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Evaluation of Hedging in the Presence of Crop Insurance and Government Loan Programs

by

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Abstract

This research evaluates the interaction of new alternative insurance designs, forward pricing tools and the government revenue protection program while assuming a government loan program is in place. A numerical analysis is conducted using a revenue simulation model that incorporates futures prices, basis, and yield variability. Three crop insurance designs at 75 percent of yield guarantee are evaluated. Optimal futures and at-the-money put option hedge ratios are derived for expected utility maximizing of soybean producers. Sensitivity to loan rate levels are examined. Our results suggest that loan programs profoundly alter the optimal producer strategy.

Keywords: crop insurance, marketing loans, forward pricing, risk, revenue distribution, yield distribution.

Introduction

Recent changes in farm policy, such as the 1996 Farm Act and new forms of crop insurance, have significantly altered the context in which farmers manage risks. The 1996 Farm Act replaced deficiency payments, which like put options provided farmers with larger payoffs when prices were low, with fixed production flexibility payments that are not responsive to shortfalls in farmers' returns. However, it continues to provide protection in the form of loan deficiency payments (LDP) and marketing loans. These payments generally did not occur in the 1996/97 and 1997/98 marketing years because commodity prices were above the loan rate(s). The situation changed in 1998 when prices for wheat, corn, barley, and soybeans fell below loan rates. Since enactment of the 1996 Act, federal farm policy has emphasized governmentally subsidized crop insurance products. In recent years, the USDA/Risk Management Agency (RMA) has offered crop revenue insurance and allowed private insurance firms to develop other revenue insurance products accepted for subsidy and reinsurance.

To date, three different forms of individual revenue insurance have been offered. The acceptance of revenue insurance products has been dramatic, capturing more than 50 percent of the national corn and soybean insurance market. Because the menu of available risk tools is rapidly evolving, crop producers must evaluate the usefulness of alternatives with which they have limited experience. Little is known about how government loan programs and crop insurance affects traditional tools such as hedging prices with futures and options. Revenue insurance subsumes with both price and yield risk, so it is relevant to ask what effect these subsidized insurance products have on optimal use of forward pricing as a risk management tool. This issue demands consideration of the interactions of price and yield risk management and the joint optimization of insurance and hedging decisions.

Much of the literature on producer hedging decisions has assumed non-stochastic yields and a single risk market, either futures or options (Myers and Thompson; Hanson and Ladd). McKinnon showed the minimum-variance hedge for a crop decreases as the yield-price correlation becomes more negative and as yield variability increases relative to price variability. Heifner and Grant provided minimum-variance hedge ratio estimates using county yield data. Miller and Kahl

showed that the estimates derived from farm level data may deviate substantially from those estimated with more aggregate county yield data.

Lapan and Moschini have addressed the hedging decision in the more general expected utility framework, incorporating yield, price, and basis variability. They found that expected utility maximizing hedge ratios depend on risk attitudes and potentially differ from minimum-variance ratios.

Other recent work has examined both futures and options as risk management instruments. Lapan, Moschini and Hanson examined futures and options in an expected utility framework with one source of risk - price variability. They concluded that futures were preferred to options when prices were unbiased. Sakong, Hayes, and Hallam allowed for price, basis, and yield risk in an analytical model, which suggested that producers underhedge in futures and purchase put options. Moschini and Lapan also found options entering the optimal portfolio, with both papers finding the optimal strategy being conditional on yield-price correlation. Hanson, Myers, and Hilker have specifically addressed the implication of censoring the price distribution on optimal hedging. Their findings suggest a strong effect on the optimal hedge. However, they do not examine the case where crop yield or revenue insurance has been added to the mix.

A natural extension of the previous work is to allow for both yield and price risk markets in a model of optimal hedging. Recent literature has started to address the components of revenue variability and incorporate the instruments that are choice variables in a preseason risk management decision process. Poitras addressed the analytical issues associated with censoring instruments, such as options or insurance, when producers have preferences for positive skewness. The combination of price and yield futures hedging has been addressed by Li and Vukina for corn in North Carolina; Tirupattur et al. for soybeans in Illinois, and by Heifner and Coble (1996a) for corn across the United States. Dhuyvetter and Kastens examined combinations of hedging with yield insurance and with a particular form of revenue insurance - Crop Revenue Coverage (CRC). However, they do not directly address hedging levels, but rather show comparisons of mean and variance of returns. Wang et al. examined the joint use of hedging with either individual yield or area yield insurance. Comparisons were made between producer willingness to pay for alternative insurance designs optimized with futures and options. However, optimal hedge levels were not reported.

