FARMERS' USE OF FUTURES AND OPTIONS UNDER ALTERNATIVE FARM PROGRAMS: A FARM LEVEL FINANCIAL ANALYSIS

Calum G. Turvey & Timothy G. Baker

Proceedings of
Regional Research Committee NC-161

FINANCING AGRICULTURE IN A CHANGING ENVIRONMENT: MACRO, MARKET, POLICY AND MANAGEMENT ISSUES

McLean, Virginia
October 4-5
1988

Department of Agricultural Economics
North Dakota State University
Fargo, ND 58105
January 1989

FARMERS' USE OF FUTURES AND OPTIONS UNDER ALTERNATIVE

FARM PROGRAMS: A FARM LEVEL FINANCIAL ANALYSIS

Calum G. Turvey and Timothy G. Baker *

Introduction

It is well accepted that farmers' use of futures and options to hedge growing and stored crops can reduce price risk and decrease the variance on the return to equity. However, despite these benefits few farmers actually use futures or options to hedge. For example, Heifner (1972a) notes that less than five percent of cattle on feed were hedged in 1969. Similarly, a 1977 report on farmers' use of futures markets by the Commodity Futures Trading Commission indicated that only five percent of farmers participate in the futures market (Berck). Patrick, Whitaker and Blake surveyed 97 Indiana corn and soybean producers, finding that only 12 to 13 percent hedged part of their corn and/or soybean crops. Recently Shapiro and Brorsen found that for a sample of 41 Indiana farmers (in 1985) 63 percent hedged at least some of their corn, soybean or wheat crop, over the previous years. However, the mean percent of crops hedged was only 11.4 percent. And a 1982 survey by the Ontario Ministry of Agriculture and Food found that only two percent of 607 livestock producers used futures markets and from this group only 62 percent used them specifically for hedging purposes.

These data are not in accordance with the expected behavior of risk averse farmers predicted by some mean variance and expected utility models of optimal hedging (Johnson; Heifner (1972a); Peck; Robison and Barry). Therefore, there must be alternative motivations to farmers' use of hedging strategies, other than reducing price risk, which are not accounted for in the traditional theory of hedging. Examining one such motivation - the liquidity position of the farm firm - is the central focus of this study.

The purpose of this research is to investigate the liquidity motive underlying farmers' use of futures and options with respect to their capital structure and alternative farm programs. Specifically, the objectives are to a) determine how the financial characteristics of the farm affect hedging strategies, and b) to determine how alternative farm programs affect the hedging strategies. In order to achieve these objectives a theoretical model of optimal hedging with credit

---

* Calum Turvey is an assistant professor in the Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario, Canada, and Tim Baker is an associate professor in the Department of Agricultural Economics, Purdue University, W. Lafayette, Indiana.

considerations is reviewed. This theoretical model provides some hypotheses which are tested using a discrete stochastic programming model of a representative Indiana cash crop farm in which corn and soybean yields and prices are stochastic. The DSP model simulataneously examines the effect of alternative farm programs and debt on the optimal hedge.

Background

Although the liquidity motive behind hedging has been discussed by some researchers (Hieronymus), it has not been examined in great detail. Indeed, the only study which looked specifically at the effects of farm debt on marketing strategies is Barry and Willmann's paper on forward contracting. They conclude that when credit is valuable, optimal plans will include contracting even for managers with little or no risk aversion.

The availability of credit is directly affected by the farm's capital structure. The debt-to-equity or debt-to-asset leverage ratios are often used by lenders to determine the amount of debt made available to farmers. The amount of unused debt, called a credit reserve, can be drawn upon in times when cash flow decreases due to low yield or price outcomes (Barry, Baker and Sanint; Robison, Barry and Burghardt). However, persistent losses which decrease retained earnings and equity also affect the leverage ratio and credit availability. Hence, in times of adversity credit reserves decrease, forcing some farmers to seek alternative sources of liquidity. One source of liquidity is the futures markets. By its very nature the problem of liquidity is associated with low product prices and other causes of reduced income. And low income due to unfavourable prices is exactly what hedging with futures and options is intended to avoid. Thus, hedging may provide an efficient substitute for other forms of liquidity such as debt. In fact, Hieronymus characterizes the hedging decision as a substitute of financial debt for commodity debt. In subsequent sections it is argued that high debt farmers with low credit reserves are more likely to hedge than low debt farmers with substantial credit reserves. This is consistent with the survey findings by Shapiro and Brorsen that farmers who perceive themselves to be highly leveraged are more likely to hedge than those who perceive themselves to be less leveraged.

Another reason why farmers may not use futures and options is the presence of farm programs. Gardner (1977,1980) has alluded to the similarities between farm programs and put options, and Turvey, Brorsen, and Baker note that the provisions of the loan program prior to harvest are like a put option, while the provisions for the post-harvest storage period are like a call option. Because of these similarities, Gardner claims that farmers' motivation to hedge are eliminated since the government is providing the same service as an option but relatively free of charge.

