the fifth year has only minor changes. Second, hedge ratios have a convex pattern but only the turning points for the first two years ($\beta = 0.3$ and 0.5, respectively) are observable within the range of β. Third, for the last year when farming is about to end, the hedge ratio is always around 25.5% for all β levels, quite different from the other years, especially those for the second to fourth year.

Since β is defined as the time discount factor, by postponing consumption to next period the farmer only gets a fraction (β) of the utility that he or she would get by consuming an equal amount during the current period. Therefore with a higher β, the farmer will have a greater propensity to consume in the future instead of the current time period. In our case, as β becomes bigger or the future consumption is less discounted, the farmer values the future income and income risk more than today's, and hedging decreases in the early years. The hedge ratios are increasing during the third until fifth year over all β values, and increasing for the first two years before β gets to the turning point.

At a specific time preference level, the farmer tends to hedge more in earlier years due to a preference for an early resolution of consumption risk. This pattern is more obvious in hedge ratios when β is low, but it then slowly changes as hedge ratios move to the turning point.

Intertemporal Substitutability

Optimal hedge ratios are generally sensitive to changes in intertemporal substitutability as shown in figure 7. Hedging percentages are primarily increasing as ρ gets larger. The pattern switches when ρ reaches the turning point in the first and second year.

A larger ρ represents a more substitution of consumption across years. Therefore, optimal hedge ratios differ for large versus small ρ values across the first four years, most noticeably in the third and fourth year. For a range between -5 to 0.8, the increase in ρ for a given α $(\alpha = -0.13)$ also affects attitudes towards risk and timing. The farmer's preference toward resolution of risk will change from late to early. Combined with the increasing substitution effect of late consumption for early consumption, it can be seen that hedge ratios for the first four years change relative to each other.

In summary, sensitivity analysis of intertemporal preferences shows that optimal hedging behavior of the representative farmer is sensitive to intertemporal preferences change. Risk aversion appears to have a larger effect on hedge ratios than time preference and intertemporal substitutability. Each of the preferences seems to have a different pattern of impact. But even in the separate analysis, the effect is often intertwined with influences from the other preferences due to relative value changes among them.

Impacts of Market Institutions: Transaction Cost and Insurance Premium Loading

Transaction costs related to futures contracts and insurance premiums are the major costs farmers pay for using hedging to reduce price risk and crop insurance to manage yield or revenue risks. To examine how these institutions affect farmers' risk management decisions, we set up different levels for transaction cost and premium loading, while other parameters in the model remain fixed. The impacts of transaction costs and insurance premium loading are studied in detail based on the base model in this section. We also briefly discuss the impacts of these two factors based on results from other EU-type models in a later section.

Transaction costs are what farmers must sacrifice from current income to receive future market price protection if they choose hedging to reduce price risk. When transaction costs are charged, hedging has offsetting impacts. More hedging improves farmers' expected utility through price risk protection, but it also reduces utility by directly lowering current consumption. Using the base model where all tools are included, we first let transaction cost vary from

$0/bushel to $0.02/bushel, including the current market level $0.017/bushel, at an increment of $0.001. Because the CCP in government programs also has a market price protection function, we remove the CCP from the risk management pool and make hedging the only tool to reduce price risk. The summarized optimal hedge ratio changes are reported in Figure 8 and Table 4.

Figure 8 displays how the hedge ratios react to variations in transaction cost for the first year. A similar pattern is also exhibited in the second through fifth year, but the ratios are at decreasing levels as implied by Table 4[10]. The optimal hedge ratios generally display a decreasing trend as transaction costs increase, and the amount of the change is quite small. From the upper panel in Table 4, we can see that 1% change in transaction costs result in about 0.3% change in the hedge ratio during the first year when the government CCP is included. The implication is that for our representative farmer, hedging is responsive but not very sensitive, to changes in transaction costs when free government price protection is available.

Comparing the lower panel with the upper panel in Table 4 shows that after the CCP is removed, the hedge ratio increases by 45%, from 0.42 to 0.61, given the same transaction cost variation. Without the CCP, the ratios also appear to decrease faster from the first year to the fifth year, implying by the steeper slope of the trend line. This suggests a smaller tolerance to a transaction cost increase without assistance from the CCP.

To find out the impact of premium loading charged for crop insurance purchases, we examined the optimal insurance coverage in response to changes in loading from 0% to 30%, with an increment of 5%. Our results based on the base model and various other portfolios show (Table 5), however, that farmers would always choose to buy the highest available coverage of 85%. One possible explanation for this could be that the crop insurance is heavily subsidized by the government. Therefore, although our representative farmer needs to pay up to 30% more on

[10] Complete results are available upon request.

premiums, the expected return from participating in the insurance program is still higher than the cost. Accordingly, it is beneficial to buy insurance at 85% rather than any lower coverage level.

In summary, the impact analysis of market institutions shows that farmers are more responsive to the changes in transaction cost than in insurance premium. But the responsiveness in hedge ratios to transaction cost is relatively small, indicating hedging might not be a major consideration in farmers' risk management decisions. Our representative farmer would always choose to purchase insurance at the highest level 85%. Apparently the expected return due to crop insurance premium subsidies covers the expenses due to premium loading up to 30%.

Impacts of Government Price Protection: Target Price and Loan Rate

Apart from hedging, government programs also contain elements of market price protection. Base on values of the parameters for the target price (P_T) and loan rate (L_R) relative to the expected market price, farmers receive price protection. Here we study the impacts of these two parameters by changing their values hypothetically, while keeping the expected cash price based on simulated distribution fixed for the next five years.

The impacts of these two parameters based on base model optimization are combined in one graph as shown in Figure 9. The graph shows how optimal hedge ratios change as the government protection level varies over the next five years. The process of combining the impacts works as follows. First, when the target price changes from the current level of $3.92/bushel down to $2.86/bushel, the loan rate remains at $2.86/bushel. Therefore, the price range from $3.92 to $2.86 on the horizontal axis represents impacts from reducing the CCP's target price. When the target price drops below $2.86, the CCP actually has a zero value and no longer plays a role in hedging decision. Thereafter, the loan rate varies from $2.86 to $0, reflecting a decreasing level of protection from the LDP. When the loan rate finally reaches $0, the LDP drops out of the hedging decision. No more direct price protection is available in government programs at this point.

From Figure 9, the pattern for target price variation is different than for the loan rate. From \$0 to \$2.86, hedge ratios decrease at an increasing rate as more price protection from government programs becomes available, implying an increasing substitution effect of LDP for hedging. When the loan rate is \$0, hedging is the only way to reduce price risk and the optimal hedge ratio for each year reaches the highest possible level of around 0.78. This maximum level is determined by the correlation between the cash and futures prices as well as the transaction cost level. Also as the loan rate increases, hedge ratios for the later years drop faster than those for the earlier years. Again, this is because early resolution of risk is preferred to late resolution.