Coble, Heifner, and Zuniga (CHZ) have investigated the analytical relationship between various insurance designs and hedging for corn in four geographically diverse regions, showing that the form of insurance may have a significant impact on forward pricing. However, that analysis looked at only short futures positions and put options and did not consider the potential effect of loan programs. This study is a natural extension of the previous mentioned research. It relaxes constraints on positions and options that (CHZ) imposed, including allowing long futures positions as possible optimal position. The analysis is accomplished by evaluating the differences in certainty equivalent gains and optimal hedge ratios between different risk management tools for soybeans in U.S.. This is done by considering the effect of the government revenue protection program for different levels of loan rates relative to future market price. The analysis for

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soybeans is replicated across three different regions, one from the South and two from the Midwest. The diversities on yield variability and yield-price correlation that the different regions provide allow comparison of how these differences affect outcomes.

The Behavioral Model

The planting time optimization behavior of a producer with yield insurance and the opportunity to hedge is examined. The producer is assumed to maximize expected utility according to a von Neumann-Morgenstern utility function defined over end-of-season wealth (W) and which is strictly increasing, concave, and twice continuously differentiable. For ease of illustration, the price basis (local cash price - futures price) is omitted from the analytical model such that price and yield remain as the two stochastic variables. Later numerical simulations relax the distributional assumptions and incorporate basis risk.

Intuitively, the loan deficiency payment is similar to a free put option. Thus, an analogy can be made to an increase in the loan rate and raising the strike price of a put option. Since, the cost is fully borne by the federal government, the benefits increase rapidly as the portion of the price distribution subsumed by the loan rate increases. Two additional characteristics of the loan program should also be noted. First, the loan program pays on the actual yield and not on predetermined quantities as do hedge contracts. Production risk interacts with the loan rate differently than with futures and options. Because of yield uncertainty, the producer is faced with the possibility of forward pricing more than is actually produced which leaves the producer essentially in a speculative position on the portion of the contract that is not produced. Conversely, if the producer forward prices less that the quantity produced, the unhedged portion is left exposed to price risk. With the loan program these problems do not exist. Secondly, loan rates are generally fairly stable over a period of years and can be argued to provide longer term price risk protection than offered by futures contracts

Loan rate policies have the effect of censoring the farmer's price distribution. If the realized harvest price p_1 is below the loan rate p_L, the obtained yield will be valued at a guarantee loan rate price. However if p_1 is above p_L the farmer can sell production at the harvest time price. Thus, the producer observes:

(1) $\qquad p_L \qquad$ if $p_1 < p_L$, and

$\qquad\quad p_1 \qquad$ if $p_1 \geq p_L$

End-of-season wealth is then conditional on whether loan rates are made and may be written as follows:

if $p_1 < p_L$,

(2) $W_L = W_0 + A[p_1 y - C + y(p_L - p_1) + h(p_0 - p_1)]$

Otherwise,

(3) $W_H = W_0 + A[p_1 y - C + h(p_0 - p_1)]$

where W_H and W_L denote end of period wealth associated with yields above and below the yield guarantee respectively. Initial wealth is represented by W_0 and crop acres by A. Crop prices are denoted by p. Price is subscripted by 0 to identify a known planting time expectation of harvest price and subscripted by 1 to denote the stochastic harvest-time price. Non-stochastic production cost is denoted as C. The quantity of the crop forward priced with a futures hedge is denoted by h. These contracts are rigidly defined as to delivery time, quality, and quantity. A growing crop can be hedged by selling futures contracts equal to a portion of the expected crop before harvest and purchasing an equal number of futures contracts later when the actual crop is sold.

Assuming stochastic harvest-time price and yield be random variates, where y is defined over the bounds $[0, \bar{y}]$, and p_1 is defined over $[0, p_L]$ for W_L and over $[p_L, \bar{p}]$ for W_H. Equation (4) shows the objective function of a producer choosing the optimal level hedge level.

