THE IMPACTS OF RISK AVERSION, TIME PREFERENCE, AND INTETEMPORAL SUBSITITUTABILITY ON FARMERS' RISK MANAGEMENT BEHAVIOR

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Abstract

This paper applies the generalized expected utility (GEU) approach developed by Epstein and Zin (1989, 1991) to dynamic agricultural risk analysis. We explore the impacts of alternative preference parameters of farmers including of risk aversion, time preference, and intertemporal substitutability on their optimal risk management portfolio selection. Furthermore, we extend the GEU model by introducing a welfare measure, the equivalence variation, and investigate the impacts of U.S. government programs and market institutions on farmers' risk management decisions. We find farmers' optimal hedge ratio is sensitive to changes in the preferences and the effects of these preferences changes are intertwined. The policy impact analysis shows government payment programs has a greater effect on farmers' optimal choice than crop insurance and crop insurance outperforms hedging. Both crop insurance and government payments are influential to farmers' welfare improvement.

Keywords: intertemporal preferences, policy, GEU, farmers' risk management

The Impacts of Intertemporal Preferences and Policy Alternatives on Farmers' Risk Management Behavior

I. Introduction

Farmers' intertemporal consumption preferences are heterogeneous in that they have different risk attitudes, different time values, and different substitution preferences towards consumptions at different periods. The risk management resources in the US also changes over time as new policies and market institutions are constantly developed to improve the risk protection features to farmers. Among most commonly used risk management instruments are futures contracts, crop insurance programs and government commodity payment programs. These programs are revisited and adjusted every few years. The changes in these programs tend to make farmers adjust their expectations accordingly, and affect farmers' intertemporal decision making and strategy construction.

Farmers have been traditionally hedging in the commodity futures markets to seek price risk management. Hedging has a long history of being one of the most available and direct risk management tools for farmers. Since 1980s, farmers' usage of crop insurance products has increased largely as the Federal Crop Insurance Corporation started to provide Multi Peril Crop Insurance (MPCI), and later included other yield and revenue insurance products. Now crop insurance has become the most popular tool for the U.S. crop producers.

Recently, the federal government increased its involvement in providing and facilitating risk protection instruments to farmers. The 2002 Farm Bill has included three major programs to farmers: loan deficiency payment (LDP), direct payment (DP), and counter cyclical payment (CCP). The LDP and DP are inherited from the 1996 bill, and the CCP is newly added to the

2002 bill as a revision and resumption of the deficiency price support program in the 1990 bill. These payment programs work as price insurance but without premium charge.

Farmers' decision making and welfare are based on individual preferences in a given risk and policy environment. In a generalized expected utility (GEU) maximization model proposed by Epstein and Zin (1989) and Weil (1990), a class of recursive preferences was developed over intertemporal consumption sets. The constant elasticity of substitution (CES) form of the objective utility function allows risk aversion to be disentangled from intertemporal substitutability of consumption. Including time preference, a decision maker's utility is subject to changes in three types of preferences, and intertemporal decisions are conditional on specific combinations of these preferences. According to the model, uncertainty about consumption resolves over time and preference orderings generally imply non-indifference to the way how it resolves. An earlier (later) resolution of consumption is generally preferable when risk aversion is greater (less) than intertemporal substitutability. The GEU model provides us a possibility to study farmers' intertemporal risk management decisions with consideration of their preferences toward risk, time, and inter-year substitution of consumption. It also allows us to examine the impacts of changing U.S. agricultural policies on farmers' behavior at the same time.

The objective of this paper is to investigate the impacts of intertemporal preferences towards risk, substitution, and time, as well as market institution and policy alternatives, on farmers' risk management behavior in a dynamic GEU maximization setting. The rest of the paper is organized as follows. Section II gives a general review of literature. Section III introduces the data source and method used for estimation, simulation, and optimization. Section IV discusses the results on impacts analyses and Section V summarizes the findings and draws conclusion.

II. Previous Research

Analyses of decision maker's preferences has drawn attention in literature and been examined in many empirical economic studies (Hansen and Singleton, 1982, 1983; Hall, 1988), but most of the research had focused on identifying or estimating the preferences rather than studying the role of the preferences in making optimal decisions. Similarly in agricultural economic literature, focuses have been put either on estimation of risk and time preferences (Saha, Shumway, and Talpaz,1994; Chavas and Holt, 1996; Barry, Robinson, and Nartea,1996) or on risk management analyses under certain given preferences (e.g. Coble, Heifner, and Zuniga, 2000; Mahul, 2003).

So far government programs have been studied either singularly (Miller, Barnett, and Coble, 2001) or in a portfolio setting together with other instruments (Makki and Miranda, 1998; Zuniga, Coble, and Heifner, 2001). However, studies focused specifically on government programs and risk management are limited (Krause and Brorsen, 1995; Knutson, et al, 1998; Goodwin, 2001). From the few studies that include government programs in risk analysis (Turvey and Baker, 1990; Hennessy, 1998; Hanson et al, 1999; Ke and Wang, 2002), new policies such as the CCP have not been thoroughly investigated with other risk management tools. Wang, Makus, and Chen (2004) detected some crowding-out effects of the government programs on hedging.

Studies on measuring farmers' welfare change have been found in literature but quite few concentrated on farmers' welfare changes under specific 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 to the Pacific Northwest dryland grain producers.