From \$2.86 to \$3.92, the impact of the CCP's target price enters the hedging decisions but takes effect step by step. From a target price level of \$2.86 to almost \$3.52, the CCP does not impact hedging. The hedge ratios essentially remain at the same level. This is from the impact of the \$0.52 direct payment (P_D)[11]. Starting from \$3.52, the target price begins to exceed the threshold. Hedge ratios drop rapidly until finally reaching 0.30~0.42, indicating an increasing influence from CCP on the risk management decisions and a greater substitution of CCP for hedging.

In summary, optimal hedging is sensitive to variations in the LDP loan rate and the CCP target price. Results indicate a strong substitution effect from the government LDP and CCP for hedging in terms of price risk protection. The impacts appear somewhat stronger in the later years than in the early years.

[11] As defined early, CCP takes effect after a "trigger price" is reached, i.e. $CCP_t = 0.85 \times 0.935 \times E_{t-1}(Y_t) \times \max[0, P_T - P_D - \max(P_t, L_R)]$ therefore CCP > 0 only if $P_T - (P_D + \max(P_t, L_R)) > 0$. When P_T is greater than L_R but $(P_T - \max(P_t, L_R))$ less than P_D of \$0.52, CCP always yields a zero value. So there is no income improvement to the farmer.

Relative Impacts of Hedging, Crop Insurance, and Government Programs

We consider four major cases, \$0.017 vs. \$0 hedging transaction cost, paired with 0% and 30% insurance premium loadings respectively, as shown in Table 5 and 6. Under each case, we set the base portfolio scenario as a full set of futures contract, crop insurance, and all three government programs (DP, LDP, CCP). Then from the base scenario, we reduce one instrument at a time to study the marginal effect of that instrument.

We design five risk management portfolios for the farmer. In addition to the optimal hedge ratios and crop insurance ratios, we also compute a CE using equation (5). CE serves not only as a measurement of welfare improvement, but also as a criterion to assess the relative effectiveness of the tools to the farmer.

We start with the most complete set of risk management tools. In the base scenario with a \$0.017/bushel transaction cost (Table 5, upper panel), optimal hedge ratios range from 25% to 32% over years. The CE of this full portfolio is \$62.28, the highest among all portfolios. As we decrease the availability of government programs by taking away CCP first and then LDP, hedge ratios generally increase from around 30% to 40% to around 60% to 75%, to cover the extra risk. Correspondingly, without the support of CCP and LDP, the CE of the portfolios also decreases a lot by more than 50% from \$62.28 to \$34.58. When the DP is also eliminated, hedge ratios increase very slightly instead, which is due to the farmer's tightened budget on transaction costs. Without any government payments, the farmer has less wealth and is not willing to pay the futures transaction cost. There is a different result for the scenario when there is no transaction cost (Table 5, lower panel). The hedge ratios are about the same with or without the DP.

Although the insurance premium loading doesn't seem to affect the optimal coverage level, it affects the farmer's evaluation of the welfare improvement due to insurance. Higher premium loading yields a smaller value of the insurance product in all portfolios..

As we take away the payment programs one by one, the change in CE discloses information about the specific values of each program. For example, the difference between the first two portfolios indicates a CCP value of $13.46 (62.28-48.82) to the farmer. We compute all these values and report them in Table 6. Among the three government programs, the DP has a highest value, while the CCP has a value close to the LDP. In total government programs account for $57.47, which is more than 90% of the total value of the base portfolio ($62.68).

When we take away all government programs, the farmer relies on hedging and insurance. He or she can still find a hedging path and rely on the highest 85% insurance coverage to manage risks but achieves a much lower welfare level (CE=$4.81). The value of hedging can be calculated when we consider another portfolio of only crop insurance and government programs (CE=62.20). The difference between the CE of this last portfolio and that of the comprehensive base portfolio ($62.28) yields $0.08. The low value of hedging is not too surprising considering farmers' low participation rates. However, the value is quite low even though they hedge at a significant percentage. Compared to insurance and government programs, futures is the only tool that does not receive any subsidy while paying a transaction cost. Considering that insurance is limited to yield insurance, the value of hedging may go even lower when revenue insurance is included. Correspondingly, when the value of CI is computed by subtracting the total government programs' value from this last value, it turns out to be $4.73 ($62.20-$57.47) under 0% premium loading and $4.60 ($62.07-$57.47) under 30% premium loading. These values are a lot less than the individual government programs but still significantly larger than hedging in the value of the full portfolio. This indicates that to the farmer, an income transfer in terms of subsidy is more valuable than risk reduction of a non-subsidized instrument like hedging.

Next we take off the transaction cost so hedging has no cost to the farmer. We see from Table 5 lower panel that optimal hedge ratios generally increase significantly. The rate of the increase slows down when hedge ratios get close to 79%. The values of the portfolios also increase slightly when the farmer saves money on hedging. The optimal insurance coverage ratio still stays at 85% with both 0% and 30% premium loadings, implying that the gain from saving on hedging still cannot replace the possible loss from lower insurance coverage.

The CE values of each risk management tool change slightly except for hedging (Table 6). The value of hedging goes up by about 35%. Despite that, the ranking of the values for these tools stays the same, that is, government programs (DP + LDP + CCP) > CI > hedging.

VII. Summary and Conclusions

In this study we apply the GEU maximization framework to analyze a risk management problem related to wheat production in the PNW. A representative soft white wheat grower in Whitman County and Grant County, Washington, maximizes his or her utility by selecting an optimal portfolio of risk management tools including hedging in the futures market, purchasing crop insurance, and participating in government commodity programs. The GEU model allows the decision maker to completely specify risk preference, time preference, and intertemporal substitution preference. It also incorporates other common expected utility maximization models like CES-EU and MR-EU models as special cases. A very popular but different type of static EU (MA-EU) model is also added for comparison purpose.

We solve the maximization problem numerically based on simulated yield and price data for the next five years. Stochastic trends are used in the simulation of Grant County yield, Portland cash price, and CBOT futures price, based on historical data.

We find optimal solutions for farmers in both Whitman County and Grant County vary with model specifications, reinforcing the importance of appropriate model selection and parameterization. Comparing the GEU model with other EU models shows that the general form of GEU has advantages in incorporating more preference information about the decision maker. The commonly used MA-EU model gives almost the same results when the risk aversion is specified at the same level as in the CES-EU, indicating that these two types of models might be interchangeable. However, these results are different than the GEU model when the preferences parameters are set at different levels. To conclude, (1) GEU is more general and can incorporate more flexible preference, (2) the commonly used additive EU models may yield biased results relative to the decisions based on the true preference. The results are completely different in the risk neutral and perfect substitution MR-GEU setting.

The optimal choice of the hedging ratios is around 30% and that of the crop insurance purchase is always 85% in both counties. These levels are in line with the existing static one period studies. The subsidy in crop insurance overshadows its risk management feature so that the optimal insurance coverage is invariant with respect to the preference alternatives.

