RISK MANAGEMENT STRATEGIES TO REDUCE NET INCOME VARIABILITY FOR FARMERS

Hamid Falatoonzadeh, J. Richard Conner, and Rulon D. Pope

Abstract

The most useful and practical strategy available for reducing variability of net farm income is ascertained. Of the many risk management tools presently available, five of the most commonly used are simultaneously incorporated in an empirically tested model. Quadratic programming provides the basis for decisionmaking in risk management wherein expected utility is assumed to be a function of the mean and variance of net income. Results demonstrate that farmers can reduce production and price risks when a combination strategy including a diversified crop production plan and participation in the futures market and the Federal Crop Insurance Program (FCIP) is implemented.

Key words: risk management, quadratic programming, expected utility, Monte Carlo simulation.

Strategies for coping with risks have been developed in a number of areas of agricultural decisionmaking, permitting more sophisticated treatment of producer decision behavior under risk and uncertainty. Numerous papers have been written about the many risks facing agricultural producers (Chavas and Pope; Ratti and Ullah; Mapp et al.; Pope and Kramer (1979); Anderson et al.; Lin et al.). Because of the complicated nature of uncertainty, researchers have chosen to implement only one or two risk strategies concurrently in their models (Peck; Sandmo; Gardner and Kramer; Pope and Kramer (1978); Lin et al.; Batra and Ullah; McKinnon). However, in a day when farmers are especially vulnerable to such serious risks as production, price and cost uncertainties, it is imperative to further explore methods of reducing these impediments to effective management. Thus, a closer examination of available risk management tools is timely.

PURPOSE AND OBJECTIVE

The purpose of this analysis is to identify the most effective strategy or strategies available to agricultural producers for minimizing the variability of net farm income. Though many risk management tools are available to farmers, this study simultaneously examines only the five most widely used alternatives: crop diversification, futures markets, forward pricing markets, cotton seller's call option, and the Federal Crop Insurance Program (FCIP). Empirically, these simultaneous choices can cause a large difference in both the optimal hedge and the location of the mean-variance frontier. Also, since FCIP is introduced into the model, *ex ante* cost-benefit analysis is used to show whether farmer participation in the futures market is advantageous.

The objective of this investigation is to delineate the factors that influence the competitive firm's participation in futures markets. The basic framework is a portfolio analysis empiricized by assuming that expected utility is a function of mean and variance of net income—the same assumption made by Peck, Rutledge, Rolfo, and Berck. The present model differs from these in that it considers that crop insurance exists in order to reduce production risk and that the insurance premium is not zero. The Federal Crop Insurance Act of 1980 is evaluated to determine whether it reduces the agricultural firm's production uncertainty.

The normative programming model designed for this study incorporates a representative dryland farm in Knox County, Texas which produces cotton, wheat, and grain sorghum, three crops typical of that County. The behavior of the competitive farm at various levels of risk aversion is evaluated using two assumptions: (1) the production level and output price of the firm are uncertain

(random events with known probability distributions) and (2) input prices and quantities are certain.

PRICE AND PRODUCTION UNCERTAINTY

Price uncertainty is the result of market supply and demand fluctuations. Futures and forward pricing markets have played an important role in the determination of prices for many agricultural commodities and have been shown to be instrumental in stabilizing price and income variability (Peck, p. 407). Agricultural firms appear to behave quite differently when futures markets exist. The forward pricing markets under price uncertainty have been discussed by Danthine, Holthausen, and Feder et al. who showed that when futures markets exist, the degree of risk aversion and price expectations do not affect the firm's output level, but do affect hedging decisions because the firm produces output where marginal cost equals the forward price under certainty. Thus, most risk-averse firms in the market make their production decisions based on the forward price. As a result, planned production is seemingly unaffected by the spot price or its variability.

Uncertainty in production is a second factor affecting farm income stability. It is caused by many factors such as weather, disease, insect infestation, technological innovations, and public and private institutional policies. These factors interact to create a uniquely difficult decisionmaking environment for agricultural producers (Mapp et al., p. 107). Because agriculture involves biological growth over which there is no ultimate control, production uncertainty may have a relatively greater effect on income than price uncertainty (Pope and Kramer (1979), p. 489).

Pope and Kramer (1978) show that hedging activities vary directly with risk aversion. This suggests that a hedger would increase the hedge in response to increased price uncertainty. However, in the case of production uncertainty, the results are ambiguous. Chavas and Pope show the effects of production uncertainty on hedging decisions using a specified multiplicative production disturbance and a mean-variance utility function. Their approach considers agricultural production's dependency on the distribution of spot prices. The authors concluded that

hedging may carry substantial risk when production is uncertain. Price and production uncertainties are fundamental factors with respect to farmer involvement in risk management programs and are therefore fundamental premises for this study.

EMPIRICAL MODEL BASED ON THEORETICAL DEVELOPMENT

Quadratic programming (QP) is a useful tool to aid the researcher in examining agricultural risks. It allows identification of the optimal profit level considering risks and expected returns (Freund; Markowitz; Musser and Stamoulis; Hazell; Rae; Wiens) and has been widely used in agricultural risk research (Anderson et al.; Robison and Brake; Berck; Lin et al.; Wiens; Musser and Stamoulis). The model designed for the present analysis reflects a representative farming firm and encompasses two steps. First, a Monte Carlo simulation model is used to indicate the distribution of profit, $[E(\Pi), V(\Pi)]$. Second, expected utility maximization facilitates determination of the conditions under which farmers should participate in, or avoid, the FCIP.

In order to make decisions under uncertainty, many could argue that the need for a utility concept is obvious. Utility theory is established to incorporate the random variables as well as the decisionmaker's attitude toward risk. The problems seem to be best handled by the von Neumann-Morgenstern utility theory because it is closely related to probability theory (Batra, p. 3). This utility theory provides utility functions which characterize the decisionmaker's attitude toward risk. It is used in decision analysis to determine the choice to be made among distributions.