U.S. farm programs affect farm liquidity in two ways. First, through price supports (i.e. loan rates) the probability distribution of prices is altered such that the probability of disastrously low price outcomes are diminished, if not eliminated. This tends to increase the density of price outcomes at, or around, the loan rate (Boehlje and Griffin; Featherstone, Moss, Baker and Preckel). The effect decreases the variance on the returns to equity and skews the returns positively. This effect increases the expected return to equity which in turn increases credit reserves available to farmers. Because credit reserves are a source of liquidity the need to hedge for liquidity purposes is diminished.

A second source of liquidity from farm programs is through direct subsidies to farmers through deficiency payments. Income augmenting farm policies provide liquidity by increasing cash flows, retained earnings, and equity, thus further reducing the need to hedge.

The effect of farm debt and government policies should have a substantial influence on farmers' use of futures and options. However, there has been little, if any, theoretical or empirical work to support the claim. This study is dedicated to doing just this. In the following sections a theoretical model of optimal hedging is reviewed. This model provides some hypotheses regarding the effect of debt on the optimal hedge. Then a discrete stochastic programming model (DSP) of a hypothetical Indiana corn-soybean operation is used to examine the simultaneous effect of farm debt and government policies on farmers' use of futures and options. The results of the model and some conclusions are then presented.

A Theoretical Model of Optimal Hedging Under Alternative Capital Structures and Risk Aversion

This section draws on the results of a theoretical model which examines farmers' use of futures under alternative debt structures (Turvey and Baker). The model is based on Collins' expected utility model of debt, equity, and risk balancing. This is an appropriate framework because it accounts for debt, risk and risk aversion.

The return on assets is defined in terms of a long futures position (Heifner 1972a; Kahl);

$$(1) \qquad \tilde{R}_A = \frac{[\tilde{P}Y + (\tilde{f}_1 - f_0)\, H + rB]}{A} + g$$

where $\tilde{P}$ is the stochastic cash price, Y is output, assumed constant; f_0 is the futures price at which a long position is taken; $\tilde{f}_1$ is the random futures price at which the hedge is lifted; H is the amount of crop hedged; r is the return on bonds; B is the amount of bonds; g is the growth rate in assets; and A is assets. The expected value of (1) is,

$$\bar{R}_A = \frac{[\bar{P}Y + (\bar{f}_1 - f_0)\ H + rB]}{A} + g \tag{2}$$

and its variance is

$$\sigma_A^2 = \frac{[\sigma_p^2 Y^2 + \sigma_f^2 H^2 + 2YH\rho\sigma_p\sigma_f]}{A^2} \tag{3}$$

where σ_p^2 is the cash price variance, σ_f^2 is the futures price variance and ρ is the correlation between $\tilde{P}$ and $\tilde{f}_1$.

Using Collin's basic framework the expected utility of the return to equity is,

$$E[U] = [\bar{R}_A - i\delta]\ \frac{1}{1-\delta} - \frac{\lambda}{2}\ \sigma_A^2\ \frac{1}{[1-\delta]^2} \tag{4}$$

Where i is the cost of debt capital; δ is the debt-to-asset leverage ratio; and λ is the risk aversion coefficient. Substituting (2) and (3) into (4) and differentiating with respect to H and Y yields,

$$\frac{\partial E[U]}{\partial H} = \frac{f_0 - \bar{f}}{A[1 - \delta]} - \frac{\lambda}{A^2[1 - \delta]^2}\ [H\sigma_f^2 + Y\rho\sigma_p\sigma_f], \text{ and} \tag{5}$$

$$\frac{\partial E[U]}{\partial Y} = \frac{\bar{P}}{A[1 - \delta]} - \frac{\lambda}{A^2[1 - \delta]^2}\ [H\rho\sigma_p\sigma_f + Y\sigma_p^2]\ . \tag{6}$$

Solving (5) and (6) simultaneously yields the theoretical equations to determine the optimal hedge, H*, and output, Y*,

$$H^* = \frac{A[1 - \delta]\ [\sigma_p^2\ [\bar{f} - f_0] - \bar{P}\rho\sigma_p\sigma_f]}{\lambda[\sigma_p^2\sigma_f^2 - \rho^2\sigma_p^2\sigma_f^2]}\ , \tag{7}$$

and

$$Y^* = \frac{A[1 - \delta]\ [\bar{P}\sigma_f^2 - (\bar{f}_1 - f_0)\rho\sigma_p\sigma_f}{\lambda[\sigma_p^2\sigma_f^2 - \rho^2\sigma_p^2\sigma_f^2]} \tag{8}$$

This is very similar to the optimal hedge discussed in Kahl; Robison and Barry; Heifner 1972a; and Bond and Thomson. The only real difference is that leverage enters as an argument in the optimal hedge.