(4) $\underset{h}{Max}L = \int_0^{p_L} \int_0^{\bar{y}} U(W_L) f(y, p_1) dy dp_1 + \int_{p_L}^{\bar{p_1}} \int_{y_g}^{\bar{y}} U(W_H) f(y, p_1) dy dp_1$

In this model, the producer's choice variable (h) represents the quantity of production to hedge given that the producer is eligible for the loan rate government revenue protection program. The first order condition is:

(5) $L_h = \left[\int_0^{p_L} \int_0^{\bar{y}} U'(W_L)(p_0 - p_1) f(y, p_1) dy dp_1 + \int_{p_L}^{\bar{p_1}} \int_0^{\bar{y}} U'(W_H)(p_0 - p_1) f(y, p_1) dy dp_1 \right]$

The effect of a change in loan rate (p_L) on the optimal hedging was also derived using the Leibnez's rule. The effect may be written

(6) $\dfrac{\partial h}{\partial p_L} = \dfrac{Lh_{PL}}{L_{hh}} = -\dfrac{1}{L_{hh}} \left[\int_0^{\bar{y}} \int_{P_-}^{P_L} U''(W_L)(p_0 - p_1)(y) f(y, p) dy dp \right]$

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This equation (6) shows a negative relationship of the optimal hedging level in response to a change in the loan rate. The right hand side denominator L_{hh} is assumed to be negative because $\partial^2 L/\partial h^2 < 0$. The second derivative of the utility function $U''(W_L)$ takes the assumed sign of < 0. The term $(p_0 - p_1)$ is positive because p_0 is assumed to be equal to $E(p_1)$. Given that the upper bound of integration p_L is not equal to $\bar{p}$, then $E(p_1| p_1 < p_L)$ will be less than $E(p_1)$. Yield is obviously > 0. The overall outcome for the portion inside the bracket is then negative, which with the negative L_{hh} numerator we have an overall positive sign. Thus, the optimal hedging level reaction to a change in the loan rate is negative. While intuition suggest loan programs and prices substitute for each other, this result shows that the degree of substitution is conditioned on yield. That is the degree of substitution is positively related to the yield level, which is not obvious without comparative statics analysis.

Numerical Model

In our numerical analysis, four insurance products are modeled to reflect the insurance products that are now appearing in the crop insurance market. Two of the designs examined are yield triggered, while the second two are revenue triggered. A brief explanation of each instrument follows.

Multi-peril crop insurance (MP), is the traditional crop yield insurance program that is generally available for major crops in most states. MP indemnifies yield losses when an insured acreage's yield falls below the guaranteed level. These losses are valued at a preseason price selected at sign up time. The indemnity equation for MP may be written as follows:

$$(7) \qquad NI_{MP} = \boldsymbol{d}f_0 * Max[\boldsymbol{g}y_0 - y_1, 0] - R_{MP}$$

where NI is the net return to insurance purchase, f_0 is the preseason price for a harvest month futures contract, $\boldsymbol{g}_y$ is the critical yield ratio, y_0 and y_1 are respectively the expected farm yield at planting and realized yield at harvest[1]. The insurance premium, R, reflects the producer paid insurance premium cost for the policy. The subscript on NI and R denote the type of insurance evaluated.

Since 1997, three types of farm level revenue insurance have been offered to U.S. producers - Crop Revenue Coverage (CRC), Income Protection (IP), and Revenue Assurance (RA). All three of these products insure the gross revenue of the insured crop. The products differ in rate setting procedures and location where they are offered. All three are reinsured and subsidized by the USDA and use harvest month futures prices at sign up and at harvest to compute losses. Because of similarities in design, IP and RA are treated as a single insurance type designated as RI. Equation 8 shows the net return from RI. Here, shortfalls in harvest revenue $(f_1 * y_1)$ trigger losses rather than y_1, as in the case of yield insurance:

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[1] The MPCI price guarantee used for MPCI is based on internal USDA forecasts rather than directly tied to the futures markets. However, preseason futures prices are used here.

(8) $NI_{RI} = Max[\boldsymbol{gf}_0 y_0 - f_1 y_0, 0] - R_{RI}$

The third insurance design is Crop Revenue Coverage (CRC). This insurance design combines the revenue insurance protection of RI with the 'upside' price protection of MVP. Ninety-five percent of the maximum of preseason price expectations or the actual harvest time futures are used to compute the coverage:

(9) $NI_{CRC} = Max[0.95\boldsymbol{gy}_0 Max[f_0, f_1] y_0 - f_1 y_1, 0] - R_{CRC}$

Two forms of forward pricing are modeled; futures hedging and the purchase of put options. The net return for each forward pricing strategy is denoted by *NF*. The net returns from futures marketing are modeled in equation 10. As shown, futures hedging protects against price risk on a given quantity hedged. The futures marketing hedge ratio is represented by $\boldsymbol{a}_F$ and is the proportion of the expected yield which is protected. In this case, the cost of risk protection, R_F, reflects commissions and interest foregone on margin deposits to carry out the hedging transaction.