Two special cases of the expected utility function, quadratic and exponential with a normal distribution, have been widely used in empirical studies to explain farmer risk attitudes (Anderson et al.; Lin et al.; Freund; Wiens; Musser and Stamoulis; Robinson and Brake). Under these assumptions, two moments (mean and variance) are considered adequate for representing the decisionmaker's behavior toward risk (Anderson et al., p. 92). However, severe limitations of the quadratic utility function, such as increasing absolute risk aversion and ignoring the higher order moments of such a function, make its

use impractical for this study. Some of these limitations are overcome by using nonpolynomial functions like the negative exponential function which has a constant absolute risk aversion for describing attitudes toward risk. Although analytic expected utility requires the assumption of normality, the exponential utility function appears best suited for this analysis. The form of the exponential utility functions used in this study is as follows:

$$(1) \quad U(\Pi) = 1 - \exp(-a\Pi)$$

where:

U = utility
and
a = a scalar risk aversion coefficient.

Freund has shown that when profit (Π) is normally distributed, the maximization of expected utility is equivalent to maximizing the following function:

$$(2) \quad EU(\Pi) = E(\Pi) - (a/2)[V(\Pi)].$$

Thus, the maximization of expected utility is also a quadratic programming problem when Π is in activity analysis form (Freund, p. 256).

When the probability distributions are non-normal, or when an agent's attitude toward risk changes the shape of the distribution of returns, E-V analysis may become meaningless (Newbery and Stiglitz, p. 88). Since negative output in agriculture has no meaning, yields cannot be distributed normally. It can be argued that, even though output price (P) and yield (Y) are normally distributed, the net return or income function (Π) includes the term P·Y which may not be normal, rendering Π non-normal (Bray, p. 594). Yet, empirical research often finds a close relationship between mean-variance and more general risk efficient sets (Porter and Gaumnitz). Further, quadratic programming or linear equivalents remain the most viable portfolio building tool. Thus, a normal distribution of net return is assumed for this study.

MODEL IN ACTIVITY FORM

Various combinations of production, marketing, and insurance activities can be chosen to represent the activities (X) in the model. This study is limited to three marketing strategies for selling wheat and grain sorghum:

hedging, forward contracting, and selling at harvest. Seller's call contracting and storage are considered for cotton only. The study considers several crop insurance purchasing plans: coverage levels of 50, 65, and 75 percent of the average county yield for a given crop. Each of these plans is coupled with a trio of price election levels-low, medium, and high-to be implemented in calculating crop losses. In total, then, nine insurance options are considered for each of the three crops evaluated.

Federal crop insurance programs and risk management schemes are presumed to reduce risk for farming firms. To achieve income stability, the assumption that farmers are risk-averse is relevant. Assuming that net incomes, Π's, are normally distributed or that the utility function is quadratic, farmers maximize expected utility.

The forms of expected utility function for a firm participating in the crop insurance program and for the same firm that is not participating in the program are as follows:

$$(3) \quad E(U_p) = E(\Pi_p) - (a/2)V(\Pi_p)$$

and

$$(4) \quad E(U_{np}) = E(\Pi_{np}) - (a/2)V(\Pi_{np})$$

where:

E = expectation,
U_p = utility for the FCIP-participating firm,
U_{np} = utility for the FCIP-nonparticipating firm,
Π_p = net income for the FCIP participant,
Π_{np} = net income for the FCIP nonparticipant,
$V(\Pi_p)$ = variance of net income for the FCIP participant firm, and
$V(\Pi_{np})$ = variance of net income for the FCIP nonparticipant.

The linear net income function is converted to activity form (equation (5)) in order to facilitate empirical study.

$$(5) \quad E(\Pi_q) = S'X$$

where:

S' = a (1 x m) row vector of expected "net return" per unit of individual activity,
X = a (m x 1) column vector of levels of activities,
m = number of activities, and
q = 1 and 2 for participation and nonparticipation in FCIP, respectively.

The expected net return per activity, S, is calculated through simulation. Using the form of the parameters for net return distribution in a programming model, the maximization of the expected utility can be accomplished by maximizing:

$$(6) \quad E(U_p) = S'X - (a/2)X'QX$$

and

$$(7) \quad E(U_{np}) = S'X - (a/2)X'QX$$

subject to:

$$(8) \quad TX \leq b,$$

$$(9) \quad \text{Prob}(MX_s < NX_p) \geq (1-\gamma)$$

and

$$(10) \quad X \geq 0$$

where:

Q = a variance-covariance matrix of net incomes (S) from X,

T = a matrix of the amount of certain scarce resources needed by the unit levels of the production process,

b = a vector of available amounts of scarce resources,

$M = (M_1, M_2, ..., M_s)$ matrix of different marketing activities,

γ = a vector of risk levels or probabilities that total sales (cash and futures) are greater than total production, and

N = a diagonal matrix with diag(N) equal to the yield per acre of individual crops.

Thus, vector X includes marketing activities (X_s'), FCIP participation activities (X_I') and production activities (X_p'). Equations (6) and (7) are maximized subject to chance constraints (equation (9)) and will be explained later.

In this study, fixed costs are ignored in the QP analysis since they are given in the short run and will not affect choice under constant risk aversion. Harvest and preharvest costs are separated because harvest costs are assumed to be stochastic, varying with yield, while preharvest costs are fixed. The insurance premium per acre of land depends on price election, production guarantee level, region, individual farm, and crop produced. Thus, the indemnity formula for cotton differs from that for wheat and grain sorghum.

Investment in a cotton crop increases during both the growing and harvest seasons. Insurance therefore provides three separate coverage periods with differing amounts of insurance coverage for each. FCIP designation of these periods are as follows.

(1) If the crop is damaged or destroyed and acreage is released from the time it is too late to plant cotton until the first blooms are shed, it is considered to be in the first stage and the guarantee will be 50 percent of the yield guarantee level of FCIP.

(2) If the crop is damaged and acreage is released after the first blooms are shed up until qualifying for the third stage, it is considered to be in the second stage. The guarantee will be 75 percent of the FCIP yield guarantee level.