Under fairly plausible assumptions, $\sigma_p^2 > \sigma_f^2$ and $\rho < 1$, which implies that the denominator is always positive. Also if it is assumed that the cash position, $\bar{P}$, dominates the return on the hedge $(\bar{f} - f_0)$ the numerator is likely to be negative. This implies a short hedge (Heifner 1972a). Differentiating (7) with respect to δ and λ gives,

$$(9) \qquad \frac{\partial H^*}{\partial \delta} > 0 \text{ , and}$$

$$(10) \qquad \frac{\partial H^*}{\partial \lambda} > 0$$

Under the assumptions of this theoretical model, an increase in the amount of debt relative to assets increases the amount of crop hedged. An identical statement is that an increase in the equity of the farm decreases the hedge. The second result, equation (10), states that as risk aversion increases, the optimal hedge increases. These results are taken as hypotheses to be tested in the empirical model.

Another hypothesis, based on the original Collin's model as well as that presented by Featherstone, Moss, Baker and Preckel, is that as farm policies reduce business risk farmers will hedge less. With respect to the results of the theoretical model, a decrease in business risk will increase expected equity thereby reducing the amount hedged.

Method

Maximizing Expected Utility

This study uses a direct expected utility maximizing model to test the above hypotheses. This optimization model is a two stage discrete stochastic program (DSP) of an Indiana corn-soybean farm (Cocks; Rae 1971a,b; Kaiser; Yaron and Horowitz). The two stages involve making hedging decisions at planting time (beginning of stage 1) for the growing crop and at harvest time (end of stage 1, beginning of stage 2) for stored crop or crop put under loan. The DSP is an appropriate model to use since it can capture the effects of liquidity across different stochastic outcomes, can account for the timeliness of the hedging decision, and can model the price distributions under alternative farm programs with no restrictions on the type of distribution used. The objective is to maximize the expected utility of terminal net worth at the end of the second stage. Balance sheet identities were defined for each state of nature in stage 1 and stage 2. At the end of the second stage terminal net worth was accumulated and transferred to the objective function. The objective function used was a power utility function of expected terminal net worth which exhibits constant relative risk aversion. Specifically, the objective function can be stated as,

$$(8) \qquad \max_{W} \sum_{i=1}^{K} \sum_{j=1}^{L} \theta_{ij} \frac{1}{1-\gamma} W_{ij}^{1-\gamma}$$

Where W_{ij} is the terminal wealth in state j of stage 2 following state i in stage 1; θ_{ij} is the discrete probability of W_{ij} occurring, and γ is the coefficient of constant relative risk aversion. There are K x L terminal (stage two) states of nature. Therefore the objective function satisfies

$$\sum_{i=1}^{K} \sum_{j=1}^{L} \theta_i \cdot \theta_{ij} = 1.$$

This study examined three levels of relative risk aversion. The risk neutral, profit maximizing producer is represented when $\gamma = 0$, the case of logarithmic utility is examined when $\gamma = 1$, and the risk averse case is examined when $\gamma = 5$. The DSP was solved using MINOS (Murtagh and Saunders).

Two performance measures often used in expected utility models are the certainty equivalent and risk premiums associated with the stochastic outcomes (Robison and Barry; Cass and Stiglitz). The certainty equivalent measures a level of certain wealth, W_i^* with which the hedger would be indifferent to the expected stochastic outcome $\bar{W}$. For the power utility function the certainty equivalent is given by,

$$(9) \qquad W^* = ((1-\gamma)\ E[U])^{1/1-\gamma}.$$

The difference between expected terminal net worth and the certainty equivalent is called the risk premium. The risk premium measures the amount of wealth the hedger is willing to give up to receive the certainty equivalent.

It is expected that as the variance of terminal net worth decreases, the risk premium decreases and the certainty equivalent decreases. As risk aversion increases the certainty equivalent decreases and the risk premium increases, and as wealth increase the certainty equivalent increases and the risk premium decreases.

Based on these expectations it follows that high-debt farms will have higher risk premiums and lower certainty equivalents than low-debt farms; the risk premium will be lower for farms that hedge relative to those that don't hedge; and, the risk premiums will be lower in the presence of farm programs than when no farm policies exist.

Simulating Alternative Farm Policies

Corn and soybean yields and cash prices were simulated using FEEDSIM, a multi-period stochastic simulation model of the U.S. corn, soybean meal and soybean oil markets (Holland and Sharples). Changing policy parameters such as loan rates and target prices alters the distribution of cash prices. Each of the farm policies simulated provided 500,000 jointly distributed price and yield observations. These observations were then converted into discrete probabilities for use in the DSP.