All the temporal and intertemporal research discussed so far was based on the traditional expected utility (EU) maximization framework. Not until Epstein and Zin developed GEU, the decision maker's risk aversion had to be intertwined with intertemporal substitutability. In their empirical paper, Epstein and Zin (1991) found the elasticity of substitution is typically small (always less than one), while the risk preference defined as one minus constant relative risk aversion (CRRA) does not significantly differ from zero (CRRA close to one). As the only one who has applied GEU approach to agricultural risk analysis, Lence (2000) estimated U.S. farmers' time preferences and risk attitudes based on historical data from 1936 to 1994. The estimates are consistent with theory. Farmers have time preference around 0.95, substitution parameter for consumption around 0.9, and CRRA greater or close to one. In particular, farmers have become less risk averse over time.

Again, apart from its ability to estimate preference parameters, the other sides of GEU, like sensitivity of dynamic optimization solutions with respect to decision maker's preferences have not been explored. Adaptation of this framework specifically to agricultural risk management has not been touched yet. This paper will make an effort to contribute to the literature in this perspective.

III. Model

The models used in this paper are adapted from the GEU model initiated by Epstein and

Zin (1989). The basic theoretical framework is defined as a decision maker to maximize his/her CES expected utility of consumption, under a set of preferences in risk, time, and intertemporal substitution of consumptions.

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

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 relative risk aversion coefficient (CRRA). A smaller α indicates greater risk aversion. ρ ($0 \neq \rho < 1$) denotes the intertemporal substitutability, equal to $(1-\sigma)^{-1}$ with σ denoting elasticity of substitution. Early (late) resolution would be preferred if $\alpha < (>) \rho$. C_t denotes the current consumption which is a function of 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.

Applying the GEU framework to the optimization problem of interest for a representative wheat grower, we define the current consumption as a net income from production and risk management using crop insurance, futures hedging, and government programs.

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

where NC_t is the net income from producing and selling the crops in the cash market; CI_t is the net income from crop insurance; FI_t is the net income from hedging in the futures market; and GI_t is the net income from government programs. Hedge ratios and insurance coverage ratios are endogenous choice variables to be determined at the optimum, based on information available at t. Specifically,

(2.1) $$NC_t = P_t Y_t - CP_{t,}.$$

P_t and Y_t represent cash prices[1] and yields for winter wheat at harvest time, with CP_t as the cost of production;

(2.2) $$FI_t = x_{t-1}[F_t - E_{t-1}(F_t)] - TC_t.$$

F_t is the futures price at time t and the futures market is treated as unbiased. x_{t-1} is the hedging amount determined at beginning of the current period, or the end of the previous period, and is positive for a long position and negative for a short position. It is in bold face to indicate the status of a choice variable. TC_t is the transaction cost of trading futures.

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

P_b is the base price used to calculate the indemnity from crop insurance with Pre_t as the premium[2]. z_{t-1} is the coverage selection of the insurance.

(2.4) $$GI_t = DP_t + LDP_t + CCP_t$$

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

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

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

DP_t is direct payment program which gives a constant payment to farmers, LDP_t is the loan deficiency payment, and CCP_t 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_t, LDP_t *and* CCP_t is specified according to the 2002 Farm Bill and calibrated to the Pacific Northwest (PNW) wheat growers, the chosen area for empirical analysis in this paper.

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[1] Cash price is a "net" price after transportation cost is deducted from the Portland price.

[2] The premium of the current year crop insurance is paid during the harvest time.

To evaluate the alternative risk management instruments through the welfare level of the farmer when using them, we adapt the model by introducing a welfare measure, equivalent variation (EV). We choose EV to evaluate alternative risk management portfolios, relative to cash sales, under certain specified preference sets. Here EV is the 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. EV can be calculated by solving:

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

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 *NI* in (2) for that period.

IV. Data, Simulation, and Model Calibration

Data Source

We select a representative farmer from Whitman County in Washington State. The County is located in the east central border of Washington and is part of the highest yield area for soft white wheat. Historical data for soft white wheat yield, cash price and futures price are collected and examined to identify time series patterns for simulation. The yield data are obtained from the U.S. Department of Agricultural National Agricultural Statistics Service (http://www.usda.gov/nass/) and Risk Management Agency (RMA) at a yearly base for 1939-2003.

Annual September wheat cash and futures prices from 1973 to 2003 are selected to represent harvest prices. September is also the time the farmer makes decisions on the following year's hedging and insurance participation, and prepares for planting next year's winter wheat.

For cash price, we take the monthly average of daily September prices at Portland spot market. They are retrieved 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 for farmers' hedging. We pick the mid-week price of the first week (Wednesday or Thursday) of September to develop our dataset.

Estimation and Simulation for Yields and Prices

Since we have long-term annual data, time variation is mainly reflected in the mean level due to the low-frequency feature of the data. From the time series plots of Whitman County (Figure 1) for 1939 to 2003, an upward trend is visible for the past 63 years. Yield is usually influenced jointly by the stochastic weather and technology changes. The randomness from weather is usually captured by the disturbances, but the randomness from technology advances is reflected in the trend. Similarly for wheat cash and futures prices (Figure 2), the unpredictable balance of supply and demand determines the price levels and inflation associated with the macroeconomic trends further influences prices.

To accommodate the possible stochastic trend in addition to disturbances, we fit a stochastic trend model (Moss and Shonkwiler, 1993) to our yield and price data. The model follows the Kalman Filter process and consists of a measurement equation,

(5) $$y_t = \mu_t + \varepsilon_t$$

and two transition equations

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t$$

$$\beta_t = \beta_{t-1} + \varsigma_t$$

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; $\begin{pmatrix} \eta_t \\ \varsigma_t \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\eta^2 & 0 \\ 0 & \sigma_\varsigma^2 \end{pmatrix}\right)$ 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. μ_t, the mean component of the dependent variable, is shown as a random walk with a drift. Therefore the final generalization shows the mean of the dependent variable grows at a random rate.