Based on GEU framework, we investigate the impacts of intertemporal preferences, hedging and crop insurance costs, and U.S. government payment programs on the risk management behavior of a Whitman County wheat producer.

The GEU framework has flexibility in the parameterization of the farmer's preferences towards risk, timing, and intertemporal substitutability of consumption. We employ this feature to examine the impacts of changes in these preferences on farmers' optimal hedging and crop insurance participation. Preference impact analysis implies that optimal hedging behavior of the representative farmer is sensitive to intertemporal preferences changes. Risk aversion appears to have a larger effect on hedge ratios than time preference and intertemporal substitution. Each of the preferences has its own impact pattern. But even in the separate analyses, the effect is often intertwined with influences from the other preferences due to relative value changes.

The market institution impact analysis shows that hedging transaction costs negatively affect optimal hedge ratios and reduces the farmer's welfare level. When crop insurance is coupled with a premium subsidy, even an insurance premium loading of 30% is not enough to keep the farmer from purchasing the highest available level of insurance coverage. However, the premium loading definitely reduces welfare. The impact analysis of government price protection parameters, the target price and loan rate, indicates that both of them are influential in hedging decisions. The corresponding government LDP and CCP have increasing substitution impact on hedging as the price protection level increases.

The relative impact analysis of current risk management tools shows both crop insurance and government programs are influential to the farmer's welfare improvement. Hedging has very limited contribution. In terms of the ranking of the value of these tools, the government programs (DP + LDP + CCP) have a greater effect on farmers' welfare than crop insurance, and crop insurance outperforms hedging. Yield insurance has a greater value than DP, LDP, or CCP separately, but less than the three combined. Among the three government programs, the DP has higher a value than the respective values of the LDP and the CCP for the representative farmer.

References

Chavaz, J., and M. T. Holt. "Economic Behavior Under Uncertainty: A Joint Analysis of Risk Preferences and Technology." *The Review of Economics and Statistics*, 78(2) (May 1996): 329-335.

Coble, K. H., R. G. Heifner, and M. Zuniga. "Implications of Crop Yield and Revenue Insurance for Producer Hedging." *Journal of Agricultural and Resource Economics*, 25(2) (December 2000): 432-452.

Crain, S. J., and J. H. Lee. "Volatility in Wheat Spot and Futures Markets, 1950-1993: Government Farm Programs, Seasonality, and Causality." *The Journal of Financ*e, 51(1) (March 1996): 325-343.

Epstein, L. G. and S. E. Zin. "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework." *Econometrica*, 57(4) (July 1989): 937-969.

-------- "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: An Empirical Analysis." *Journal of Political Economy*, 99(2) (April 1991): 263-286.

Hansen, L. P., and K. J. Singleton. "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns." *Journal of Political Economy*, 91(2) (April 1983): 245-265.

Hinman, H. R., and R. Baldree. "Using Budgets for Profit Making Decisions (Winter Wheat-Dry Pea Example)." Paper presented at the Dryland Farm Management Series in Colfax, Washington, January 30, 2004.

Howitt, R. E. et al. “Calibrated Stochastic Dynamic Models for Resource Management.” selected paper, World Congress of Environmental and Resource Economists – Monterey California, June 2002.

Knapp K. C., and L. J. Olson: “Dynamic Resource Management: Intertemporal Substitution and Risk Aversion”, *American Journal of Agricultural Economics*, 78(4) (November 1996): 1004-1014.

Kreps, D. M., and E. L. Porteus. “Temporal Resolution of Uncertainty and Dynamic Choice of Theory.” *Econometrica*, 46(1) (January 1978): 185-200.

Lence, S. H.. “Using Consumption and Asset Return Data to Estimate Farmers’ Time Preferences and Risk Attitudes.” *American Journal of Agricultural Economics*, 82(4) (November 2000): 934-947.

Mahul, O.. “Hedging price risk in the presence of crop yield and revenue insurance.” *European Review of Agricultural Economics*, 30(2) (June 2003): 217-239.

Makus, L. D., B. Lin, J. Carlson, and R. Krebill-Prather. “Factors Influencing Farm Level Use of Futures and Options in Commodity Marketing.” *Agribusiness*, 6 (November 1990): 621-632.

Martinez, S. W., and K. D. Zering. “Optimal Dynamic Hedging Decisions for Grain Producers.” *American Journal of Agricultural Economics*, 74(4) (November 1992): 879-888.

Mehra, R., and E. Prescott. “The Equity Premium: A Puzzle.” *Journal of Monetary Economics*, 15(2) (March 1985): 145-161.

Moss, C. B., and J. S. Shonkwiler. “Estimating Yield Distributions with a Stochastic Trend and Nonnormal Errors.” *American Journal of Agricultural Economics*, 75(4) (November 1993): 1056-1062.

Myers, R. J.. “The Value of Ideal Contingency Markets in Agriculture.” *American Journal of Agricultural Economics*, 70(2) (May 1988): 254-267.

Nyambane, G. G. et al. “Dynamic Risk Management under Credit Constraints.” selected paper, NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, Missouri, April 22-23, 2002.

Platt, T., H. Hinman, and A. Esser. “2003 Enterprise Budgets for Summer Fallow-Winter Wheat, Spring Barley and Spring Wheat Using Conventional Tillage Practices, Lincoln County, Washington.” *Farm Business Management Reports, EB1964E*, March 2004.

Saha, A., C. R. Shumway, and H. Talpaz. “Joint Estimation of Risk Preference Structure and Technology Using Expo-Power Utility.” *American Journal of Agricultural Economics*, 76(2) (May 1994): 173-184.

Vandeveer, M. L., and C. E. Young. “The Effects of the Federal Crop Insurance Programs on Wheat Acreage.” A special article in *Wheat Situation and Outlook Yearbook*, Economic Research Service, US Department of Agriculture, WHS-2001, March 2001.

Wang, H. 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(4) (November 1998): 806-820.

Wang, H. H., L. D. Makus, and X. Chen. “The Impact of US Commodity Programmes on Hedging in the Presence of Crop Insurance.” *European Review of Agricultural Economics*, 31 (2004), 331-352.

Weil, P.. “Nonexpected Utility in Macroeconomics.” *Quarterly Journal of Economics*, 105(1) (February 1990): 29-42.

Zuniga, M., K. H. Coble, and R. Heifner. "Evaluation of Hedging in the Presence of Crop Insurance and Government Loan Programs." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis, Missouri, April 2001.