Three policies were examined. The first policy, NOBILL, eliminated all target prices and loan rates. This was used to simulate the economic environment if farm programs were completely eliminated. Since the variance of prices is expected to increase under such a program, it was expected that farmers' use of futures and options increased. The second policy, LOAN, introduced support prices to the model. Loan rates were set at \$1.55/bu. for corn and \$4.95/bu. for soybeans. The policy provides liquidity to participating farmers if cash prices fall below the loan rate. Because the government program acts as a contingent claim on the cash commodity (Turvey, Brorsen and Baker), it is expected that farmers will use less futures and options under the policy. The third policy, TARGET, introduces a target price of \$1.84/bu. for corn in addition to the corn and soybean loan rates. This policy of income augmentation, as well as price support, was expected to reduce the hedging requirements even more.

Corn and Soybean Price and Yield Distributions

The FEEDSIM price and yield observations are based on national average prices and yields. It was therefore necessary to convert the national average prices, through historical relationships, to better reflect yields and prices in Indiana. The FEEDSIM model was modified to take on this role.

The stochastic nature of corn and soybean yields were modelled in the following manner (Featherstone and Baker),

$$Y_{it} = M_i + b_{it} - e_{it}$$

Where Y is yields, M is maximum yield potential, b is the estimated trend in yields and e are the error terms distributed multivariate normal with mean υ and variance Σ. The subscript i identifies corn and soybeans and the subscript t identifies the time period.

Local corn and soybean prices are assumed to be stochastically related to national average prices according to the following stochastic process,

$$P^L_{it} = P^N_{it} + (\bar{P}^L_i - \bar{P}^N_i) + e_{it}$$

Where P^L_{it} is the local price, P^N_{it} is the national average price, $\bar{P}^L_i - \bar{P}^N_i$ is the historical difference between local and national average prices and e_{it} are normally distributed error terms with means equal to zero and variance σ^2. This relationship was used to generate both harvest and post-harvest cash prices by appropriately adjusting the value for $\bar{P}^L_i - \bar{P}^N_i$.

For use in the DSP the local observations for yield, harvest prices and post-harvest prices were converted into discrete probability states. In all there were 3 states of nature defined for each of corn and soybean yields, 5 states of nature for each of corn and soybean harvest prices, and 5 states of nature for each of post-harvest corn and soybean prices. Since these states of nature define joint probabilities there were 225 (3 x 3 x 5 x 5) possible states of nature at the end of the first stage and 5,625 (225 x 5 x 5) possible states of nature at the end of the second stage.

The Distribution of Futures Prices

There are two possible times at which the farmer can hedge; at planting the growing crop is hedged, and at harvest the stored crop (or crop under loan) is hedged. Future prices are required each time a hedge is placed or lifted. Therefore, 4 future prices were specified for each of corn and soybeans.

To obtain futures prices random shocks from a joint normal distribution of local basis were applied to each of the 225 harvest price and 5,625 post-harvest price states of nature. The basis data were generated from weekly price or futures observations at a Lafayette, Indiana elevator over the period 1979 through 1986. The resulting futures prices represented October futures prices on the November soybeans, and December corn futures contracts, and the April futures prices on the May corn and soybean futures contracts.

Specifically, the stochastic process used to determine these futures prices is given by,

$$f_i = P_i + \bar{B}_i + e^B_i$$

Where f_i is the futures price, P_i is the cash price, $\bar{B}_i$ is the mean basis, and e^B_i is the jointly distributed error of the basis with mean 0 and variance σ^2_B. The subscript i refers to the state of nature. This process is used to generate the futures prices at which a short position is offset (i.e. these are the long future prices).

It is assumed that the initial futures prices, i.e. those prices at which a short futures position is taken, are unbiased estimates of the stochastic long future prices. This assumption implies a zero profit from the hedge (actually a negative profit when transaction costs are included). The short futures price for corn and soybeans initiated at the beginning of stage 1 is therefore calculated as,

$$f_0 = \sum_{i=1}^{K} \theta_i \cdot f_i \cdot p_i$$

Where f_0 is the initial futures price, f_i is the state i futures price and θ_i is the state i probability of f_i occurring. The term $\sum_{i=1}^{K} \theta_i \cdot f_i$ is just the expected value of the harvest futures price on November soybean or December corn across all states of nature. Therefore, the initial futures price is just the expected value of the harvest futures price.

Similarly the initial harvest time futures contracts on May corn and soybeans are defined to equal the conditional expectations of the post-harvest (April) futures prices. This can be represented as,

$$f_{0i}^{h} = \sum_{i=1}^{K} \sum_{j=1}^{L} \theta_{ij} \cdot f_{ij}$$

where the h superscript denotes initial futures price at the end of stage 1 (harvest time), the j subscript refers to stage 2 states of nature following state i in the first period, and θ_{ij} is the probability of state ij occurring.

Put Option Premiums

Agricultural options are written on commodity futures contracts. A put option grants the holder the right, but not the obligation, to sell one futures contract at a specified strike price. In this study it is assumed that all options are purchased at-the-money. Thus the strike price is equal to the expected futures prices across all states of nature. The returns distribution on a put option can be characterized as MAX [0, E - f], where E is the strike price and f is the futures price at expiration. The difference E - f is the intrinsic value of the option. If E is greater than f, then the option is exercised such that a futures contract is sold at price E and another purchased at price f.