Model fitting results by maximum likelihood estimation programmed in GAUSS are listed in Table 1. It shows that the stochastic trend does not exist in Whitman County wheat yield, for σ_η and σ_ς are insignificant, but does in Portland cash prices and CBOT futures prices. The plots of predicted values versus actual values show that in general the stochastic trend models fit the data well in capturing the long-run variation in the trend for wheat prices (Figure 3). The 95 percent confidence intervals have included nearly all the realizations. A deterministic time trend model is fitted to Whitman yield after checking for autocorrelation[3].

Based on the fitted linear time trend and stochastic trend models, an empirical distribution with 2000 samples is simulated for each of the next five years and for Whitman yield, Portland cash prices, and CBOT futures prices. All the series are first simulated independently without autocorrelations or contemporaneous correlations. For cash and futures prices, we then impose a correlation of 0.871 and keep yields and prices uncorrelated based on historical data. Table 2 gives the descriptive statistics of the simulated data.

[3] A more detailed discussion of the properties and the model fitting of stochastic model for PNW wheat production data can be found in Du and Wang (2004).

Parameter Calibration

Since Lence (2000) used a similar dynamic GEU model to estimate the US farmers' preference parameters based on aggregated consumption and asset return data for three periods in the history. We use his estimated values for 1966-1994, $\alpha = -0.13$, $\beta = 0.89$ and $\rho = 0.9493$, as the base for the representative farmer.

In the determination of current consumption (or net income) level, transportation cost between the Portland spot market and Whitman County is set at \$0.50 per bushel; production cost is determined as \$203 per acre for Whitman County (Hinman and Baldree, 2004); 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 (actuarially fair premium level) and 1 minus the regressive subsidy rate specified by current policies.

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. The target price (P_T) for CCP is \$3.86 per bushel. These parameters are based on the current US farm policies.

V. Results

In the GEU maximization setting, we examine the impact of risk aversion, time preference, and intertemporal substitutability on farmers' optimal choice of hedging and crop insurance participation, and the impacts of market institution and government programs, referring to the parameterization of futures and crop insurance payments, and availability of certain programs, on farmers' optimal portfolio structure. The policy impact is not only reflected in the direct choice of 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 assume the set of policy and market risk management tools available to the farmer is the same while allowing his/her preferences to vary. Similarly, we assume the farmer keeps the base preference set constant when the available risk management tools change.

Impact on Optimal Risk Management Portfolio from Intertemporal Preferences Changes

We solve the GEU optimization problem by dynamic programming using GAUSS for risk aversion parameter ranging from -5 to 1 (Arrow-Pratt CRRA 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 only change 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 to only assign feasible values within the range.

At this time, the farmer can choose from hedging in commodity futures market and a no-load MPCI yield insurance. He/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 4 displays how hedge ratios in the next five years respond to risk aversion changes[4]. In general, the farmer's optimal hedge ratios are very sensitive (between 35% to close to zero) to α from around -3 to close to 1. As for the evolution of hedging ratios for each year, it shows a similar pattern during the five years. All ratios[5] first increase slowly when the farmer's risk aversion varies at high level (α from -3 to -1 or CRRA from 4 to 2), and then switch one by one to decrease as risk aversion gets smaller. Specifically, the turning points are at α equal to -2, -0.8, -0.6, 0.1, and 0.6 for the first until fifth year, respectively. After the turning point, hedge ratios generally decrease at a faster rate. The post-turning point part of the pattern is consistent with the corresponding risk aversion variation. That is, less risk averse people tend to hedge less. The pre-turning point part, however, it is still possible to happen. Similar pattern has been seen in empirical dynamic hedging research (e.g. Martinez and Zering, 1992).

For a specific risk aversion level, the optimal hedging 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 much risk averse (α greater than 0.2). For farmers who have mild risk aversion, the pattern is mixed. Depending on the specific point he/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 would want to resolve risk as early as possible by hedging more in early years, and vice versa. But with ρ fixed, the increase in α not only reduces risk aversion but also may transfer a preference for early resolution into a preference for late preference. This relative change in values among the two types of preferences is probably the reason for hedging pattern to turn at certain points. Similar

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

[5] Here we mean the magnitude not the sign.

observations will also exist in the sensitivities of time preference and intertemporal substitution.

Time Preference

From Figure 5 we notice that first of all, the hedge ratios are sensitive 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 25% and 30%. Ratios for the second to fourth year only change from 30% to 32%, and ratio for the fifth year has only minor changes within one percentage point. Second, hedge ratios may also have a convex pattern but only the turning points for the first two years fall in the feasible range of β, which are at $\beta = 0.3$ and 0.5 respectively. Third, for last year when farming is about to end, the hedge ratio is always around 25.5% for all β levels, quite away from other years especially those for the second to fourth year.

As β is defined as time discount factor, by postponing consumption to next period, the farmer only gets a fraction (β) of the utility that he/she would get by consuming an equal amount at current period. Therefore with a higher β, the farmer will have a greater propensity to consume in the future instead of now. In our case, as β becomes bigger, the farmer tends to trade more consumption for hedging. The hedge ratios are increasing in percentage throughout the third until fifth year over all β values and 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 his/her 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 6. Hedging percentages are primarily increasing in ρ, and again the pattern changes until ρ reaches the turning point as in the first and second year.

When the value of ρ grows, the substitutability of consumption across years becomes bigger. Therefore optimal choice of hedging shows a substitution pattern among the first four years, especially reflected in the third and fourth year. For a range between -5 to 0.8, a change in ρ for 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 substitution effect, it can be seen that hedge ratios for the first four years change the ranks 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 larger effect on hedge ratio variation than the other two. Each of the preferences seems to have a different pattern of impact. But even in the separate analysis, the effect is often intertwined with influence from the other preferences due to relative value changes among them.