Figure 1. Historical Soft White Wheat Yields in Whitman and Grant (1972-2003)

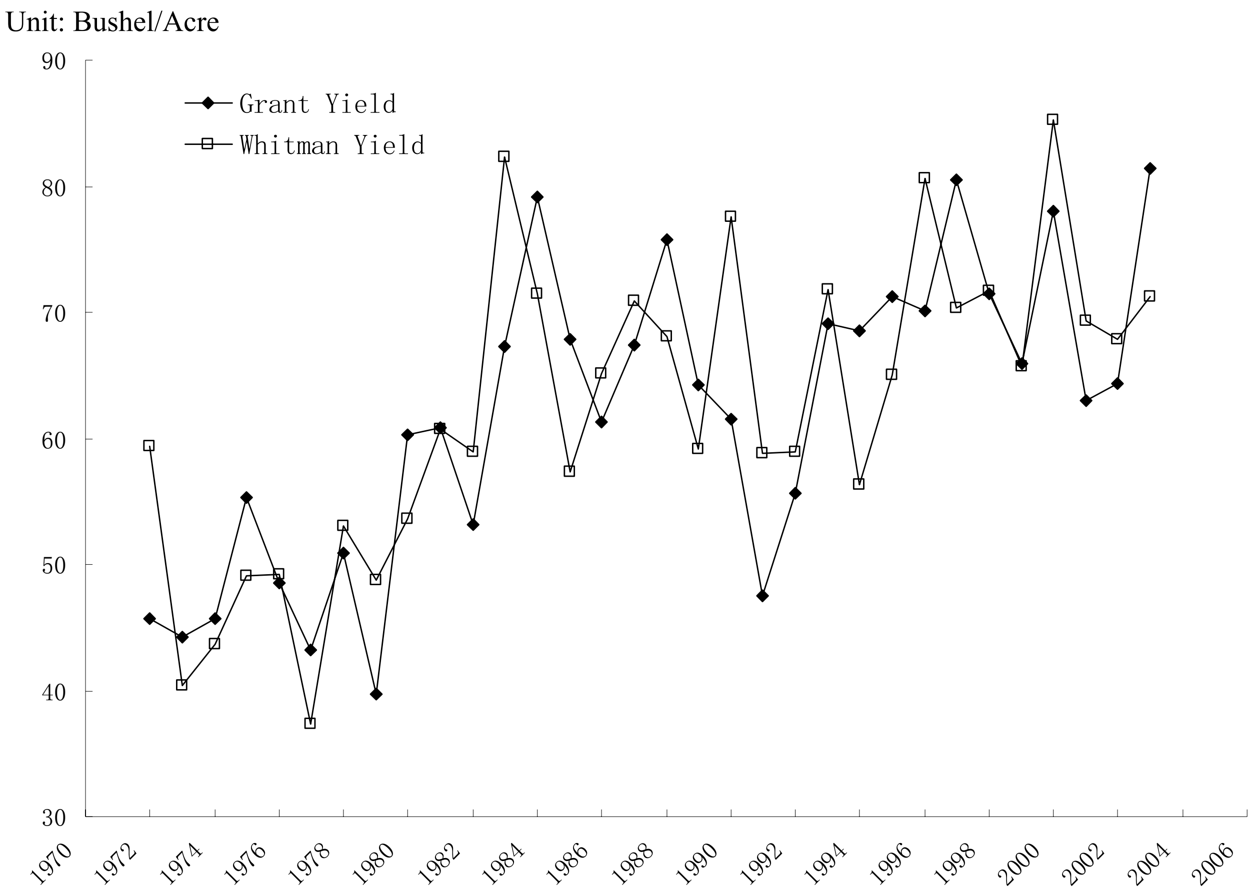

Figure 2. Historical Wheat Cash and Futures Prices (1973-2003)

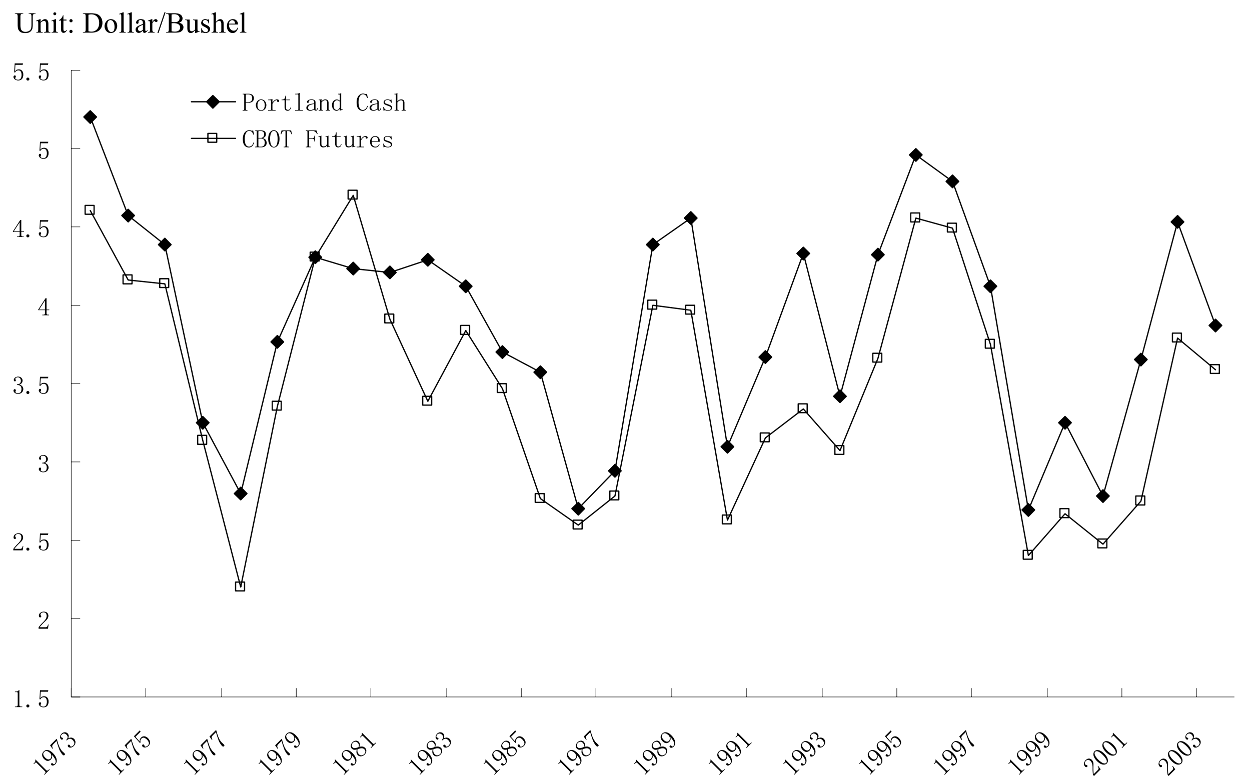

Figure 3. Stochastic Trend Model Fitting for Grant Wheat Yield (1972-2003)

Predicted vs. Actual

Unit: Bushel/Acre

Note: The lower bound and upper bound are based on 95% confidence intervals.