(10) $NF_F = \boldsymbol{a}_F y_0 (f_0 - f_1) - R_F$

The returns from a put option contract are shown in equation 11. In this case, the put option ratio is represented by $\boldsymbol{a}_P$ and represents the proportion of the expected yield which is covered by options. The option strike price relative to the futures price is $\boldsymbol{g}_f$. The cost of a put option, R_P, includes the option premium, commissions, and interest charges for capital invested.

(11) $NF_P = \boldsymbol{a}_p y_0 * Max(\boldsymbol{gf}_0 - f_1, 0) - R_p$

Equation 12 shows the net return from the loan deficiency payment, which is triggered when the difference between the loan rate and the futures prices at harvest time f_1 is positive, the loan rate is represented by the loan rate ratio $\boldsymbol{g}_{LR}$ times the expected futures price. This difference is paid times the actual yield y_1.

(12) $NLDP = Max[((\boldsymbol{g}_{LR} * f_0) - f_1, 0] * y_1$

Combining forward pricing and insurance results in additional terms added to the end-of period revenue states, which may be written:

(13) $W_{jk} = W_0 + A[p_1 y_1 - C + NI_j + NF_k + NLDP]$

where j represents the alternative insurance design and k the forward pricing alternative and W_{jk} is the wealth at the end of the period.

Stochastic Specification

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The numerical integration model used in the analysis is a function of three random variables, farm yield deviation from expectation, price change from planting to harvest and harvest time basis. At decision time, expected yield, current futures price for the harvest month contract f_0, and the expected harvest time basis are assumed known. Harvest time futures prices are generated assuming a multiplicative shock such that:

$$(14) \qquad f_1 = f_0 * e_1,$$

where $å_1$ is the relative futures price movement from planting to harvest time and assumed to follow a log-normal distribution.

Local harvest time prices are generated as follows:

$$(15) \qquad p_1 = f_0 * e_1 + b_0 + e_2,$$

here b_0 reflects the expected harvest time basis and e_2 represents deviations in the realized basis from the expected basis. Basis risk, e_2, is assumed normally distributed. The expected futures price was set at \$6.00 and for price variability over the growing season at 20%, to represent typical price levels and volatility. The mean and variance for each location were calculated from differences between state average prices received by farmers, as reported by NASS, and monthly averages of futures settlement prices for the month of November over the years 1976-1995.

Farm yield variability is represented by augmenting the potentially non-normal county yield series with information on the difference between county yield and farms in the county. This approach is taken to augment fairly short available farm yield series with the added information available at the county level.

NASS county yield data over the years 1956-1995 was used to estimate each county yield distribution[2]. Technological trend in yields were taken into account by a linear trend estimator using weighted least squares to correct for heteroscedasticity. The variances of farm-county yield differences were estimated by combining 1985-94 farm yield observations provided by the RMA with corresponding county yield observations and pooling all farms in the county. Farms with at least six years of actual yields during the ten-year period were used in the analysis. Farm yield variances by county were estimated as the sum of the estimated county yield variance and the average variance of farm-county yield differences for farms in the county. Omission of covariances is justified by the assumption that farm-county yield differences are, on average, uncorrelated with county yields (Miranda). Given a representative farm for a particular county is being constructed, the mean farm-county yield difference is assumed equal to zero. By construction the acre-weighted average of all farm-county yield differences will equal zero.

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[2] Jerry Skees of the University of Kentucky assembled the county yield observations prior to 1972.

Potential non-normality of the county yield is addressed by using the hyperbolic tangent transformation proposed by Taylor. The transformation to normality involves first expressing the cumulative density as a hyperbolic tangent function of linearly detrended yield, $\tilde{y}$,

$$(16) \qquad F(\tilde{y}) = 0.5 + 0.5 * \tanh\left(\boldsymbol{b}_0 + \boldsymbol{b}_1 \tilde{y} + \boldsymbol{b}_2 \tilde{y}^2 + \boldsymbol{b}_3 \tilde{y}^3 \right)$$

where $F(\tilde{y})$ is the empirical CDF and the $\boldsymbol{b}$'s are estimated with maximum likelihood procedures. We assume third order polynomials for all counties. The hyperbolic tangent polynomial function serves to transform the potentially non-normal data to approximate normality.