Impacts on Optimal Risk Management Portfolio from Market and Policy Changes

Since transaction cost is the main cost farmers pay for risk management, we consider two major cases, \$0.017/bushel vs. \$0 transaction cost as shown in Table 3 and 4. 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 base scenario we reduce one instrument at a time to study the marginal effect of that instrument.

Impacts of Transaction cost

Table 3 presents the results the farmer pays for buying futures contract. Note that all hedge ratios are in short position but we only present the level (magnitude) of the ratios in the table for simplicity.

By comparing the upper panel with the lower panel, we can see transaction cost plays an active role in hedging decisions. For instance, hedge ratios increase from 0.25~0.32 to 0.27~0.42 after the $0.017/bushel transaction cost is removed for the first portfolio. This is usually more obvious in earlier stages of hedging than in later stages.

Impacts of Hedging, Crop Insurance, and Government Programs

We design five risk management portfolios for the farmer. Apart from optimal hedge ratios and crop insurance ratios, we also compute the cash value of each portfolio, i.e. EV, using (3). EV 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 from the most complete set of risk management tools. In the base scenario under $0.017/bushel transaction cost (Table 3, upper panel), optimal hedge ratios are in a range of 25% to 32%. The cash value of this full portfolio is $108.49, the highest among all portfolios. As we decrease the availability of government programs by taking away CCP first and then LDP, hedge ratios increase largely from around 30% to 40% then to around 78% to cover the extra risk. Correspondingly, without the support of free government subsidies, the cash values of the portfolios also decrease a lot by more than 50% from $108.49 to $51.13. When we further take away DP, hedge ratios do decrease instead, which is due to the farmer's budget on transaction cost if comparing it with the scenario when there is no transaction cost (Table 3, lower panel).

As we take away the payment programs one by one, the variation of EV discloses information about the specific values of each program. For example, the difference between the first two portfolios indicates a value of $13.35 to the farmer. We compute all these values and include them in Table 4. Among three of the government programs, DP has a highest value, while CCP has similar value as LDP. In total the government programs account for more than half of the total value of base portfolio which is $57.36.

When we further take away DP, the farmer only relies on hedging and insurance. He/she can still find a hedging path to manage risks but can only achieve a lower welfare level (EV=$51.13). The value of hedging can be calculated when we consider another portfolio of only crop insurance and government programs. The difference between the EV of this last portfolio and that of the first portfolio yields $1.50. It is not too surprising considering farmers' low participation rate in reality, but still impressive to find out as the value is so 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 we only include yield insurance so far, the value of hedging may go even lower if we include revenue insurance which also covers price risk. Correspondingly, when the value of CI is computed by subtracting the total government programs' value from this last value, it turns out to be as high as 49.53, almost covering the other half of the full portfolio value. This indicates that to the default farmer, an income transfer in terms of subsidy is more valuable than a risk reducing feature in a non-subsidized instrument like hedging.

Next we take off the transaction cost so hedging has no cost to the farmer at all. We see from Table 3 that optimal hedge ratios generally increase significantly, especially for the first two portfolios. The rate of the increase slows down when hedge ratios get close to around 79%. The values of the portfolios also increase slightly when the farmer saves money on hedging. The optimal insurance coverage ratio still keeps at 85%, implying that the gain from saving on hedging still cannot afford the possible loss from lowering insurance coverage.

The EV values of each insurance tools change slightly too (Table 5). The value of hedging goes up by about 35%. The insurance and government programs have slightly changed cash values. Despite that, the ranking of the values for these tools stays the same, that is, government programs (DP + LDP + CCP) > CI > hedging.

VI. Concluding Remarks

We investigate the impacts of intertemporal preferences, hedging and crop insurance costs, and U.S. government payment programs on a PNW wheat producer's dynamic risk management behavior. By using the GEU model, we solve the dynamic optimization problem numerically based on simulated yield and price data for 2004 through 2008.

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. Results imply 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 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.

The impacts of market institution and policy alternatives are more straightforward. Transaction costs of hedging negatively affect optimal hedge ratios, and reduce the farmer's welfare level. Among the three major risk management tools, hedging has very limited contribution to the welfare improvement compared to the heavily subsidized crop insurance and government programs. In terms of the ranking of the value of these tools, the government programs (DP + LDP + CCP) are in total ranked higher than yield insurance and than hedging. MPCI has greater value than DP, LDP, or CCP separately, but less than them combined. Among the three government programs, DP is greater than LDP and CCP, and the values of LDP and CCP are close to each other for this representative farmer.

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Figure 1. Historical Soft White Wheat Yields in Whitman County, Washington (1939-2003)