(3) After harvesting at least 20 percent of the poundage guarantee per acre, the acreage qualifies for stage three. However, if the quantity harvested is less than 20 percent of the pound guarantee per acre, only the second stage guarantee will be available. Both situations assume the quality of harvested crops to be normal, making quality adjustment unnecessary.

These stage distinctions are unique to cotton, as is the following indemnity-calculating formula:

$$(11) \quad INDEM_{L,K} = [(.5PR_1 + .75PR_2 + PR_3)YGL_K \cdot FCIYD - Y] \cdot PE_L$$

for all L = 1, 2, 3, and for all K = 1, 2, 3,

where:

L = elected price option,

K = elected yield guarantee option,

PR_1 = proportion of an acre destroyed in first stage,

PR_2 = proportion of an acre destroyed in second stage,

PR_3 = proportion of an acre destroyed in third stage,

FCIYD = federal crop insurance yield,

INDEM = per acre indemnity for ith crop losses,

YGL_K = yield guarantee level for K option,

Y = actual yield,

PE_L = price election for L option,

and

(12) $PR_1 + PR_2 + PR_3 = 1$.

Calculating indemnities for wheat and grain sorghum requires a different formula:

(13) $INDEM_{L,K} = [(YGL \cdot FCIYD) - Y] \cdot PE_L$

for all L = 1, 2, 3, and
for all K = 1, 2, 3.

If wheat and grain sorghum are not harvested, the producer does not incur harvest costs and the production guarantee will be reduced, for wheat, by the lesser of three bushels or 20 percent for any acreage that is not harvested. This reduction for grain sorghum will be the lesser of 5 bushels or 20 percent for any acreage that is not harvested.

In order for the crops under scrutiny to be eligible for indemnity, certain conditions must be met. For wheat and grain sorghum, actual yield must be less than the quantity per acre guaranteed by FCIP, or:

(14) $YGL_K \cdot FCIYD - Y > 0$.

Likewise, actual cotton production must fall short of the quantity per acre guaranteed by FCIP in each of the three production stages. Expressed in another way:

(15) $(.5PR_1 + .75PR_2 + PR_3)YGL_K \cdot FCIYD - Y > 0$.

As indicated by equations (11) and (13), participation in the Federal Crop Insurance Program tends to truncate the lower part of the yield distributions. Consequently, a normal net return distribution under nonparticipation will likely not be normal under participation.

The amount of FCIP indemnity paid to cotton producers depends upon which stage of production prevails when the damage occurs. It is therefore necessary to estimate the probability of failure in each stage. As noted earlier, one of the components of the QP model is expected net return per unit of activity. For calculating expected net return per unit of each crop insured under FCIP, the indemnity receivable in the event of a crop failure is needed. Thus, from selected FCIP participation data, Table 1, two assumptions are made: (1) FCIP participation from 1965 to 1972 is representative of the typical dryland farm in Knox County and (2) there exists equal probability of cotton crop failure in both stages 1 and 2 ($PR_1 = PR_2$).

The first assumption is made because of the lack of "acreage released unharvested" data in stages 1 and 2 prior to 1965 and after 1973. Table 1 shows that the number of FCIP participant farms in Knox County fell from 154 in 1967 to a mere 5 in 1979 due to the existence of the Disaster Payment Program. Thus, this study does not consider the diminished participation between 1973 and 1979 as representative of the farms in the program.

It is unclear how much of the acreage released unharvested between 1965 and 1972

TABLE 1. FEDERAL CROP INSURANCE PARTICIPATION AND ACREAGE SUMMARY FOR KNOX COUNTY, TEXAS, 1965-79

Year	Number of participants	Net acreage indemnified	Acreage released unharvested	Probability of failure in stages 1 and 2
1965	122	1,532	362	.236
1966	138	1,835	80	.044
1967	154	1,214	131	.108
1968	118	1,523	126	.083
1969	91	3,275	2,015	.615
1970	100	1,405	34	.024
1971	102	1,353	573	.424
1972	72	205	36	.176
1973	47	139	0	—
1974	27	330	0	—
1975	19	292	0	—
1976	16	0	0	—
1977	14	0	0	—
1978	8	0	0	—
1979	5	0	0	—

Source: Texas Agricultural Extension Service.

121

belongs to stage 1 or 2, so the average probability of failure for both stages was obtained from the data for this period. In the event of crop failure, and assuming equal failure probabilities in the first two production stages, the probability of failure in stage three (PR_3) is equal to $[1 - (PR_1 + PR_2)]$. Thus, the probabilities of failure in case of crop damage in stages 1, 2, and 3 are 10.7 percent, 10.7 percent, and 78.6 percent, respectively.

CHANCE CONSTRAINTS

It is necessary at this point to explain the constraints (equation (9)) which allow total sales to be limited to less than total production. Suppose that a representative farm maximizes equation (6) subject to the following chance constraints:

(16) $\text{Prob}(MX_s - NX_p \leq 0) > (1 - \gamma)$,

where the crop yields per acre are random variables distributed as $N \sim N[E(N), \Sigma_N]$. The probability statement indicates that the quantity of crop sold (MX_s), must be less than or equal to the quantity of crops produced with at least $(1 - \gamma)$ probabilities. In the terminology of stochastic programming, the probability vector $(1 - \gamma)$ is referred to as confidence levels, while its counterpart vector (γ) is called "risk levels." It is assumed that the representative farm, confronted by a risky environment, chooses risk levels acceptable to its management. The smaller the values in vector (γ), the smaller the propensity for risk-taking of the representative farm. From the theory of chance-constrained programming (Vajda, p. 78; Paris, p. 270), it can be shown that:

(17) $(1 - \gamma) = \text{prob}[MX_s - NX_p \leq 0]$,

$= \text{prob}[(-NX_p + E(N)X_p)/(X_p'\Sigma_N X_p)^{1/2} \leq T_N]$

$= \text{prob}[E(N)'X_p - T_N(X_p'\Sigma_N X_p)^{1/2} \leq NX_p]$.