Farm yields for a farm with a mean yield equal to the county mean is modeled as $y_f = \boldsymbol{m}_i + \boldsymbol{e}_3$ with $\boldsymbol{e}_3$ defined as:

$$(17) \quad \boldsymbol{e}_3 = \boldsymbol{a} \, (T^{-1} F(\boldsymbol{e}_n) - \boldsymbol{m}_i)$$

where y_f is farm yield, $\boldsymbol{m}_i$ are the expected county yield, $\boldsymbol{a}$ is the ratio of farm yield standard deviation relative to the county yield standard deviation estimated from the variances of county yield and farm-county yield differences, T^{-1} is the inverse of the Taylor transformation and $F(\boldsymbol{e}_n)$ is the standard normal distribution.

Product moment correlations are used to model relationships between the transformed random variables. The correlations between yield, futures price, and basis were estimated using transformed data over the 1975-1995 period.

Certainty Equivalent Gains and Optimal hedging

The certainty equivalent is the amount of certain income that a risk-averse individual finds equally desirable to an alternative random income with a known probability distribution. This measure is useful for comparing alternative strategies for a given farm or location, but comparison between farms and locations may be misleading because they rest on assumptions about wealth and risk aversion. To price forward, a farmer must choose not only the type of contract cash, futures, or options, but also the proportions of the expected crop to sell at different times of the year. When hedging with options, the strike price also must be selected. The optimal amount to price forward occurs at the point where the marginal gain in certainty equivalent revenue declines below the marginal cost of forward pricing. The marginal cost of futures hedging includes commissions, interest foregone on margin deposits, and costs of maintaining credit reserves for meeting margin calls. For options hedging, it includes commissions plus interest on the premium, to the degree that the interest rate the farmer pays or receives at the margin, exceeds the market interest rate that determines the premium.

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<u>Model Simulation</u>

Model simulations are conducted with GAUSS software. Computation of expected values are performed using Gaussian quadrature (Miranda and Fackler).   Because this model contains multiple random variables, higher order quadratures are used where applicable. The accuracy of the gaussian quadrature approximations is conditional on the number of quadrature nodes used. The GAUSS software allows a maximum of forty quadrature nodes that is applied to all random variables in this analysis. Bounds of plus and minus four standard deviations are imposed on the multivariate normal distribution. Gaussian quadrature is used initially, as needed, to estimate the expected value of crop sales and fair premiums for insurance and options. Then it is used to estimate expected utility for alternative scenarios.

The search for optimal hedge ratios conditional on insurance coverage is done by using a quadratic approximation of the response of expected utility to variation in the hedge ratio. This is the starting point for a step search that changes the ratio up and down in 1% increments until an optimum is found.

<u>Representative Farms and Base Scenarios</u>

Because price variability tends to differ little among farms and basis risk is small relative to price risk, regional differences are most apparent in yield variability and yield-price correlation. Three counties were chosen to represent farms from areas with differing levels of yield variability and yield-price correlation. Statistics for these counties are reported in Table 1.

The three soybean counties represent diverse production regions. La Salle County in east central Illinois was chosen to represent the typical high yield region usually associated with a negative yield-price correlation (Heifner and Coble 1996b). Bolivar County in Mississippi represents an area with relatively high yield variability and moderately high yield-price correlation. Wright County in Minnesota is an area with high yield variability and low yield-price correlation in the upper Midwest.

Certainty equivalent gains are estimated for a combination of initial wealth and risk aversion using constant relative risk aversion (CRRA) utility functions. Initial wealth level for a farm is set at $300,000. Relative risk aversion is set at 2 to represent moderate risk aversion.

Table 3 shows common parameters across all locations. In all locations and scenarios the cost of using futures and at-the-money options are specified with commission of $50 per contract and margin deposits at 10%. The crop insurance designs were assumed to be at the 75% coverage level and have a price election equal to the expected futures price. Interest rate effect was omitted from the model, setting margin deposits and options premiums opportunity cost to 0%. Insurance is assumed to be actuarially fair, with no administrative costs included[3].

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[3] RMA crop insurance programs are subsidized at varying levels. This would clearly influence the decision to insure and the level of insurance coverage. These decisions are made

Results

       The results for the different combinations of risk management strategies were evaluated based on the certainty equivalent gains and optimal hedge ratios. The certainty equivalent gain is reported on a per acre basis. These results appear in Table 4 and 5, respectively. Alternative scenarios were examined, with and without loan rates. A sensitivity analysis was done for different levels of loan rates relative to future price. The ratios included in the analysis were from 0.7 to 1.1, with increments of 0.1. The loan rate effect was evaluated alone, in combination with forward pricing tools and with forward pricing and crop insurance together.