Figure 4. Stochastic Trend Model Fitting for Wheat Cash Prices (1973 to 2003)

Predicted vs. Actual

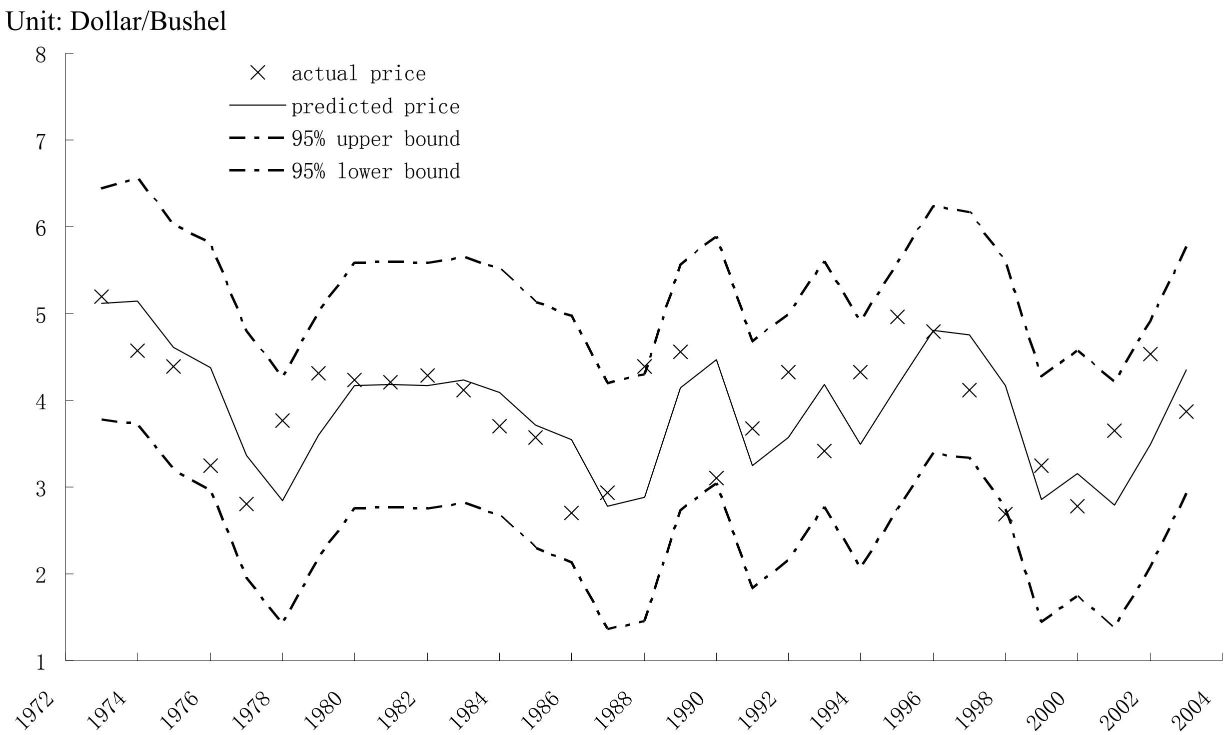

Figure 5. Sensitivity of Optimal Hedge Ratios in Response to Risk Aversion

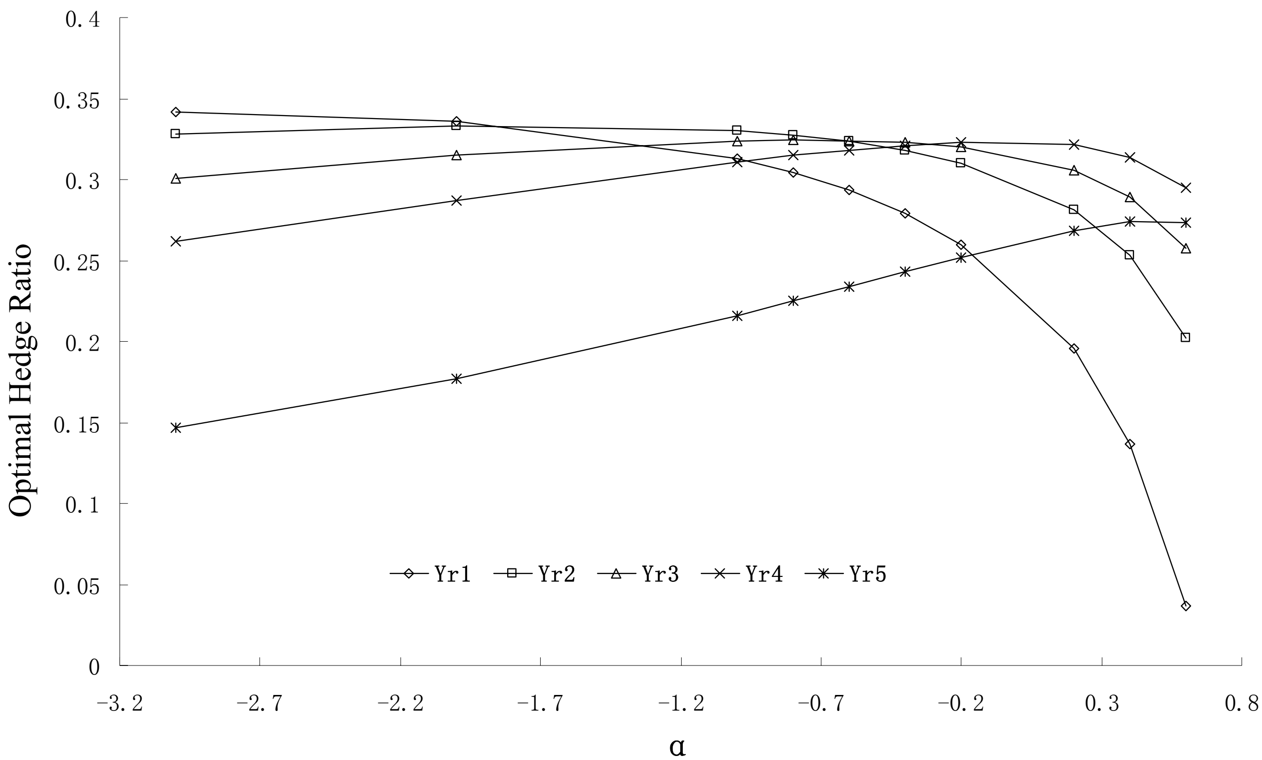

Figure 6. Sensitivity of Optimal Hedge Ratios in Response to Time Preference

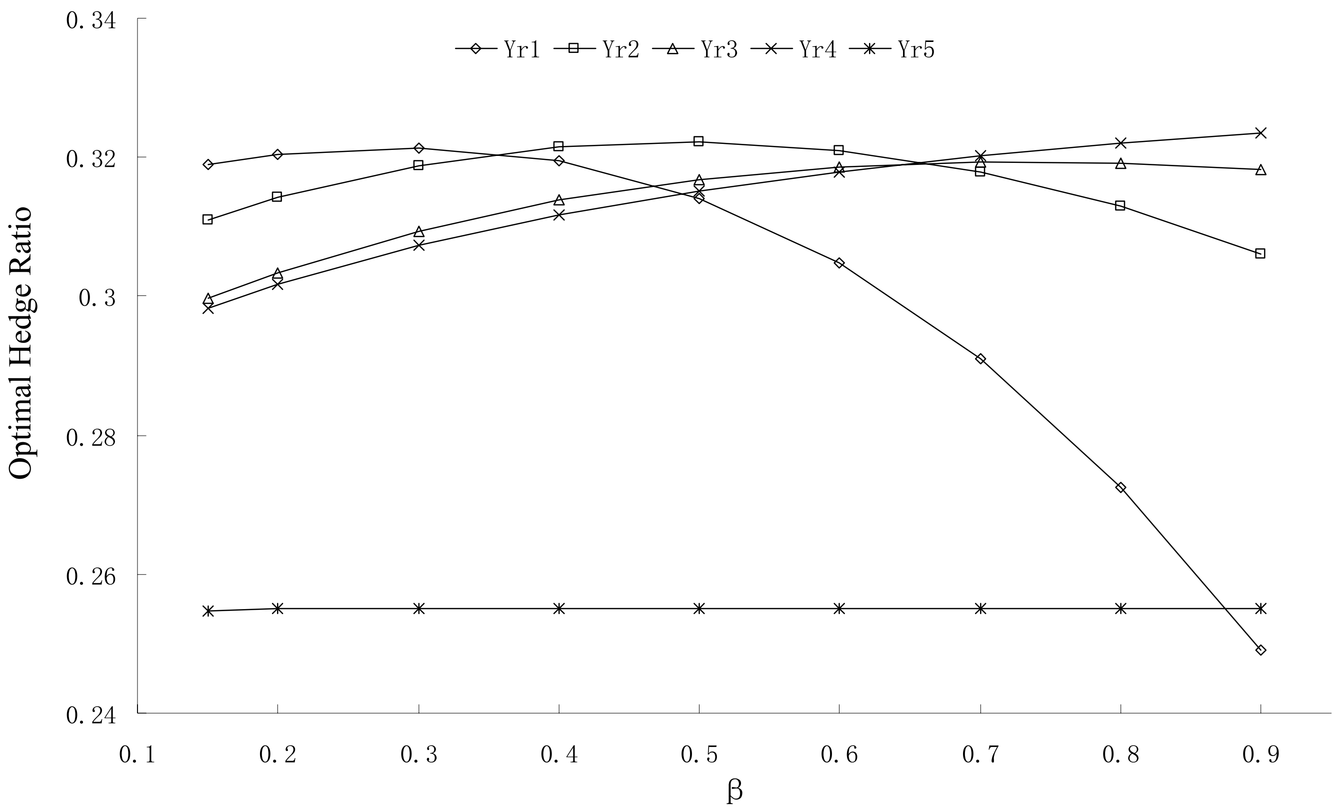

Figure 7. Sensitivity of Optimal Hedge Ratios in Response to Intertemporal Substitutability