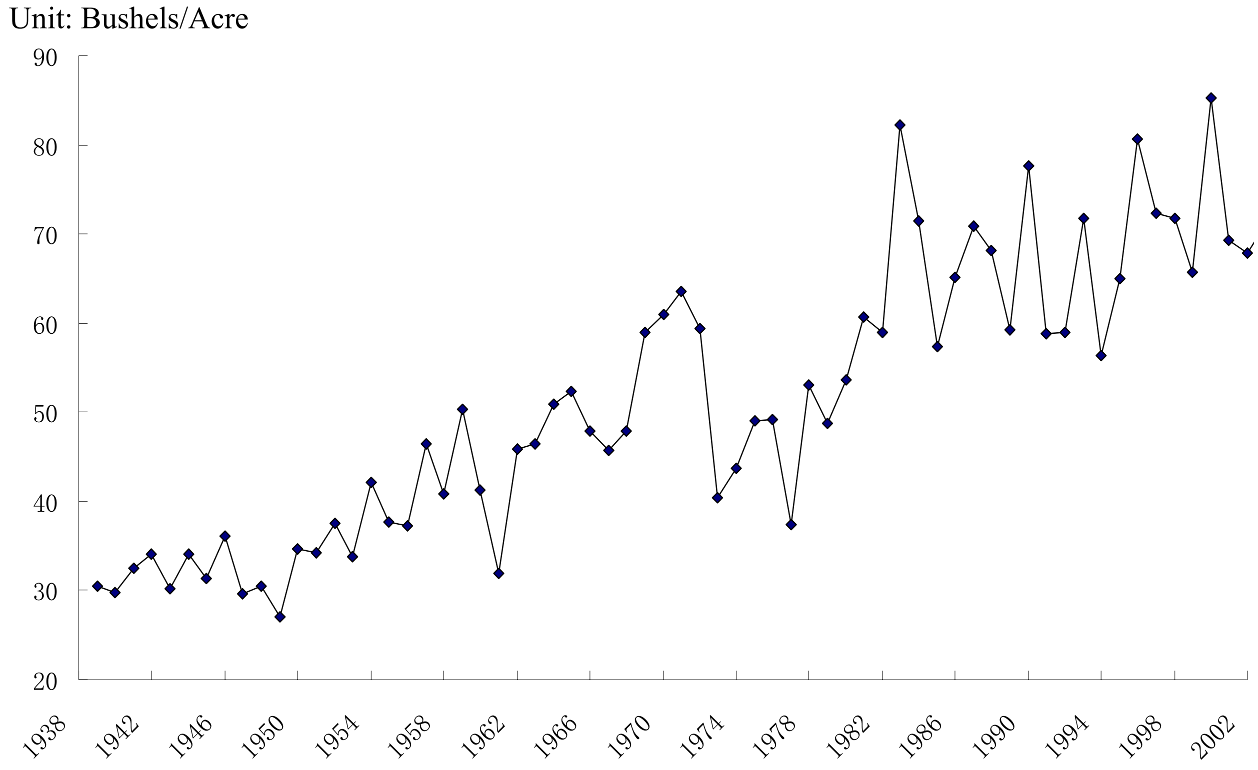

Figure 2. Historical Wheat Cash and Futures Prices (1973-2003)