Certainty Equivalent Gains

       When the loan rates were analyzed alone, without the effect of forward pricing tools and crop insurance, certainty equivalent income increased with the loan rate, as expected. These certainty equivalent gains increments were smallest between 0.7 and 0.8 of loan rate ratios, but increased at an increasing rate after as the loan rate increased in all three examined locations. For example, in La Salle County the certainty equivalent gain for a loan rate of 0.70 is 1.68 dollars per acre and increases to 5.13 dollars per acre when the loan rate is increased to 0.80. The next increment to 0.90 results in a certainty equivalent of 11.81 dollars per acre, which is 94 percent greater than the previous increment.   Since increasing the loan rate increases the proportion of the price distribution subsumed, the expected value of the loan program increased rapidly through the range of loan rates examined.

       When low levels of loan rates were combined with forward pricing, either put options or futures gives higher certainty equivalent gains than loan rates alone. However, the marginal increase in the certainty equivalent resulting from adding put options or futures is not large, because these private instruments are priced at their expected value. Thus, the certainty equivalent gain from these products arises solely from their risk reduction benefits. Wright County shows an example of this. When the loan rate was 70% of the expected futures, only $1.06 per acre of certainty equivalent gain was obtained. In contrast, 2.28 dollars per acre was obtained when futures were added to the loan rate. On the other hand, as the level of loan rates increased, the potential gains from forward pricing declined and vanished. This can be explained by Table 5 that shows optimal hedge ratios going to near zero with higher levels of loan rates. Because of the similarity of the loan deficiency payment and forward pricing tools they are strong, but not perfect, substitutes. At low loan rates the addition of futures or options covers an additional portion of the price distribution. However, as the loan rate increases, this additional benefit diminishes. It was also observed that futures show a higher risk reduction than put options, especially at low loan rate ratios.

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prior to the sign-up deadline, which is generally prior to planting. Subsidies are omitted in this analysis to clarify the risk benefits of the instruments.

The effect of adding crop insurance to the previous combination of forward pricing tools and low loan rate levels generated a larger risk reduction than the one obtained when just forward pricing was added to the loan rate. Bolivar county shows a jump from $1.22 per acre to 2.46 dollars per acre of certainty equivalent gain when a put option was used with MPCI yield insurance and the loan rate ratio was set at 0.7. The difference was larger than when RI insurance was used, which only reached 2.37 dollars per acre of certainty equivalent gain. However, the risk-reduction contributions of the addition of crop insurance decreases as the loan rate's ratios were increased.

Table 4 shows a lower marginal contribution of crop insurance at 1.1 loan rate ratio, as compared to no loan rate. This can be observed when comparing the certainty equivalent gains provided by the loan rate alone and the certainty equivalent gain of having crop insurance, forward pricing and loan rate. Thus, as the loan rate increases, and assuming optimal hedge level, the two certainty equivalent gains become more similar, suggesting that the effect of the crop insurance and forward pricing is providing less marginal reduction in the farmer's risk. It was also observed, that within a forward pricing tool, and given optimal hedge positions; differences across insurance designs become less apparent as loan rates are increased. Bolivar County shows differences between insurance designs of no more than 42 cents per acre when put options were at its optimal level and the loan rate was set at a ratio of 0.9. A slight dominance of futures over put options is observed when they were combined with crop insurance. However, this dominance of futures over put options decreases as the loan rate ratio was increased.

Optimal Hedge Ratio

The optimal hedge ratio resulting from alternative combinations of insurance and forward pricing with and without loan rates, is reported in Table 5. In our analysis, we first add the forward pricing strategies to the loan rate. The highest hedge ratios were generally obtained when no loan rate was considered. As the loan rate is increased, the optimal hedge ratio tended to rapidly decrease. This behavior was found in each of the three analyzed counties. Put options showed higher optimal hedge ratios than futures at lower loan rates. Then as the loan rate was increased at some loan rate ratio between 0.7 and 0.9, the optimal hedge ratio becomes higher than the optimal put ratio. Both the optimal hedge ratio and the optimal put ratio declined rapidly and in all three counties reached zero. Optimal put ratios tended to reaches zero more quickly than futures. Further, the optimal hedge ratio reached negative values in Bolivar, MS. This suggests that the farmer take a long position - buying futures contracts.

Next, crop insurance was added to forward pricing and loan rate. The same pattern of decreasing optimal hedge ratios as loan rates were increased was observed. We also observe that optimal put ratio reached zero more quickly than futures. Therefore, a higher sensitivity of decreasing optimal hedge ratio to the loan rate was found with put options than with futures. Revenue insurance products generated lower hedge ratios than yield insurance product. This was found in all the counties and with all the combinations of forward pricing and loan rate ratio.