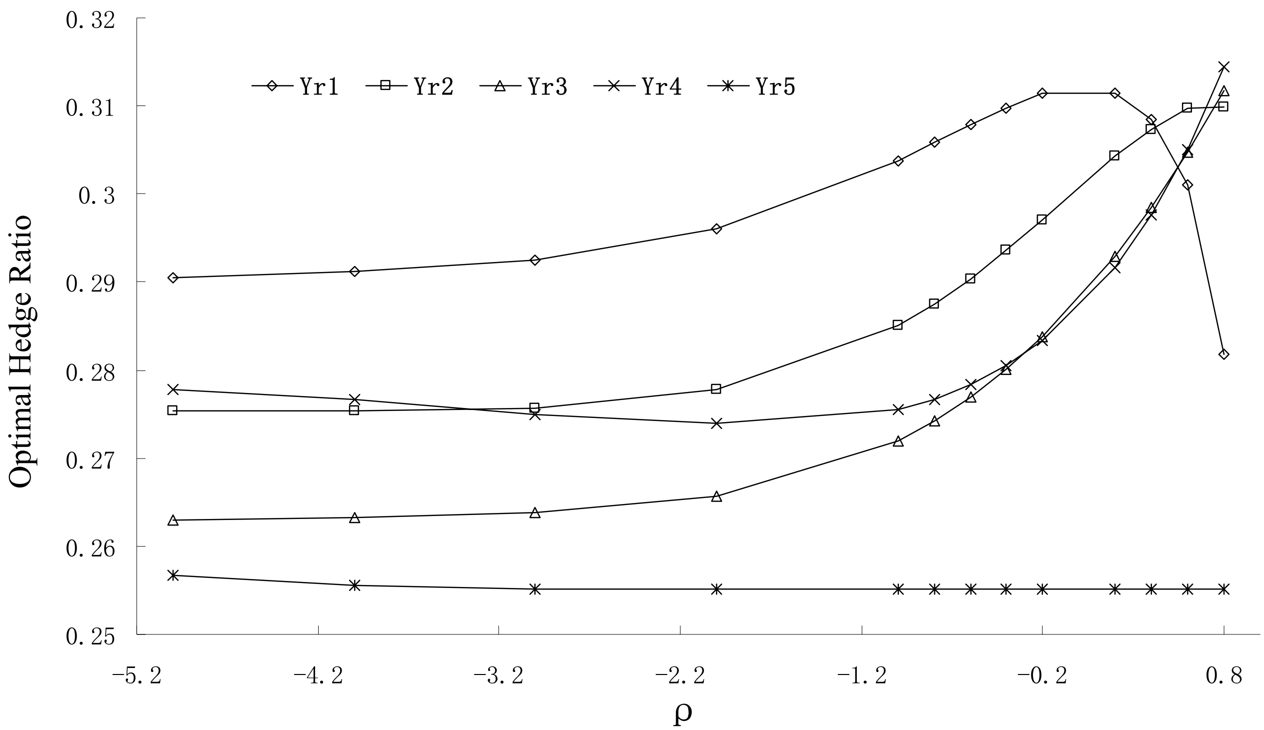

Figure 8. Sensitivity of Optimal Hedge Ratios in Response to Transaction Cost

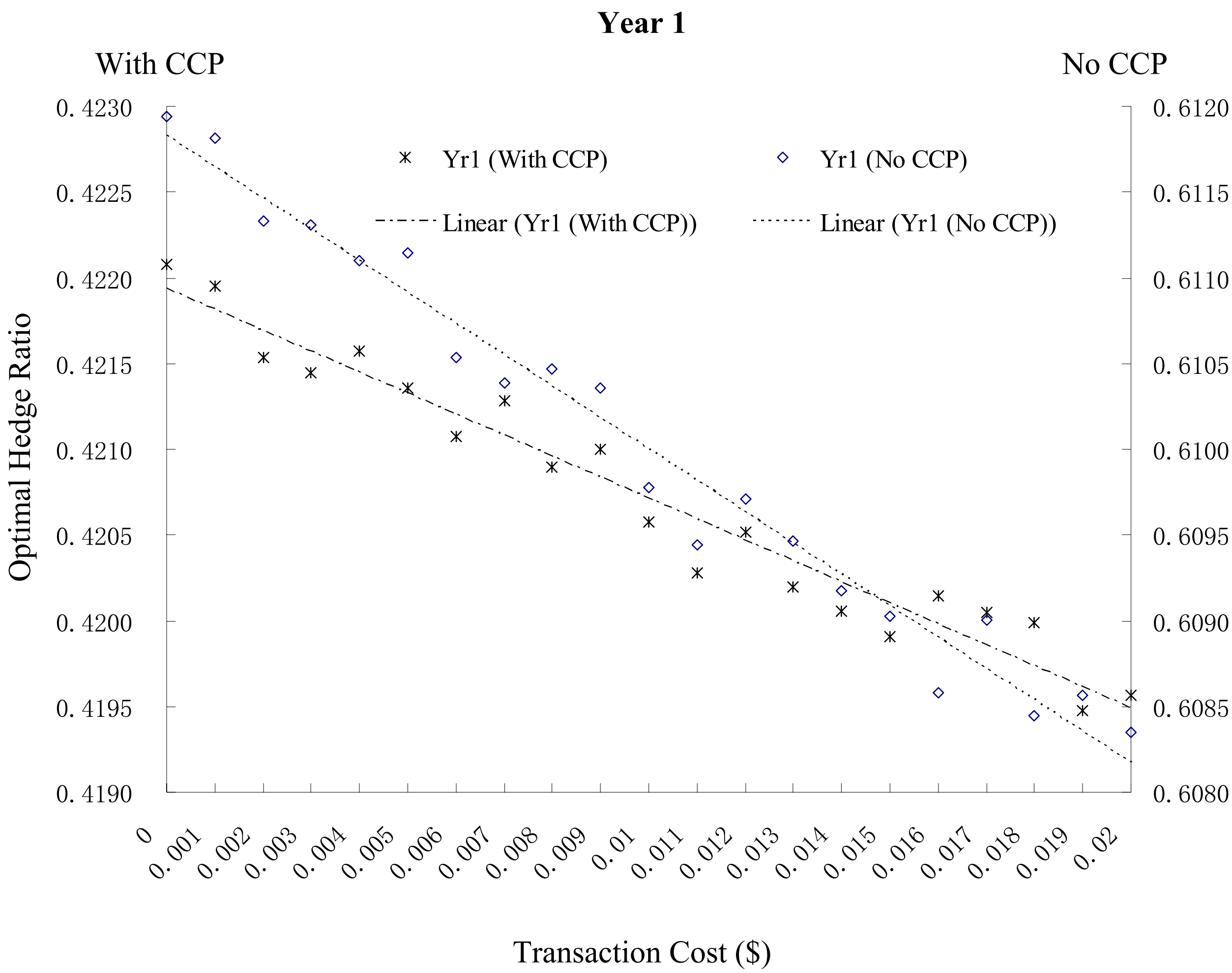

Figure 9. Sensitivity of Optimal