The choice of T_N is made to satisfy:

(18) $\gamma = (1/\sqrt{2\pi}) \int_{-\infty}^{T_N} \exp[-(\tfrac{1}{2})w^2]dw$,

where W is a standardized normal variate and when $\gamma < \tfrac{1}{2}$, $T_N > 0$. Adapting Vajda (p. 80),

If MX_s is not larger than $E(N)'X_p - T_N (X_p'\Sigma_N X_p)^{1/2}$, it is not larger than any of those NX_p which are not smaller than $E(N)'X_p - T_N (X_p'\Sigma_N X_p)^{1/2}$, and the prob-

abilities of such NX_p are $(1 - \gamma)$. Hence, the constraints $Prob[MX_s - NX_p \leq 0] \geq (1 - \gamma)$ are equivalent to the nonstochastic constraints:

(19) $MX_s \leq E(N)'X_p - T_N(X_p' E_N X_p)^{1/2}$.

But the optimal allocation of land among crops should be derived using quadratic programming. The inclusion of the variance-covariance matrix (Σ_N) as a constraint in a QP model requires manual allocation of land to different crops and thus defeats the optimal use of land by QP, since the purpose of using the QP model is to obtain the optimal allocation of resources. The variance-covariance matrix (Σ_N) is therefore not used in these constraints. Instead, only the variance ($\sigma_{N_i}^2$) for i crop is implemented. Consequently, constraints (equation (19)) are substituted by the following constraints:

(20) $M_i X_{si} \leq E(N_i)X_{pi} - T_{N_i}\sigma_{N_i}X_{pi}$

where:

X_{pi} = acres of land allocated to crop i,

X_{si} = units of ith crop sold, and

N_i = yields obtained from ith crop per acre.

Probabilities of 90 percent, $(1 - \gamma)$, were selected for the chance constraints to assure that total crop sales through marketing activities would not exceed total production. Consequently, the values for T_{N_i} from the Table of Percentage Points of t-Distributions will be 1.282. It is important to indicate the possible relationship between confidence levels, $(1 - \gamma)$, in constraints (equation (16)) and the risk aversion coefficient "a" in equations (6) and (7). γ is a vector of probabilities for the physical realization of events which may lead to net income or debt. On the other hand, "a" is a risk-averse coefficient (RAC) for money measured in terms of dollars. No direct and explicit relationship exists between the two parameters. If such a relationship did exist, different values for "a" necessitate calculating different values for γ. However, changing the level of probabilities (γ) does shift the E-V frontier. For example, the expected net return for a specified risk aversion coefficient and given level of risk are different for various γ levels. This is an implicit relationship between γ and "a".

The choice of "a" in this study adheres to the method used by Sharpe. This approach derives E-V frontiers as the change of basis

solutions when "a" is parameterized. Various degrees of farmer risk aversion are considered given both FCIP participation and nonparticipation. Comparisons of E-V frontiers may help in deciding whether or not to be involved in the program.

It will be assumed that a farmer insures the total acreage rather than only a particular piece(s) of land. It is further assumed that the general model of expected utility maximization is sufficient for obtaining an adequate description of farmer behavior (Anderson et al., pp. 65-66).

ESTIMATED COMPONENTS OF THE QUADRATIC PROGRAMMING MODEL

Empirical implementation of the QP model requires estimating the net return vector (S) and variance-covariance matrix of net return (Q) for each activity, as well as relevant resource constraints (b) and related input-output coefficients (T). In this section, the empirical estimation of S and Q for the QP model is clarified. A total of 76 activities for cotton, wheat, and grain sorghum are included in the empirical model. Of these, only three are FCIP activities. Production activities comprise another three while the remainder consists of various marketing options. (S) represents the net return calculated for each activity.

To obtain the distribution of net returns per unit (S) for each activity in the model, a simulation model is used. The Monte Carlo approach estimates the net return vector(s) and a variance-covariance matrix of net returns (Q) for 76 activities. The expected value and variance of net returns for each activity were estimated for a representative farm, assuming both participation and non-participation in FCIP. A set of time series data of net returns for all activities undertaken by the representative farm is constructed for the Monte Carlo simulation. Based on actual historical relationships (1965-1979), these data are instrumental in building the mean vector and variance-covariance matrix of net returns. Use of simulation is prompted by the fact that yield and price distributions are multiplied and truncated to obtain the distribution of net returns (See Falatoonzadeh for details.)