Intuitively, this derives from the complementarity of yield insurance to forward pricing and the mixed effect of revenue insurance.

Optimal futures hedge ratios are negative with revenue insurance products at the highest loan rate ratio. Table 5 showed negative hedge ratios in Bolivar County for the two revenue insurance products, and only with RI revenue insurance at the other two counties. When revenue insurance products are present and loan rate ratio is above one, buying futures contracts appears to be the optimal hedging strategy. This novel result is generated by the complex layering of instruments occurring when revenue insurance, loan programs, and futures hedging are combined. A producer with revenue insurance and a high loan rate relative to expected prices has two price mechanisms in place. We would suggest that the optimal result of taking a long futures position is risk reducing because it counterbalances the insurance and loan program effects.

Conclusions

This study moves toward greater realism in the evaluation of producer risk management strategies - considering free governmentally provided price risk protection and federal crop insurance in a model of optimal forward pricing level selection. This is especially applicable to the current market context where market prices for many major crops are hovering near the loan rate and government outlays for crop insurance programs have increased dramatically.

Our results show a strong substitution effect between the marketing loan program and the optimal use of market-based tools such as futures, options, and to a lesser degree, insurance instruments. This result appears consistent with the Hanson, Myers, and Hilker results in suggesting the free government price protection has a strong negative effect on the optimal hedge ratio. Many authors have suggested explanations of why producers do not use market-based risk tools to a greater extent. Our results suggest a 'crowding out' of private risk management tools from a model which explicitly optimize the hedge ratio.

The study also extends the past work, such as that of Wang et al., and Heifner, and Coble. While reconfirming that there are interactions between risk management tools, such that evaluation of each in exclusion will lead to sub-optimal decisions, the inclusion of the loan rate reveals an even more complex relationship between instruments. For example, an insurance design, such as CRC which subsumes price risk and has an increasing price coverage, is shown to have different implications for the optimal hedge than does yield insurance. By also considering the loan rate, the optimal hedge is again significantly altered. Ultimately, this type of analysis provides new insights into the difficult decision environment a producer faces. It also suggests caution in making prescriptive suggestion for producer risk management. Generic recommendations, which do not account for differences in the underlying risk context, the risk management alternative strategies in use, and the farm policy context, would appear to be quite unable to maximize individual producer utility.

Table 1 Estimated parameters for Soybean and Cotton counties included in the numerical analysis.

Parameter		Soybean Counties		
		Bolivar, MS	La Salle, IL	Wright, MN
Basis, $/bu	Mean	-0.19	-0.32	-0.51
	Std. Dev.	0.33	0.32	0.35
Futures price-basis	Correl.	-0.55	-0.33	-0.42
County yield-basis	Correl.	-0.19	0.03	0.14
Farm price	Mean	5.59	5.55	5.31
	CV	0.19	0.21	0.21
Farm yield	Mean	24.97	43.63	36.33
	CV	0.4	0.17	0.3
Farm yield-price	Correl.	-0.23	-0.26	-0.16

Table 2 Estimated coefficients for hyperbolic tangent yield transformation.

Counties	Coefficients in cubic function			
	$alpha_0$	$alpha_1$	$alpha_2$	$alpha_3$
Bolivar, MS soybeans	-17.38	150.10	-437.31	468.75
La Salle, IL soybeans	-28.60	199.87	-517.55	478.78
Wright, MN soybeans	-27.19	224.51	-667.79	700.79

Table 3   Parameters common to all locations.

Parameters	Values
Expected Futures price.	6 $/bu
Price volatility	20%
Months to harvest	7 months
Insurance coverage level	75%
Insurance price election	6 $/bu
Acres of crop	500 acres
Harvest cost.	30 $/acre
Percentage of cost production	70%

Table 4 Soybean certainty equivalent gains from alternative combinations 75% of insurance coverage and forward pricing with and without loan rate.