Hedge Ratios in Response to Target Price / Loan Rate

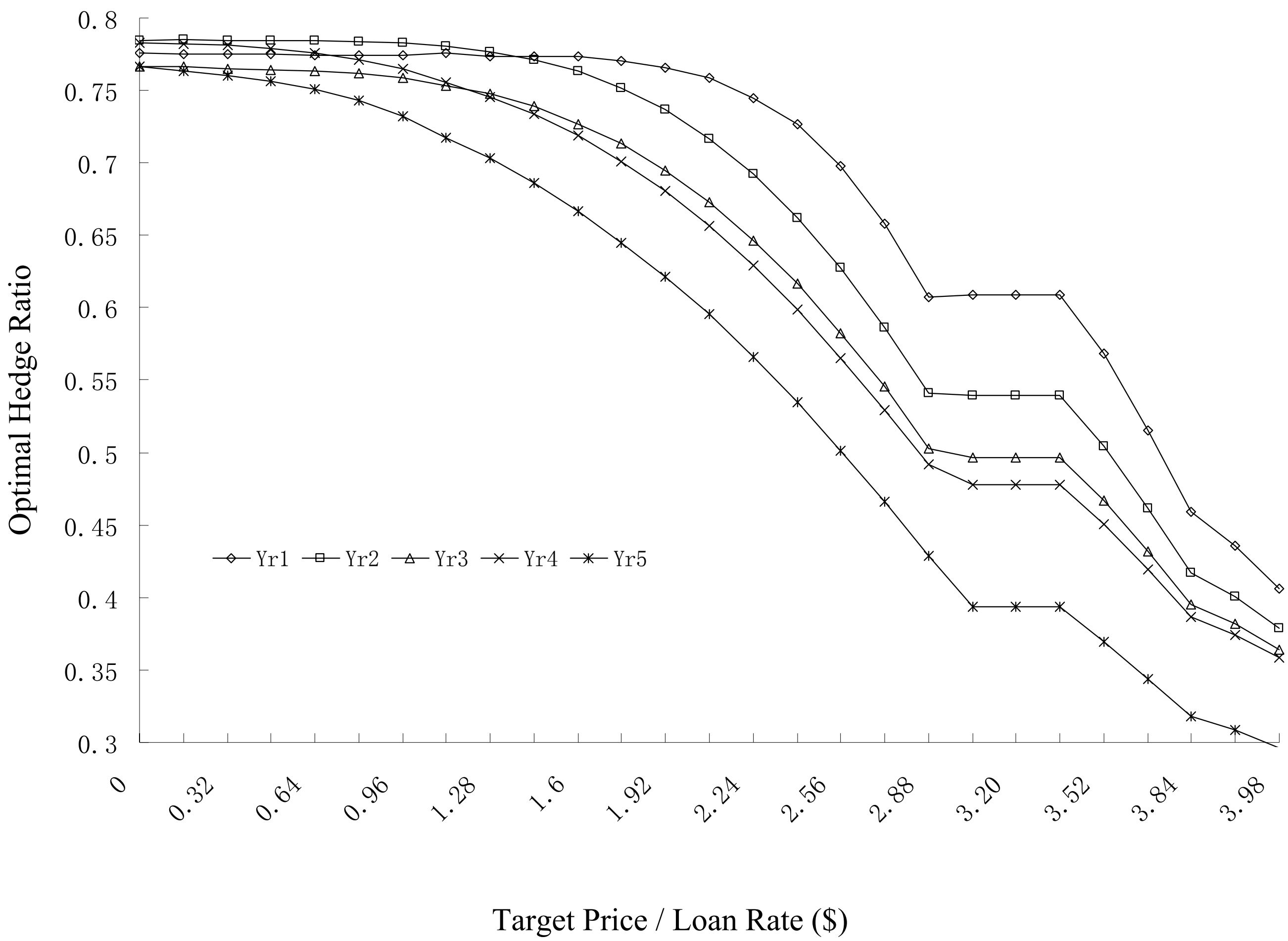

Table 1. Stochastic Trend Estimation of Historical Yield and Price Data

(Normal distribution)