In a discrete probability model an appropriate method for determining the purchase price of the option is the binomial pricing model (Cox and Rubinstein). This model exactly prices options according to their intrinsic and time value. The price of a put option is just the present value of the probability that in state i the option will expire in-the-money;

$$P_0 = (1 + r)^{-T} \sum_{i=1}^{K} \theta_i \cdot \mathrm{MAX}[0,\ E - f_i]$$

and

$$P^h_{0i} = (1 + r)^{-T} \sum_{c=1}^{K} \sum_{i=1}^{L} \theta_{ij} \cdot \mathrm{MAX}[0,\ E - F_{ij}]$$

where r is the treasury bond interest rate, E is the strike price equal to either f_0 or f^h_{0i}, and f_i and f_{ij} are, respectively, the observed harvest and post-harvest futures prices. T is the period over which the option is to be held.

The difference between put options and futures is found in the returns. A routine futures hedge has unlimited loss whereas hedging with put options limits the loss to the premium on the put option. But because the premium is always paid on the put option the maximum profit potential from put options is always less than the maximum profit potential from the futures hedge.

Other Considerations In Model Building

The DSP farm model was assumed to represent the stochastic hedging decisions facing an 800 acre corn-soybean farm in west central Indiana. As well as activities for hedging, there were also activities for cash renting land, cash selling crops, purchasing and selling land, acquiring credit, and holding cash reserves.

Unfortunately, however, the size of the DSP model prohibited defining a constraint set which would realistically restrict farm production. Ideally, temporal labor and machinery constraints would be included. It was, therefore, implicitly assumed that variable and fixed factors of production were non-binding and these constraints were left out. Thus only constraints relevant to the problem were used. These included constraints which limited the amount of crop hedged to be less than or equal to expected production (in stage 1), or the amount of harvested crop stored or put under loan (in stage 2). Other constraints restricted debt, and kept track of assets, liabilities and owner's equity.

The design of the DSP was based on a philosophy of internally consistent relationships based on steady state prices. To account for land value changes under each of the alternative farm policies land valuation equations similar to those reported in Featherstone and Baker were used. A feedback control ensured that initial cash rent and land values started off in steady state. Therefore, under each state of nature capital gains and losses were treated as deviations from steady state with an expected value of zero. Similarly, by assuming that the expected value of futures prices equalled the initial short futures price the average gain to the hedge was zero. And since the options premiums were based on internally consistent futures prices the put premiums and returns to the put premiums were also internally consistent. In the type of model used internal consistency is important. Since the input coefficients, probability states and farm policies are an abstraction from reality, internal consistency ensures that the results reflect expected economic behavior under the assumed conditions.

Steady State Cash, Futures and Options Prices

Cash prices and crop yields under each of the three policy scenarios were simulated under steady state conditions. The simulated steady state observations were converted into discrete probabilities. Historical basis relationships were then used to convert the cash prices into futures prices. And the binomial optimum pricing model was used to calculate the put option premia.

Expected corn and soybean yields were approximately 113 and 38 bushels per acre, respectively. The marginal distributions of cash, futures and put prices are given in Table 1 for each of the three policies. The "initial" period is defined as the beginning of stage 1, the "harvest" period is described by the marginal distributions of the stage 1 outcomes (end of stage 1, beginning of stage 2), and the "spring" period is described by the conditional (marginal) probabilities of prices at the end of stage 2.

Under steady state conditions there is not a large difference in prices among the different policies. Corn prices are slightly higher and soybean prices are slightly lower under the NOBILL program than LOAN or TARGET. But the standard deviation of cash prices is substantially higher under NOBILL reflecting the fact that government price supports and deficiency payments do reduce risk.

This risk reduction is reflected in the standard deviation of futures prices. As expected a decrease in the standard deviation of cash prices due to farm programs decreases the standard deviation of futures prices. In response to this decrease in the variance of futures prices, option premiums are decreased substantially relative to the NOBILL program.

These results are consistent with the expected behavior of cash and futures prices under the alternative farm programs. As program benefits (i.e. loan rates and target prices) decrease, or are eliminated, the market risk of cash and futures prices increase. It is this increase in price risk which induces farmers to hedge more of their corn and soybean crops under the NOBILL farm program, than LOAN or TARGET programs.

This section has described, in terms of the marginal distributions, the stochastic relationships between cash prices,

Table 1. Steady State Cash, Futures and Options Prices Under Alternative Farm Programs ($/bu.)