Risk Management Tools			Bolivar, MS Yield Price Corr: -0.23 Farm Yield C.V.: 0.40							La Salle, IL Yield-Price Correlation: -0.26 Farm Yield C.V.: 0.17							Wright, MN Yield-Price Correlation: -0.16 Farm Yield C.V.: 0.30					
Forward Pricing	Crop Insur.	Loan Rate	No Loan Rate	Loan Rate % of future price					No Loan Rate	Loan Rate % of future price					No Loan Rate	Loan Rate % of future price				
				0.70	0.80	0.90	1.00	1.10		0.70	0.80	0.90	1.00	1.10		0.70	0.80	0.90	1.00	1.10
		LR	- - -	0.84	2.73	6.40	12.71	21.44	- - -	1.68	5.13	11.81	23.24	39.14	- - -	1.06	3.85	9.25	18.5	31.35
Put Opt.		+ LR	0.11	1.22	2.95	6.53	12.74	21.44	0.94	2.78	5.75	11.86	23.24	39.15	0.48	2.03	4.48	9.49	18.5	31.35
Futures		+ LR	0.21	1.31	3.01	6.54	12.74	21.45	1.32	3.21	6.14	12.11	23.86	39.15	0.71	2.28	4.7	9.6	19.16	31.36
Put Opt.	+ CI	+ LR	1.34	2.46	4.19	7.44	14.11	22.54	1.83	3.67	6.63	12.74	24.33	39.54	3.74	5.28	7.75	12.81	22.31	34.75
Put Opt.	+ RI	+ LR	1.25	2.37	3.86	7.31	13.91	22.28	1.53	3.31	6.27	12.00	23.97	39.08	3.05	4.59	7.08	11.81	21.59	33.93
Put Opt.	+CRC	+ LR	1.66	2.77	4.26	7.73	14.38	22.79	1.98	3.76	6.73	12.88	24.46	39.62	3.46	4.98	7.46	12.19	22.04	34.46
Futures	+ CI	+ LR	1.47	2.58	4.29	7.72	14.35	22.79	2.3	4.18	7.11	13.07	24.83	39.96	4.07	5.73	8.08	13.01	22.70	35.11
Futures	+ RI	+ LR	1.32	2.41	4.12	7.56	14.16	22.60	1.94	3.72	6.62	12.59	24.41	39.52	3.28	4.81	7.25	12.22	21.95	34.31
Futures	+CRC	+ LR	1.78	2.87	1.97	7.99	14.62	23.05	2.49	4.27	7.17	13.12	24.91	40.05	3.83	5.35	7.77	12.70	22.40	34.82

Table 5 Soybean Optimal Hedge Ratio from alternative combinations 75% of insurance coverage and forward pricing with and without loan rate.

Risk Management Tools			Bolivar, MS Yield Price Corr: -0.23 Farm Yield C.V.: 0.40						La Salle, IL Yield-Price Correlation: -0.26 Farm Yield C.V.: 0.17						Wright, MN Yield-Price Correlation: -0.16 Farm Yield C.V.: 0.30					
Forward Pricing	Crop Insur.	Loan Rate	No Loan Rate	Loan Rate % of future price					No Loan Rate	Loan Rate % of future price					No Loan Rate	Loan Rate % of future price				
				0.70	0.80	0.90	1.00	1.10		0.70	0.80	0.90	1.00	1.10		0.70	0.80	0.90	1.00	1.10
Put Opt.		+ LR	0.51	0.32	0.11	0.00	0.00	0.00	0.89	0.70	0.49	0.15	0.00	0.00	0.74	0.56	0.35	0.03	0.00	0.00
Futures		+ LR	0.40	0.32	0.23	0.08	0.00	-0.09	0.62	0.54	0.45	0.30	0.10	0.00	0.53	0.45	0.36	0.21	0.02	0.00
Put Opt.	+ CI	+ LR	0.62	0.43	0.22	0.00	0.00	0.00	0.95	0.76	0.55	0.21	0.00	0.00	0.88	0.69	0.49	0.15	0.00	0.00
Put Opt.	+ RI	+ LR	0.23	0.04	0.00	0.00	0.00	0.00	0.70	0.52	0.31	0.00	0.00	0.00	0.58	0.40	0.19	0.00	0.00	0.00
Put Opt.	+CRC	+ LR	0.38	0.18	0.00	0.00	0.00	0.00	0.78	0.60	0.39	0.05	0.00	0.00	0.72	0.53	0.32	0.00	0.00	0.00
Futures	+ CI	+ LR	0.49	0.41	0.31	0.16	0.00	-0.02	0.67	0.59	0.50	0.35	0.14	0.00	0.63	0.56	0.47	0.31	0.11	0.00
Futures	+ RI	+ LR	0.26	0.18	0.09	0.00	-0.05	-0.25	0.54	0.47	0.38	0.22	0.01	-0.04	0.46	0.38	0.29	0.14	0.00	-0.10
Futures	+CRC	+ LR	0.39	0.31	0.22	0.06	0.00	-0.12	0.60	0.53	0.44	0.28	0.08	0.00	0.57	0.50	0.41	0.25	0.05	0.00

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