Parameter	Whitman Yield	Grant Yield	Cash Price	Futures Price
μ_0	27.29**(3.63)	44.22**(6.29)	5.24**(3.25)	4.64 (3.24)
β_0	0.73 (1.00)	0.94 (1.16)	-0.04 (1.02)	-0.03 (1.11)
σ_ε	7.13**(0.63)	6.92**(1.46)	0.00 (1.02)	0.00 (0.23)
σ_η	0.00 (0.15)	3.10*(2.04)	0.75*(0.10)	0.71*(0.09)
σ_ς	0.00 (0.03)	0.00 (0.25)	0.00 (0.07)	0.00 (0.07)

Note: 1. Standard errors of the estimates are included in the parentheses.

2. "*" denotes the estimate is statistically significant at 0.10 level, and "**" denotes significance at 0.05 level.

Table 2. Descriptive Statistics of the Simulated Yield and Price Data

Statistics	Year1	Year2	Year3	Year4	Year5	Year1	Year2	Year3	Year4	Year5
	Whitman Simulated Yield (bushel/acre)					***Grant Simulated Yield (bushel/acre)***				
Mean	75.28	75.93	76.77	77.36	78.24	75.19	76.27	76.30	77.34	78.02
Std Dev.	7.26	7.22	7.28	7.06	7.23	7.49	8.15	8.36	9.46	9.65
Skewness	-0.01	-0.03	0.02	0.07	-0.04	-0.08	-0.02	0.03	-0.05	0.02
Kurtosis	0.24	0.14	-0.03	0.07	-0.005	0.08	0.26	-0.09	0.16	-0.4
	Portland Cash Price (dollar/bushel)					***CBOT Futures Price (dollar/bushel)***				
Mean	3.93	3.86	3.82	3.79	3.77	3.56	3.51	3.49	3.46	3.44
Std Dev.	0.66	0.91	1.07	1.21	1.34	0.68	0.96	1.15	1.29	1.44
Skewness	0.02	0.02	0.06	0.10	0.06	-0.04	0.02	0.10	0.07	0.05
Kurtosis	-0.05	0.06	-0.06	0.20	-0.12	0.03	0.01	-0.20	-0.26	-0.31

Table 3. Optimal Hedge Ratio and Crop Insurance Coverage: Model Comparison

Alternative Model Specifications	Hedge Ratio					Crop Ins. Cov. Ratio
	Year1	Year2	Year3	Year4	Year5	Year1-5
Whitman County						
GEU full (α= -0.13, β = 0.89, ρ = 0.9493)	0.25	0.31	0.32	0.32	0.26	0.85
CES-EU (α = ρ = -1, β = 0.89)	0.29	0.27	0.25	0.25	0.22	0.85
MR-EU (α = ρ = 1, β = 0.89)	0	0	0	0	0	0.85
MA-EU (α = -1, U(C) = -1/C, β = 0.89)	0.29	0.27	0.25	0.25	0.22	0.85
Grant County						
GEU full (α= -0.13, β = 0.89, ρ = 0.9493)	0.25	0.31	0.32	0.32	0.24	0.85
CES-EU (α = ρ = -1, β = 0.89)	0.31	0.28	0.26	0.25	0.21	0.85
MR-EU (α = ρ = 1, β = 0.89)	0	0	0	0	0	0.85
MA-EU (α = -1, U(C) = -1/C, β = 0.89)	0.31	0.28	0.26	0.25	0.21	0.85

Table 4. Summarized Optimal Hedge Ratio in Response to Transaction Cost

	Optimal Hedge Ratios (With CCP)				
	Year1	Year2	Year3	Year4	Year5
Mean	0.4207	0.3856	0.3651	0.3520	0.2677
Max	0.4221	0.3862	0.3655	0.3523	0.2679
Min	0.4195	0.3849	0.3648	0.3517	0.2676
Range	0.0026	0.0013	0.0008	0.0005	0.0002

	Optimal Hedge Ratios (No CCP)				
	Year1	Year2	Year3	Year4	Year5
Mean	0.6100	0.5398	0.4972	0.4780	0.3933
Max	0.6119	0.5405	0.4976	0.4784	0.3935
Min	0.6083	0.5389	0.4967	0.4776	0.3932
Range	0.0036	0.0016	0.0009	0.0008	0.0003

Note: The hedging transaction cost varies from $0/bushel to $0.02/bushel.

Table 5. Impacts of Market Institutions and Government Policies on Farmers' Optimal Risk Management Portfolio

Alternative Portfolios	Hedge Ratio					Crop Ins. Coverage	0% Premium Loading	30% Premium Loading
	Year1	Year2	Year3	Year4	Year5	Year1-5	CE($)	CE($)
With Transaction Cost ($0.017/Bushel)								
H & CI & G(DP, LDP, CCP)	0.25	0.31	0.32	0.32	0.26	0.85	62.28	62.15
H & CI & G(DP, LDP)	0.39	0.44	0.44	0.44	0.38	0.85	48.82	48.69
H & CI & G(DP)	0.28	0.57	0.65	0.72	0.74	0.85	34.58	34.45
H & CI	0.32	0.59	0.66	0.72	0.74	0.85	4.81	4.68
CI & G(DP, LDP, CCP)	--	--	--	--	--	0.85	62.20	62.07
Without Transaction Cost ($0/bushel)								
H & CI & G(DP, LDP, CCP)	0.42	0.39	0.37	0.35	0.27	0.85	62.68	62.54
H & CI & G(DP, LDP)	0.61	0.54	0.50	0.48	0.39	0.85	49.39	49.26
H & CI & G(DP)	0.78	0.79	0.77	0.79	0.77	0.85	35.44	35.31
H & CI	0.78	0.79	0.77	0.79	0.77	0.85	5.67	5.54
CI & G(DP, LDP, CCP)	--	--	--	--	--	0.85	62.20	62.07

Note: The base portfolio is the portfolio that includes all risk management tools, i.e. H & CI & G(DP, LDP, CCP).

Table 6. Evaluation of Risk Management Instruments

Alternative Instruments	$0.017/bushel Futures Transaction Cost		$0/bushel Futures Transaction Cost	
	$ 0% premium loading	30% premium loading	$ 0% premium loading	30% premium loading
Gov't programs (total, $)	57.47	57.47	57.00	57.00
CCP	13.46	13.46	13.29	13.29
LDP	14.24	14.24	13.94	13.94
DP	29.78	29.78	29.77	29.77
Crop Insurance (MPCI, $)	4.73	4.60	5.20	5.07
Hedging ($)	0.08	0.08	0.48	0.48