Unit: Cents/Bushel

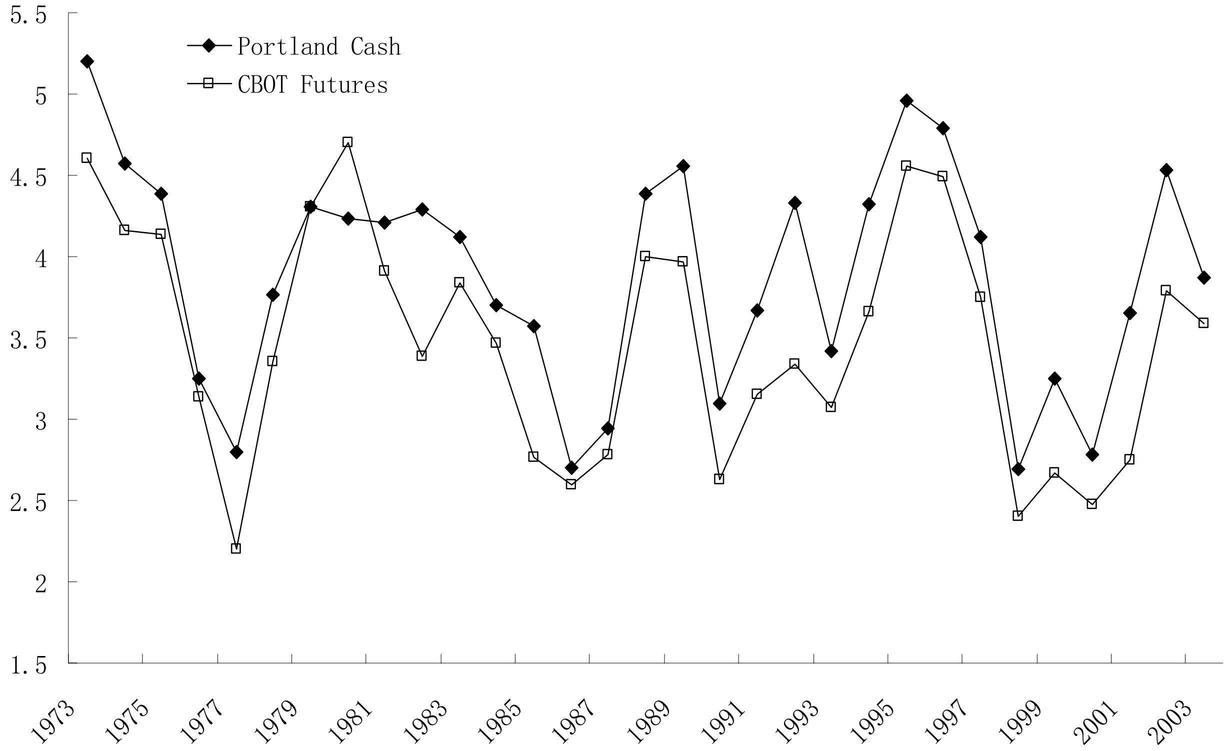

Figure 3. Stochastic Trend Model Fitting of Wheat Cash Prices

Predicted Vs. Actual 1973 to 2003

Unit: Cents/Bushel

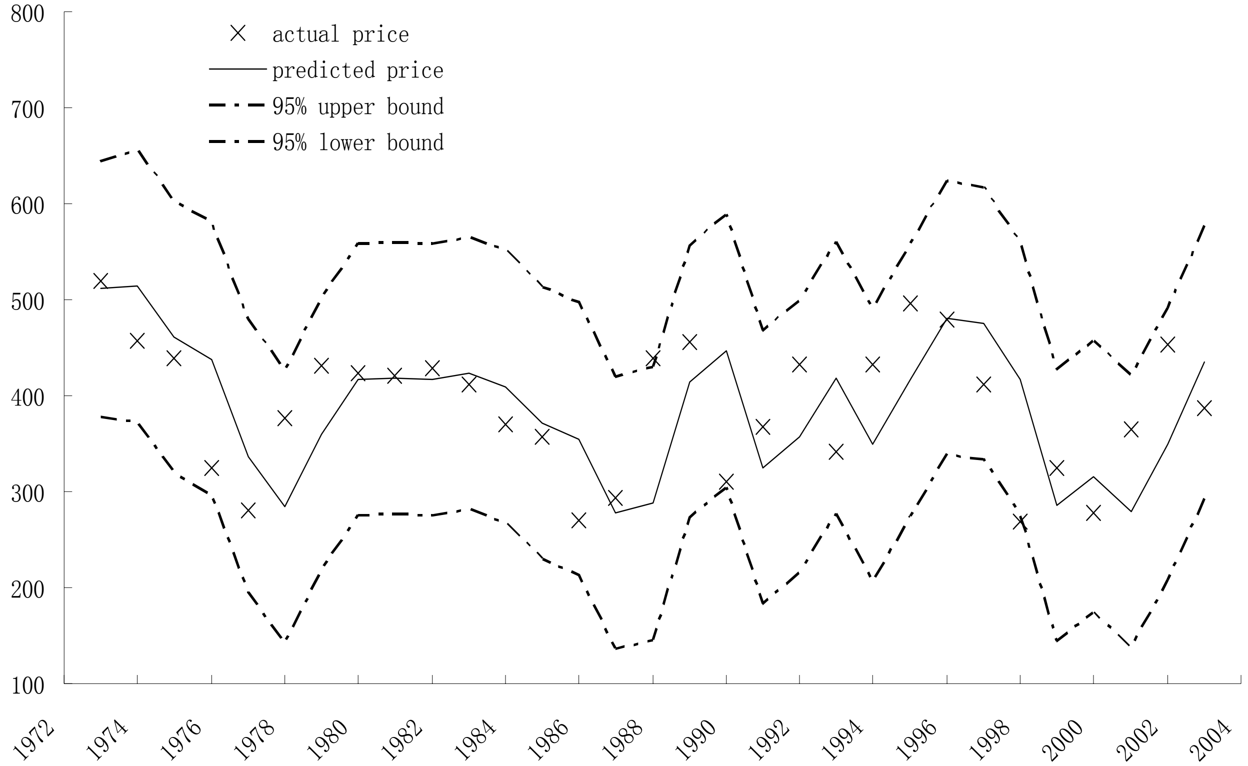

Figure 4. Sensitivity of Optimal Hedge Ratios in Response to Risk Aversion