The ability of Monte Carlo simulation to implement any objective function makes computing a utility function defined in terms of mean and variance of net returns an easy task. The simulation model used herein is especially advantageous in that it enables exploration of the consequences of stochastic dependence resulting from the interdependence of several variables (i.e., yield and prices on hedging, forward pricing and seller's call contracting, storage activities, and cash sales). Thus, simulation seems to indirectly handle the correlation among the variables through hierarchical structures of dependency. In this study, net returns for (n) years have been simulated, Figure 1. A sample size of 170 observations was chosen after the authors determined that tested increases in the sample size (n=185; n=200) effected no significant changes in net return while incurring greater computer costs.
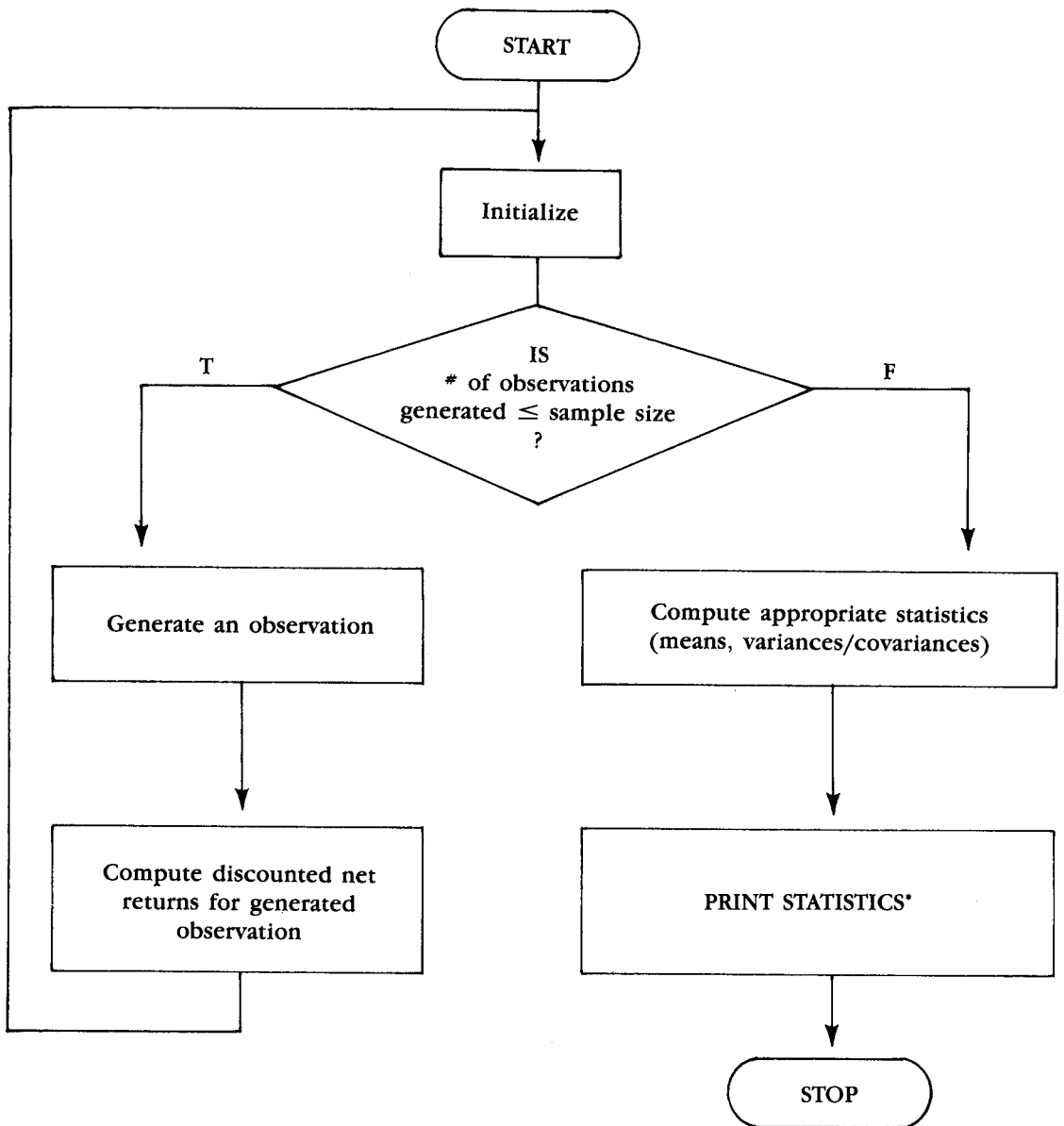
It is important to note that all prices and costs have been discounted to the same period in order to ensure consistency in monetary value. September, 1979 was targeted as the discount period since that was the earliest planting season (for wheat) for the crops under consideration. Discounting facilitates production and marketing decisions by providing a present value of net return basis.

CALCULATION OF PROBABILITY DISTRIBUTION OF PRICES AND YIELDS

Simulation is used extensively in specifying the model for a representative farm in Knox County, Texas and for using the model to evaluate various risk-reducing strategies. Such simulation necessitates generating crop yields and prices characteristic of Knox County's dryland conditions. Yields and output prices are considered to be the only sources of net return variability in this study. Therefore, yield and output price are treated as random variables, and input prices are assumed to be known.

As was indicated earlier, crop yields are prone to unpredictable or random variation due to numerous factors. It follows, then, that control over any one of these factors results in a lesser degree of yield variation. The prevailing assumption here is that future variability of a particular crop is closely related to past variability. The time trend method can be implemented when yields are regressed with regard to time if the following estimating equation is employed:

(21) $y = a + bT + \varepsilon,$

123

Figure 1. Flow Chart of Expected Net Returns Per Unit of Activity Using Monte Carlo Simulation.

The flowchart contains the following elements:

START

Initialize

IS
# of observations
generated ≤ sample size
?

T — Generate an observation → Compute discounted net returns for generated observation

F — Compute appropriate statistics (means, variances/covariances) → PRINT STATISTICS* → STOP

* Some of the statistics are written directly into disc files to facilitate easy access for Quadratic programming.

where: (y) is yield, (a+bT) is the mean yield in year T, (ε) represents the residuals, and a and b are parameters.

Hedging decisions are based upon price expectations and available information, namely current and past spot prices, and futures prices. These price data may offer the best estimate of harvest price because they are the only information available for predicting harvest price at planting time. Finding the conditional distribution of cash prices at harvest, given futures prices and the cash price at planting is necessary. Rockwell and Telser's conclusion that futures prices are unbiased estimates of subsequent spot prices will be adopted. The following notation defines the basis, or the difference between the cash and futures prices, for two periods, hedging and harvesting:

$$(22) \quad Basis_t = FP_{t,t+i} - CP_t$$

and

$$(23) \quad Basis_{t+i} = FP_{t+i,t+i} - CP_{t+i}$$

where:

CP_{t+i} = Cash or spot price at time t+i, i.e., harvest time,

CP_t = Cash price at time t, i.e., planting time,

$FP_{t+i,t+i}$ = Futures price at time (t+i), contract maturity at time (t+i),

$FP_{t,t+i}$ = Futures price at time t, contract maturity at time (t+i), ith time in the future,

$Basis_{t+i}$ = Basis at time (t+i), i.e., at harvest time, and

$Basis_t$ = Basis at time t, i.e., at planting or hedging time.

Because of location or grade differences, the basis at time (t+i) may not be zero.