Price Category	NOBILL		LOAN		TARGET	
	Expected Value	Standard Deviation	Expected Value	Standard Deviation	Expected Value	Standard Deviation
Cash Prices						
Corn Harvest Price	1.60	.606	1.59	.386	1.58	.382
Soybean Harvest Price	5.56	1.100	5.65	.751	5.59	.706
Corn Spring Price	1.76	.516	1.88	.388	1.89	.384
Soybean Spring Price	6.34	1.603	6.12	.76	6.05	.713
Futures Prices						
Initial Price December Corn	1.72	-	1.68	-	1.70	-
Initial Price November Soybeans	5.71	-	5.80	-	5.73	-
Fall Price December Corn	1.72	.611	1.68	.405	1.70	.380
Fall Price November Soybeans	5.71	1.111	5.80	.756	5.73	.697
Fall Price May Corn	1.78	.362	1.90	.319	1.91	.299
Fall Price May Soybeans	6.38	.750	6.17	.741	6.09	.674
Spring Price May Corn	1.78	.528	1.90	.413	1.91	.397
Spring Price May Soybeans	6.38	1.61	6.17	.771	6.09	.704
Put Premiums						
Initial Premium December Corn	.227	-	.157	-	.152	-
Initial Premium November Soybeans	.395	-	.287	-	.252	-
Fall Premium May Corn	.147	.034	.101	.029	.100	.026
Fall Premium May Soybeans	.526	.130	.069	.015	.065	.015

futures prices, and put option premiums under alternative farm programs. In the following section the hedging results of the DSP are described.

Results

The results of the DSP hedging model are summarized in Tables 2, 3 and 4. These tables reflect the major objectives of the study which were to determine how the firm's financial characteristics, and how farm policies affect hedging decisions.

Table 2 provides results consistent with the hypothesized results of the theoretical model. These results were generated from the NOBILL policy scenario. As relative risk aversion increases the amount of crop hedged increases. The risk neutral farmer ($\gamma = 0$) hedges very little, as expected, relative to the log utility ($\gamma = 1$) or risk averse case ($\gamma = 5$). The effects of different levels of debt, however, are clear. The high-debt farm uses 16,145 put options to hedge the growing crop, but only a negligible amount of stored corn and soybeans are hedged using put options. Futures contracts do not enter the hedging plan. As risk aversion increases, the proportion of crop hedged increases. For example, the high-debt log utility case hedges 33,869 of an expected 48,285 bushels of corn using put options. This implies a hedge ratio of about 70 percent on total expected production. For stored crops, that is crops sold in the second stage, 6,458 of 12,946 bushels of corn and 2,702 of 5,649 bushels of soybeans were hedged, implying hedge ratios of 49.9 percent and 47.8 percent for corn and soybeans respectively. For the low-debt farm, none of expected corn or soybean production was hedged but a negligeable amount of stored corn (.247 percent) and about 56 percent of stored soybeans was hedged.

The amount of crop hedged by the risk averse farmer ($\gamma = 5$) was more than the risk neutral or logarithmic utility farmer. Both put options and futures contracts were used to hedge expected corn production. The percentage of expected corn hedged using either put options or futures was 79, 77, and 70 percent, for the high, medium and low- debt farm, respectively. The proportion of stored crop was somewhat higher. For all levels of debt, virtually all of the soybeans were hedged with put options. Using both puts and futures, 97.2 percent of corn was hedged by the high-debt farm and using put options only 96.7 percent and 97.1 percent of corn was hedged by the medium and low-debt farms.

Some general conclusions relating to the hypotheses can be derived from these results. It is clear that as risk aversion increases, so does the amount of crops hedged. But it is also evident that hypotheses regarding the firm's capital structure can be accepted. As the amount of debt relative to assets increases and credit availability is restricted, farmers will hedge more of their crops. In light of Barry and Willmann's conclusion for forward contracting, the same conclusions apply

Table 2. Farmers' Use of Futures and Put Options Under NOBILL Program With Varying Degrees of Risk Aversion and Debt

	Risk Neutral $\gamma = 0$			Log Utility $\gamma = 1$			Risk Averse $\gamma = 5$		
Activity	High Debt	Med. Debt	Low Debt	High Debt	Med. Debt	Low Debt	High Debt	Med. Debt	Low Debt
FINANCING									
Initial Owners' Equity	201050	335090	469120	201050	335090	469120	201050	335090	469120
Initial Debt	469120	335090	201050	469120	335090	201050	469120	335090	201050
Terminal Net Worth	209994	359906	509109	209166	359576	509038	209166	359576	509038
Certainty Equivalent	209994	359906	509109	205398	356671	506145	195787	350896	502044
Risk Preimum	0	0	0	3773	2906	2893	12062	7319	5687
Std. Dev. of Terminal Net Worth	45960	43750	43960	38247	39640	42736	33349	33970	35614
HEDGING									
Buy Dec. Corn Put	0	0	0	33869	22458	0	23090	22339	25538
Buy Nov. Soy Put	16145	0	0	0	0	0	0	0	0
Short Dec. Corn Futures	0	0	0	0	0	0	14890	14995	8136
Short Dec. Soy Futures	0	0	0	0	0	0	0	0	0
Buy May Corn Put	40	41	42	6458	55	41	11442	12851	15516
Buy May Soy Put	2	2	2	2702	4083	3307	5373	5542	5634
Short May Corn Futures	0	0	0	0	0	0	96	0	0
Short May Soy Futures	0	0	0	0	0	0	0	0	0
MARKETING									
Sell Corn in Fall	35218	34183	31577	35339	34346	31705	36420	35008	32311
Sell Soybean in Fall	10418	10295	10255	10496	10315	10255	10765	10590	10510
Sell Corn in Spring	13067	14101	16708	12946	13939	16580	11865	13277	15974
Sell Soybeans in Spring	5727	5850	5890	5649	5830	5890	5380	5556	5636