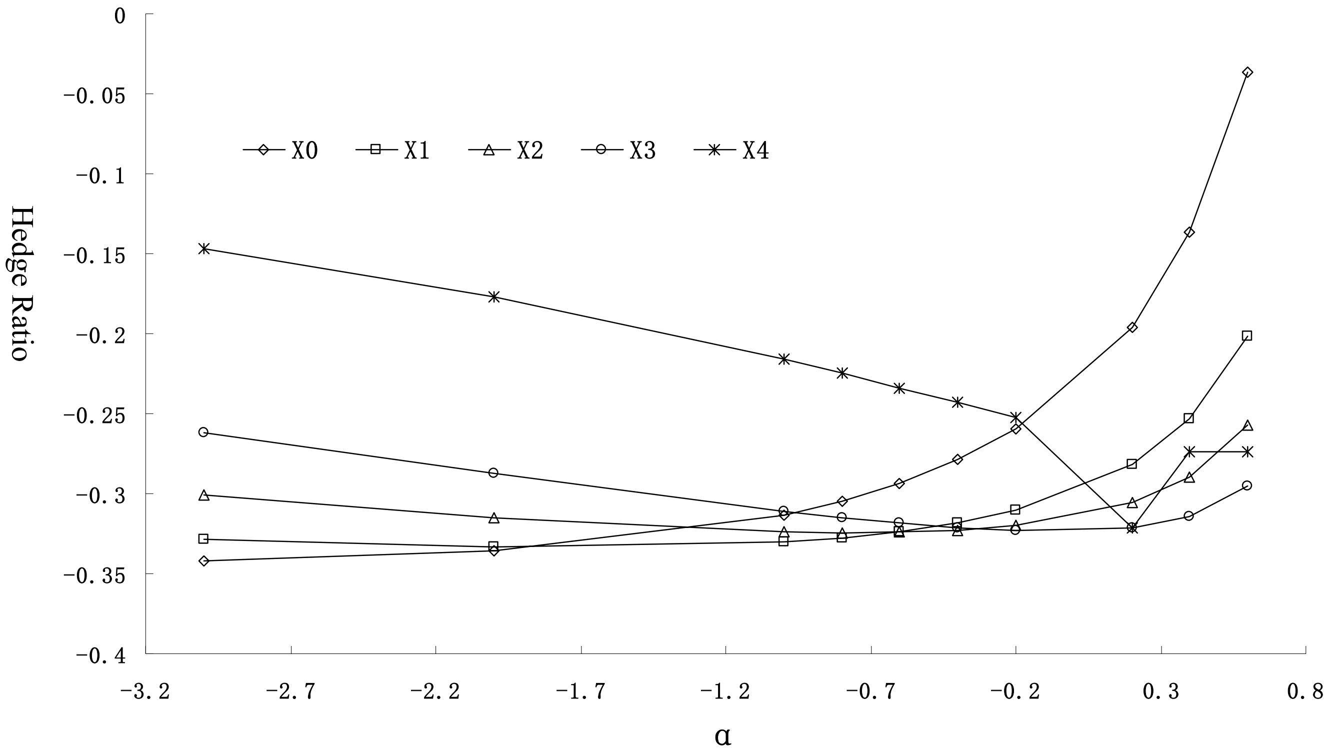

Figure 5. Sensitivity of Optimal Hedge Ratios in Response to Time Preference

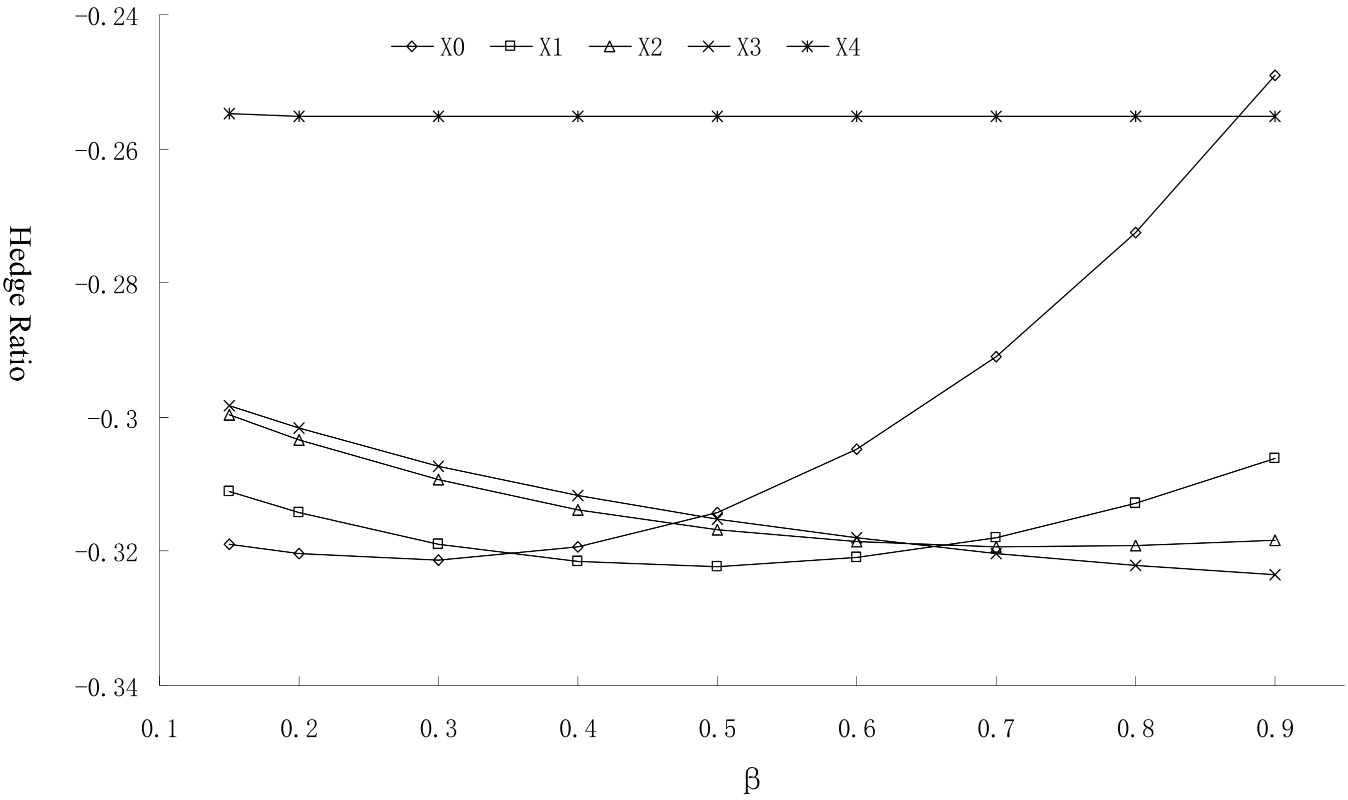

Figure 6. Sensitivity of Optimal Hedge Ratios in Response to Intertemporal Substitutability