The spot price can be obtained by subtracting equations (22) and (23):

$$(24) \quad CP_{t+i} = \Delta FP + \Delta Basis + CP_t$$

where:

$\Delta Basis$ = a column vector of changes in the basis for the three crops and

ΔFP = a column vector of changes in the futures prices between two periods of time for the three crops.

The ΔFP and $\Delta Basis$ are assumed to be normally distributed.

Equation (24) is an identity. In order to find the conditional distribution of the spot price given the cash and futures prices at planting, ΔFP and $\Delta Basis$ are assumed to have linear relationships with the cash and futures prices at the time of planting. Thus,

$$(25) \quad \Delta FP = a_1 + a_2 FP_{t,t+i} + a_3 CP_t + e_1$$

and

$$(26) \quad \Delta Basis = b_1 + b_2 FP_{t,t+i} + b_3 CP_t + e_2.$$

If equations (25) and (26) are substituted into identity equation (24), it can be concluded that the distribution of spot prices depends on both the cash and futures prices at planting, or:

$$(27) \quad D(CP_{t+i}) = f(CP_{t+i}/FP_{t,t+i}, CP_t).$$

Using identity equation (24) allows calculation of ΔFP and $\Delta Basis$ and, more importantly, it generates the random cash prices, futures prices, and bases at harvest. Estimates of the latter two at harvest allow the farmer to decide at planting time when to hedge and set forward contract and seller's call contract prices.

The distributions of the residuals (e_1 and e_2) of the ΔFP equation and $\Delta Basis$ equation indicate the distribution of the changes in both the basis and futures prices, respectively. These residuals are therefore utilized in variance-covariance matrices to randomly generate changes in bases and futures prices because the spot and futures prices at harvest are unknown. Thus, the harvest price distribution will be conditional upon the futures and cash prices observed at planting. The variance-covariance matrix of the yield equation residuals, the futures price change residuals, and the basis change residuals are used to randomly generate yields, changes in prices, and changes in the basis by the simulations. Equations (21), (25), and (26) are used to obtain the variance-covariance matrix. Seemingly Unrelated Regression is used to obtain the variance-covariance matrix and asymtotic efficient estimates of parameters involved in these equations.

RESULTS

Linear programming (LP) results reflect the behavior of a risk-neutral farm in selecting different marketing strategies for selling its crops. These results show that the expected

net returns for FCIP participants are higher than those for nonparticipants. The higher the production and price election protection levels, the higher the expected net returns for a farm involved in FCIP. As anticipated, the LP solutions indicate that total acreage is allocated only to cotton, the highest risk crop analyzed.

Quadratic Programming (QP) results show that the risk aversion coefficient (RAC) is an important factor in determining marketing and production strategies. These strategies vary markedly as the RAC changes. The extreme RAC values relate to either variance minimizing or expected profit maximizing behavior. The lowest RAC value (a = .000020) is associated with an expected profit maximum while the highest RAC (a = .001250) represents the minimum variance for a given portfolio.

Allocation of land among different crops varies depending upon the FCIP participation status of a given farm. Less land is allocated to wheat production under FCIP participation. Thus, wheat sales made via hedging do not change. More land is allocated to cotton production under FCIP participation, causing a definite impact on the implementation of seller's call contracting. The percentage of total cotton sales made via seller's call contracting remains constant, however, regardless of the producer's FCIP participation status. Grain sorghum production appears to increase given FCIP participation, boosting the quantity sold via hedging as a consequence. As both the protection and price election levels increase, the quantity hedged increases. Alternatively, decreasing RAC levels reduce land allocation to grain sorghum production, thereby reducing the quantity of grain sorghum hedged.

The QP results show that expected net returns are affected by participation in the Federal Crop Insurance Program. Participants receive a higher expected net return than nonparticipants for all risk aversion coefficient levels. Expected net returns to a non-participant farmer vary between $5,646 and $22,566. By contrast, a participant receives between $7,031 and $24,612 for low protection levels (50 percent), and $10,124 to $36,417 for high ones (75 percent). These results appear to indicate that FCIP is beneficial to farmers. However, the level of risk entailed in higher expected returns may be questioned. As expected, the variance under FCIP participation decreases steadily as the guarantee level increases.

A comparison of expected returns, variances of returns and expected utilities for dual and triple crop production reveals several benefits of diversification. A substantial increase in variance for the same level of expected return is observed under dual crop production as compared to triple crop production for various levels of RAC's. Also, expected utilities for a dual crop production program possess a wider variation range than that of the triple crop production process. Thus, diversification reduces risk and expected utility variation for different RAC levels.

TABLE 2. EXPECTED UTILITIES AND COEFFICIENTS OF VARIATION FOR FCIP NONPARTICIPANT FARMS IN KNOX COUNTY, TEXAS, 1980

OBS	RAC	EXPU1	COFV1
			percent
1	0.001250	−295,694	389
2	0.000960	−225,773	383
3	0.000750	−175,118	376
4	0.000500	−114,756	360
5	0.000375	−84,420	309
6	0.000250	−53,677	275
7	0.000210	−43,774	267
8	0.000170	−33,815	257
9	0.000130	−23,747	243
10	0.000110	−18,636	234
11	0.000090	−13,427	232
12	0.000080	−10,763	222
13	0.000070	−8,037	216
14	0.000050	−2,244	208
15	0.000045	−668	189
16	0.000040	995	178
17	0.000030	4,756	167
18	0.000025	7,028	162
19	0.000022	8,620	160
20	0.000020	9,823	158

OBS	RAC	EXPU2	COFV2
			percent
1	0.001250	−261,648	295
2	0.000960	−199,303	291
3	0.000750	−154,135	287
4	0.000500	−100,302	277
5	0.000375	−73,248	247
6	0.000250	−45,783	222
7	0.000210	−36,917	216
8	0.000170	−27,989	209
9	0.000130	−18,947	199
10	0.000110	−14,344	192
11	0.000090	−9,642	184
12	0.000080	−7,228	179
13	0.000070	−4,746	174
14	0.000050	574	161
15	0.000045	2,033	158
16	0.000040	3,583	154
17	0.000030	7,139	148
18	0.000025	9,325	145
19	0.000022	10,874	144
20	0.000020	12,056	144

Exponential utilities have been calculated for both FCIP participation and nonparticipation for a representative farm in Knox County. The inverse relation between expected utility and risk aversion is suggested by utility theory. The relationship is shown in Table 2; that is, the expected utility (EXPU1) for nonparticipation varies from about -295,694 to 9,823 for the various RAC values. The lower the level of absolute risk aversion, the higher the expected utility.