here; as credit becomes more valuable, farmers will tend to increase their use of futures and options to hedge their crops.

In terms of the direct expected utility approach used in the study the relative values of the standard deviation and certainty equivalents of expected terminal net worth, and the risk premiums provide some insights into hedging behavior under uncertainty. As risk aversion increased, the standard deviation of terminal net worth decreased. For the high-debt farms these standard deviations were $45,960, $38,247 and $33,349, for γ equal to 0, 1 and 5, respectively, and the certainty equivalents decreased from $209,994 to $205,398, and $195,787. The risk premium for all levels of debt was zero for the risk neutral farmers and was higher for the log utility and risk averse farmer. From Table 2, as debt increased, the risk premium increased. For example, for γ equal to 5, the risk premium was $12,062, $7,319 and $5,687, for the high, medium and low-debt farmers, respectively. This illustrates that the capital structure of the farm does affect the marketing and hedging strategies. But, since liquidity was constrained by credit reserves, the results also lend substantial support to the value of credit reserves as a source of liquidity. And when credit becomes constraining, hedging with futures and options can be an effective source of liquidity.

The second objective of this study was to examine how alternative farm programs affect hedging decisions. This objective was achieved by eliminating loan rates and target prices (NOBILL), introducing loan rates only for corn and soybeans (LOAN), and introducing a target price for corn along with the loan rate (TARGET). The results of the analyses are presented in Table 3 and 4, for alternative capital structures and γ equal to 5. Table 3 presents the results when either put options or futures can be used. Table 4 restricts the use of both futures and options to zero. The differences in terminal net worth, certainty equivalent, risk premium and standard deviation described by the two tables are indicative of the role put options and futures can play in providing liquidity and reducing risk.

Table 3 presents the hedging results under alternative farm policies. As expected, the standard deviation of terminal net worth was most under the NOBILL plan and lowest under the TARGET plan. Because the steady state conditions differ across policies, the certainty equivalents are not directly comparable, but the risk premiums can be. Since government programs reduce the return to equity and increase expected credit reserves across all states of nature, it was expected that the amount of crops hedged would decrease. Viewing Table 3 these expectations were borne out. The greater amount of crop hedged occurred from the NOBILL plan with the least amount of hedging occurring for TARGET. Under NOBILL the hedge combined corn puts and futures to hedge expected corn production. Stored corn and soybeans were hedged predominantly with put options.

most in terms of hedging. Alternatively, lenders may wish to require high-debt farms to hedge with futures and options in order to receive extra funds. This recommendation is consistent with Heifner's (1972b) claim that lenders will benefit from hedging by either decreasing the riskiness of their loan portfolio or increasing their loan portfolio without an increase in risk.

Finally, policy makers should be aware of the relationship between farmers use of futures and put options when farm programs are in place. The results of this study support the general arguments put forth by Gardner that farm policies provide disincentives to hedge. With the possible elimination of loan rates and target prices in future Farm Bills, farmers' use of futures and options will increase substantially. Therefore policy makers should promote further research and increase extension efforts in the area of futures and put options.

References

Barry, P. J., C. B. Baker and L. R. Sanint, "Farmers Credit Risk and Liquidity Management", American Journal of Agricultural Economics 63 (1981):216-227.

Barry, P. J., and D. R. Willmann, "A Risk Programming Analysis of Forward Contracting with Credit Constraints", American Journal of Agricultural Economics, 58 (1976): 62-70.

Berck, P., "Portfolio Theory and the Demand for Futures: The Case of California Cotton", American Journal of Agricultural Economics 63 (1981): 466-474.

Boehlje M.D and S. Griffin, "Financial Impacts of Government Price Support Programs", American Journal of Agricultural Economics, 61 (1979): 285-296.

Bond, G. E. and S. R. Thompson, "Risk Aversion and the Recommended Hedge Ratio", American Journal of Agricultural Economics 67 (1985): 870-872.

Cass, D. and J. E. Stiglitz, "Risk Aversion and Wealth Effects on Portfolios with Many Assets", Review of Economic Studies 39 (1972): 331-354.

Cocks, K. D., "Discrete Stochastic Programming", Management Science, 15 (1968): 72-79.