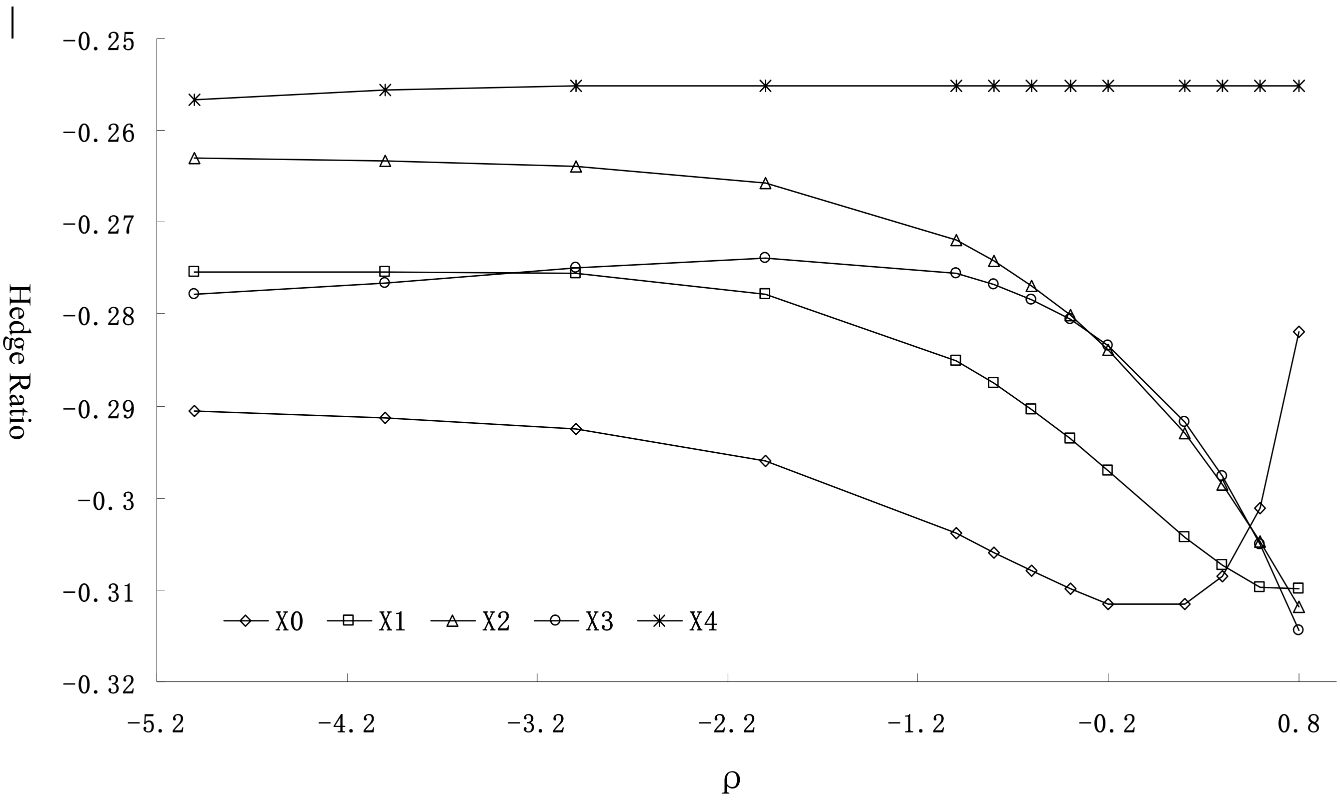

Table 1. Stochastic Trend Estimation of Yield and Price Distributions

(Normal distribution)

Parameter	Whitman Yield	Cash Price	Futures Price
μ_0	27.29**(3.63)	515.06**(72.91)	463.89**(70.12)
β_0	0.73 (1.00)	-3.92 (11.64)	-3.40 (12.67)
σ_ε	7.13**(0.63)	27.06 (33.23)	0.01 (0.46)
σ_η	0.00 (0.15)	62.24**(25.56)	68.90**(8.75)
σ_ς	0.00 (0.03)	0.00 (0.37)	0.00 (0.36)

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 the significance at 0.05 level.

Table 2. Descriptive Statistics of the Simulation

Statistics	Whitman Simulated Yield (bushel/acre)					Portland Cash Price (cents/bushel)					CBOT Futures Price (cents/bushel)				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
Mean	75.28	75.93	76.77	77.36	78.24	392.68	386.16	382.32	379.39	376.59	356.02	350.67	349.39	345.95	343.92
Std Dev.	7.26	7.22	7.28	7.06	7.23	66.42	91.02	106.55	121.22	133.68	68.18	95.80	114.89	128.62	143.83
Skewness	-0.01	-0.03	0.02	0.07	-0.04	0.02	0.02	0.06	0.10	0.06	-0.04	0.02	0.10	0.07	0.05
Kurtosis	0.24	0.14	-0.03	0.07	-0.005	-0.05	0.06	-0.06	0.20	-0.12	0.03	0.01	-0.20	-0.26	-0.31

Table 3. Impacts of Market Institutions and Government Policies on Farmers' Optimal Risk Management Portfolio

Alternative Portfolios	Hedge Ratio					Crop Ins. Coverage	EV($)
	2004	2005	*2006*	*2007*	*2008*	*2004-2008*	
			With Transaction Cost				
H & CI & G(DP, LDP, CCP)	0.25	0.31	0.32	0.32	0.26	0.85	108.49
H & CI & G(DP, LDP)	0.39	0.44	0.44	0.44	0.38	0.85	95.14
H & CI & G(DP)	0.78	0.79	0.77	0.79	0.77	0.85	81.59
H & CI	0.00	0.39	0.55	0.66	0.72	0.85	51.13
CI & G(DP, LDP, CCP)	--	--	--	--	--	0.85	106.89
			Without Transaction Cost				
H & CI & G(DP, LDP, CCP)	0.42	0.39	0.37	0.35	0.27	0.85	108.92
H & CI & G(DP, LDP)	0.61	0.54	0.50	0.48	0.39	0.85	95.76
H & CI & G(DP)	0.79	0.79	0.78	0.79	0.77	0.85	81.60
H & CI	0.77	0.80	0.77	0.79	0.77	0.85	51.90
CI & G(DP, LDP, CCP)	--	--	--	--	--	0.85	106.89

Table 4. Evaluation of Risk Management Instruments

Alternative Instruments	$0.017/bushel Futures Transaction Cost	$0 Futures Transaction Cost
Gov't programs (total, $)	57.36	57.02
CCP	13.35	13.16
LDP	13.55	14.16
DP	30.46	29.70
Crop Insurance (MPCI, $)	49.53	49.87
Hedging ($)	1.5	2.03