Expected utility for FCIP participant farms displays a lower range for the different participation options as opposed to nonparticipation, Table 3. Negative expected utilities are found for high to moderate levels of risk aversion, but positive values prevail for very low risk levels. The specific expected utility (EXPU2) range for 50 percent guaranteed production starts at -261,648 and goes up to 12,056. Thus, expected utility varies much more widely under FCIP noninvolvement than for involvement. Participation brings about a lower expected utility for high and moderate levels of risk aversion, while nearly risk-neutral and neutral farmers experience high levels of expected utility under FCIP participation. These levels increase as production and price election protection levels increase, Table 4.

The Federal Crop Insurance Program is the point of controversy as some economists debate whether it has successfully fulfilled its original purpose of reducing production risk for farmers. Results of this study bolster the argument that FCIP is indeed an effective means of production risk reduction. A comparison of the coefficients of variation (CV) of net returns for FCIP participants versus nonparticipants can be found in tables 2-4 (COFV1, COFV2, COFV10). These coefficients represent a specific risk level for a given net return mean and standard deviation. The CV value for FCIP nonparticipants ranges from 389 percent to 158 percent, COFV1, Table 2. As a farmer's risk aversion coefficient (RAC; column A) decreases, the CV value decreases.

Table 3 represents the minimal production guarantee, 50 percent, for FCIP participants. For RAC's between .00125 to .000020, participant CV values are less than those for nonparticipants, indicating a lower risk level. Nonparticipant farmers bear more risk as the RAC decreases.

What is the effect when the production guarantee level is increased? Table 4, Option 9 represents a production guarantee level of 75 percent. Again, participant CV values are lower than those for nonparticipants. This pattern held for all nine FCIP options. Thus, it was concluded that FCIP participation does reduce risk under production protection levels of 50 percent or greater.

CONCLUSIONS

This study has investigated five of the most widely used risk management tools available to agricultural producers in order to discover the most effective strategy for minimizing the variability of net farm income. With assumptions of random production and output prices

127

TABLE 4. EXPECTED UTILITIES AND COEFFICIENTS OF VARIATION FOR PARTICIPATING FARMS IN OPTION (9) OF FCIP, KNOX COUNTY, TEXAS, 1980

OBS	RAC	EXPU10	COFV10
			percent
1	0.001250	−171,520	168
2	0.000960	−129,378	168
3	0.000750	−98,794	163
4	0.000500	−62,267	152
5	0.000375	−43,679	135
6	0.000250	−24,479	122
7	0.000210	−18,222	120
8	0.000170	−11,863	116
9	0.000130	−5,326	112
10	0.000110	−1,932	109
11	0.000090	1,622	106
12	0.000080	3,495	104
13	0.000070	5,468	102
14	0.000050	9,955	100
15	0.000045	11,276	99
16	0.000040	12,738	99
17	0.000030	16,359	100
18	0.000025	18,799	102
19	0.000022	20,629	104
20	0.000020	22,045	104

coupled with certainty of input prices and quantities, a normative programming model for a simulated dryland farm in Knox County, Texas was developed and tested. The results indicate that active involvement in FCIP, particularly at high production guarantee and price election levels, motivates futures market participation for the QP selected crop(s). Futures markets offer farmers a viable tool for minimizing price uncertainty. Wheat and grain sorghum sales transacted via hedging, and cotton sales made through seller's call contracting guarantee the producer a set price for the crop despite market fluctuations.

The variation of expected utility is reduced under crop diversification and a higher expected net return for a given level of risk is achieved. Thus, FCIP participation coupled with involvement in futures markets and a diversified crop production plan comprise the optimal risk management strategy for dryland farmers in Texas.

The risk aversion coefficients (RAC) play a significant role in determining optimal marketing and production strategies. An individual farmer's risk aversion coefficient, or attitude toward risk, greatly influences the farm's expected net return. The smaller the RAC levels, the greater the farm's expected net returns for FCIP participants. Nonparticipants have a lower expected return for all RAC levels. Thus, FCIP appears to be a beneficial strategy for a representative farm in Knox County, Texas.

The chance constraints implemented in this study created some limitations for the model. These constraints resulted in the percentage of sales of total production through various marketing strategies at different levels of risk aversion coefficients being held constant. This limitation arises because the risk levels (γ) were held constant for various levels of risk aversion coefficients (a). But γ may vary at different levels of (a). As explained earlier, (a) and γ may not be directly or explicitly related; however, changing γ and/or (a) shift the E-V frontiers. One solution to this problem may be to parameterize γ at various levels of (a). However, the problem needs further research in order to explain the relationship of γ and (a).

In the final analysis, the education endeavor to inform farmers about FCIP and futures market mechanics should not only be continued, but should receive more emphasis. Farmers should be made aware that negligence of the opportunity to take advantage of these effective tools is the most risky production and marketing strategy of all. However, caution must be taken to find those participation levels which are most beneficial to the individual producer. Farmers should be encouraged to see the whole portfolio management picture. These educational efforts should stress to farmers the equal importance of production and marketing diversification, and the effectiveness of FCIP and futures markets in accomplishing these endeavors.

REFERENCES

Anderson, Jock R., John L. Dillon, and Brian Hardaker. *Agricultural Decision Analysis,* Ames, Iowa: The Iowa State University Press, 1st ed., 1977.

Batra, Raveendra N. *The Pure Theory of International Trade Under Uncertainty,* New York, New York: John Wiley and Sons, 1975.