Collins, R. A. "Expected Utility, Debt-Equity Structure and Risk Balancing", American Journal of Agricultural Economics 67 (1985): 627-629.

Commodity Futures Trading Commission, "1977 Report on Farmers' Use of Futures Markets and Forward Contracts", Washington, D.C. 1978.

Cox, J. C., S. A. Ross and M. Rubinstein, "Option Pricing: A Simplified Approach", Journal of Financial Economics 6 (1979): 229-263.

Featherstone, A. M. and T. G. Baker, "Farm Portfolio Adjustments to the Elimination of U.S. Target and Support Price Provisions", in the Proceedings of Regional Research Committee NC-161, Financing Agriculture in a Changing Environment: Macro, Market, Policy and Management Issues, St. Paul, Minnesota, Oct. 7-8, 1986.

Featherstone, A. M., C. B. Moss, T. G. Baker and P. V. Preckel, "The Theoretical Effects of Farm Policies on Optimal Leverage and the Probability of Equity Losses", American Journal of Agricultural Economics 70 (1988): 572-579.

Gardner, B. L., The Governing of Agriculture, Regent Press of Kansas, Lawrence Kansas, 1981.

Gardner, B. L., "Commodity Options for Agriculture", American Journal of Agricultural Economics 59 (1977): 986-992.

Heifner, R. G. "Optimal Hedging Levels and Hedging Effectiveness in Cattle Feeding", Agr. Econ. Res. 24 (1972a): 25-36.

Heifner, R. G., "Implications of Hedging for the Agricultural Lender", Agricultural Finance Review, 33 (1972b): 8-14.

Hieronymus, T. A., Economics of Futures Trading for Commercial and Personal Profit, Commodity Research Bureau Inc., N.Y., N.Y., 1971.

Holland, F. D. and J. A. Sharples, "FEEDSIM: Model 15, Description and Computer Program Documentation", Station Bulletin No. 387, Department of Agricultural Economics, Agricultural Experiment Station, Purdue University, August 1982.

Johnson, L. L., "The Theory of Hedging and Speculation in Commodity Futures", Rev. Econ. Stud., 27 (1960):139-151.

Kaiser, H. M., "An Overview and Empirical Application of Discrete Stochastic Sequential Programming", Unpublished Manuscript, Cornell Univeristy, 1986.

Kahl, K. H., "Determination of the Recommended Hedging Ratio", American Journal of Agricultural Economics, 65 (1983): 603-605.

Murtagh, B. A. and M. A. Saunders, MINOS 5 User's Guide, Technical Report, SOL 83-20, Systems Optimization Laboratory, Dept. of Operations Research, Stanford University, Dec. 1983.

Ontario Ministry of Agriculture and Food, "A Survey of Attitudes among Ontario Beef Producers", Prepared by The Creative Research Group Limited, Toronto, Ontario, March, 1983.

Patrick, G. F., S. H. Whitaker and B. F. Blake, "Farmers Goals and Risk Aversion: Some Preliminary Analyses". In Risk Analysis in Agriculture: Research and Educational Developments, Dept. of Agricultural Economics, AE-4492, University of Illinois, 1980.

Peck, A. E., "Hedging and Income Stability: Concepts, Implications and an Example", American Journal of Agricultural Economics 57(1975):410-419.

Rae, A. N., "Stochastic Programming, Utility and Sequential Decision Problems in Farm Management", American Journal of Agricultural Economics 53(1971a): 448-460.

Rae, A. N., "An Empirical Application and Evaluation of Discrete Stochastic Programming in Farm Management", American Journal of Agricultural Economics, 53(1971b):625 -638.

Robison, L. J. and P. J. Barry, The Competitive Firm's Response to Risk, MacMillan Publishing Co., N.Y., N.Y., 1987.

Robison, L. J. and P. J. Barry and W. G. Burghardt, "Borrowing Behavior Under Financial Stress by the Proprietory Firm: A Theoretical Analysis", Western Journal of Agricultural Economics, 12 (1987): 144-151.

Shapiro, B. L. and B. Wade Brorsen, "Factors Affecting Farmers' Hedging Decisions". North Central Journal of Agricultural Economics 10 (1988): 145-154.

Turvey, C. G. and T. G. Baker, "Optimal Hedging Under Alternative Capital Structures and Risk Aversion", Working Paper WP88/15, Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario, September, 1988.

Turvey, C. G., B. W. Brorsen and T. G. Baker, "A Contingent Claim Pricing Model for Valuing Non-Recourse Loan Programs and Target Prices", Selected Paper, Presented at the A.A.E.A. annual meetings, Knoxville, Tenn., Aug. 1-3, 1988.

Yaron, D. and U. Horowitz, "A Sequential Programming Model of Growth and Capital Accumulation of a Farm Under Uncertainty", American Journal of Agricultural Economics 54 (1972):441-451.