Batra, Raveendra N. and Aman Ullah. "Competitive Firm and the Theory of Input Demand Under Price Uncertainty." *J. Polit. Econ.,* 83(1974):537-48.

Berck, Peter. "Portfolio Theory and the Demand for Futures: Theory and the Case of California Cotton." *Amer. J. Agr. Econ.,* 63(1981):466-74.

Bray, Margaret. "Futures Trading, Rational Expectations, and the Efficiency Markets Hypothesis." *Econometrica,* 49(1981):575-96.

Chavas, Jean-Paul and R. D. Pope. "Hedging and Productive Decisions Under a Linear Mean-Variance Preference Function." paper in press, Dept. of Agr. Econ., Texas A & M University, 1982.

Danthine, J. P. "Information, Futures Prices and Stabilizing Speculation." *J. Econ. Theory,* 17(1978):79-98.

Falatoonzadeh, Hamid. "An Analysis of the Role of Futures Markets and Federal Crop Insurance in Risk Management." Ph.D. dissertation, Texas A & M University, 1983.

Feder, G., R. E. Just, and A. Schmitz. "Futures Markets and the Theory of the Firm Under Price Uncertainty." *Quart. J. Econ.,* 44(1980):317-28.

Freund, R. J. "The Introduction of Risk into a Programming Model." *Econometrica,* 24(1956):253-63.

Gardner, Bruce L. and Randall A. Kramer. "The U.S. Experience in Crop Insurance Programs." presented paper at the Conference on Agricultural Risks, Insurance, and Credit in Latin America, San Jose, Costa Rica, February, 1982.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning Under Uncertainty." *Amer. J. Agr. Econ.,* 53(1971):53-62.

Holthausen, D. "Hedging and the Competitive Firm Under Price Uncertainty." *Amer. Econ. Rev.,* 69(1979):989-95.

Lin, William, G. W. Dean, and C. V. Moore. "An Empirical Test of Utility Vs. Profit Maximization in Agricultural Production." *Amer. J. Agr. Econ.,* 56(1974):497-508.

Mapp, Harry P., Jr., Michael L. Hardin, Odell L. Walker and Tillak Persaud. "Analysis of Risk Management Strategies for Agricultural Producers." *Amer. J. Agr. Econ.,* 63(1979):1,071-77.

Markowitz, Harry. *Portfolio Selection, Efficient Diversification of Investments,* New Haven, CT: Yale University Press, 1970.

McKinnon, R. I. "Futures Markets, Buffer Stocks, and Income Stability for Primary Producers." *J. Polit. Econ.,* 75(1967):844-6.

Musser, Wesley N. and Kostas G. Stamoulis. "Evaluating the Food and Agriculture Act of 1977 with Firm Quadratic Risk Programming." *Amer. J. Agr. Econ.,* 63(1981):447-56.

Newberry, David M. G. and Joseph E. Stiglitz. *The Theory of Commodity Price Stabilization,* New York, New York: Oxford University Press, 1981.

Paris, Quirino. "Revenue and Cost Uncertainty, Generalized Mean-Variance, and the Linear Complementarity Problem." *Amer. J. Agr. Econ.,* 61(1979):268-75.

Peck, Anne E. "Hedging and Income Stability: Concepts, Implications and an Example." *Amer. J. Agr. Econ.,* 90(1976):407-23.

Pope, Rulon D. and Randall A. Kramer. "Hedging and Risk." Unpub. Paper, Dept. of Agr. Econ., University of California, Davis, California, 1978.

Pope, Rulon D. and Randall A. Kramer. "Production Uncertainty and Factor Demands for the Competitive Firm." *So. Econ. J.,* 46(1979):489-501.

Porter, R. B. and J. E. Gaumnitz. "Stochastic Dominance vs. Mean-Variance Portfolio Analysis: An Empirical Evaluation." *Amer. Econ. Rev.,* 62(1974):438-46.

Rae, Allan N. "An Empirical Application and Evaluation of Discrete Stochastic Programming in Farm Management." *Amer. J. Agr. Econ.,* 53(1971):625-38.

Ratti, Ronald A. and Aman Ullah. "Uncertainty in Production and the Competitive Firm." *So. Econ. J.,* 42(1976):703-10.

Robison, Lindon J. and John R. Brake. "Application of Portfolio Theory to Farm and Lender Behavior." *Amer. J. Agr. Econ.,* 61(1979):158-64.

Rockwell, Charles S. "Normal Backwardation, Forecasting and the Returns to Commodity Futures Traders." *Food Res. Inst. Stud.,* supplement to 8(1967):107-30.

Rolfo, Jacques. "Optional Hedging Under Price and Quantity Uncertainty: The Case of the Cocoa Producers." *J. Polit. Econ.,* 88(1980):100-16.

Rutledge, David J. "Hedgers' Demand for Future Contracts: A Theoretical Framework with Applications to the United States Soybean Complex." *Food Res. Inst. Studies,* 11(1972):237-56.

Sandmo, A. "Competitive Firm Under Price Uncertainty." *Amer. Econ. Rev.,* 61(1971):65-73.

Sharpe, William F. *Portfolio Theory and Capital Markets,* New York, NY: McGraw-Hill Book Co., 1970.

Telser, Lester G. "The Supply of Speculative Services in Wheat, Corn and Soybeans." *Food Res. Inst. Stud.,* supplement to 8(1967):131-76.

Texas Agricultural Extension Service. *Crop Insurance Analysis Sheet 2- Participation and Acreage Summary,* Texas A & M University, College Station, Texas; March, 1981.

Vajda, S. *Probabilistic Programming,* New York, New York; Academic Press, 1972.

Von Neumann, J. and O. Morgenstern. Theory of Games and Economic Behavior. Second ed., Chapter 3 and Appendix. Princeton, New Jersey: Princeton University Press, 1947.

Wiens, Thomas B. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." *Amer. J. Agr. Econ.,* 48(1976):629-43.