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IMPACT OF FEDERAL CROP INSURANCE ON OUTPUT MIX AND WELFARE

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IMPACT OF FEDERAL CROP INSURANCE
ON OUTPUT MIX AND WELFARE

by

Yao Kouadio

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As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Yao Kouadio

entitled Impact of Federal Crop Insurance on Output-Mix and Welfare

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ABSTRACT

The Federal Crop Insurance program is a management tool which is available to U.S. farmers and which is designed to protect them against low yields arising from natural disasters. Since the program is optional in nature, its provision cannot be detrimental to a rationally behaving farmer.

This work analyzes but goes beyond the private benefits of the Federal Crop Insurance program to farmers and represents a qualitative and quantitative attempt at investigating the implications of the availability of the program on risk-taking behavior and social welfare.

Analytically, a simple model of the allocation of land among two crops (one safe and the other risky in the yield) is used along with the behavioral hypothesis of expected utility maximization. It is indicated that a subsidized program will, in general, induce greater risk-taking behavior. The impact of the program on crop-mix is, however, ambiguous when the expected insurance indemnities fall short of the premium paid. Given insurance availability, however, it is demonstrated that, under some reasonable assumptions about farmers' risk preferences, a premium subsidy will tend to induce greater risk taking.

A major portion of the empirical work, which is undertaken within an expected value of income-variance of income framework, relates to the estimation of farmers' risk preferences on the basis of actual crop-mix

data for individual farms in Arizona and estimated subjective distributions about prices, yields and costs of production. The estimation of the subjective distribution of prices is based on futures as well as cash prices. Given the risk aversion coefficient estimates for a sample of thirteen farmers, predicted crop-mixes are then obtained under the cases of insurance availability and no insurance.

Results of the empirical study suggest that the Federal Crop Insurance program (in its pre-1980 version at least) does not have a significant impact on crop-mix. Finally, using the Arrow-Lind criterion of welfare assessment under uncertainty, the study casts doubt on the social desirability of the Federal Crop Insurance program.

CHAPTER 1

INTRODUCTION

A farm unit operates in an environment of high uncertainty. In addition to being susceptible to a host of social and economic uncertainties, e.g., fire, technological change, and fluctuations in prices, a farm business is susceptible to the vagaries of weather and also to the risks arising from insects and plant diseases. Natural risks have obvious impacts on crop yields and capital stocks; but superimposed on natural risks are what Gardner (1978) labels policy-induced risks, i.e., risks in agriculture induced by policy directed at agricultural and non-agricultural goals.

More than twenty years ago, Ray (1958, p. 23) observed that although agriculture is undeniably a risky venture, "human ingenuity has not failed to derive ways and means to reduce risks or to mitigate their results." One such means of reducing risks, which has received policy attention in the United States, is provided by the Federal Crop Insurance program (FCI).

The FCI program was implemented in 1938 to complement private crop insurance since the latter was not offered on a number of risks, such as drought, which tend to affect a large number of farms during a given period (Miller and Trock, 1979).

Although the FCI program was initially provided for wheat only, it was progressively extended to other field crops. It offers all-risk coverage, i.e., it covers unavoidable losses due to factors such as unfavorable weather, insect infestation and plant diseases. The FCI program does not, however, cover losses due to poor management and low market prices. As in most insurance schemes, the decision to participate in the federal crop insurance program is voluntary. A farmer who elects to be covered must pay a premium that is based on the coverage percentage that he selects as well as the risk inherent in his farming activity. By way of illustration, the main features of the FCI program as it existed prior to 1980 can be sketched as follows.

Suppose that a farmer grows wheat with an average or normal yield of 40 bushels per acre and a market price of $2.50 per bushel. Under the FCI program, as it existed in 1977 for instance, the farmer could elect to purchase no policy or to choose a 75 percent coverage on the normal wheat yield. With a 75 percent coverage and a normal yield of 40 bushels per acre, the guaranteed yield is 30 bushels per acre. Three price elections, that is, payment rates used to compute insurance indemnities are provided with premium levels varying with the price election. Assume that the given farmer opts for coverage and that he chooses a price level of $2.00 per bushel. If actual yield happens to be 20 bushels per acre, the farmer receives $20 in insurance benefits ($2 per bushel times the difference between the guaranteed yield of 30 bushels per acre and actual yield). In addition, the farmer receives $50 per acre as gross revenue per acre for selling 20 bushels per acre at the market price of $2.50 per bushel. If actual yield is above the guaranteed yield of 30 bushels per acre, the farmer does not receive any insurance benefit.

It is generally believed that the FCI program tends to reduce risk to the farmer and therefore is desirable. Much of the debate concerning the FCI program has, however, centered on the magnitude of federal budget outlays and the inadequacies inherent in the implementation of the program. It is not suggested here that either the costs of federal crop insurance or problems related to its implementation lack relevance. It is noted, however, that there are a host of equally important questions which have lacked systematic and rigorous examination. Among these, Miller (1979) suggests the following: should the federal government provide insurance that the private sector is reluctant to offer; how does federal crop insurance affect crop-mix; does it inappropriately encourage production in high-risk areas and does it decrease the need for diversification and thereby provide an unnecessary substitute for other risk-reducing strategies?

A few recent studies seem to suggest that the federal government should provide crop insurance. In a study based on a single-crop representative farm in Weld County (Colorado), King and Oamek (1981) attempt to evaluate the role of the Federal Crop Insurance program and the Agricultural, Stabilization, and Conservation Service (ASCS) programs in the risk management strategies of farmers. The ASCS programs feature two main components:

- Deficiency payments, which are made to an eligible farmer when the average market price for a commodity falls below the target price.

- Disaster assistance, which is provided for either prevented plantings or low yields.

King and Oamek consider the following alternatives:

1. No participation in either the ASCS program or FCI.
2. Participation in the ASCS program but no insurance coverage.
3. Participation in the ASCS program with purchase of federal crop insurance.
4. Purchase of crop insurance coupled with participation in the ASCS program but with disaster assistance waived.
5. Purchase of crop insurance and no participation in the ASCS program.
6. Participation in the ASCS program alone but with no disaster assistance.

Using a simulation model, King and Oamek's empirical analysis suggests that risk neutral (or expected profit maximizing) decision makers would prefer strategy (1); low risk averse individuals (risk averters being those preferring a certain prospect to a stochastic prospect with the same expected value) would choose alternatives (2) and (3); and moderate and high risk averters would prefer strategy (2). Their findings further indicate that elimination of the disaster assistance program would make most farmers worse off.

Kramer (1981) has also studied the ASCS and FCI programs. Using a single-crop representative farm model for Loudon County (Virginia), Kramer confronts farmers with the following alternatives:

1. Purchase federal crop insurance only.
2. Purchase federal crop insurance and participate in the ASCS commodity program and forego disaster assistance (with a premium subsidy on insurance).
3. Purchase crop insurance (with no subsidy on the premium) and participate in the ASCS program.
4. No participation in either program.

The results of Kramer's investigation suggest that all risk averse utility groups would prefer strategy (2) over (1); highly risk averse decision makers would prefer (3) to (1); and all risk averse decision makers would choose (1) over (4). He concludes that crop insurance can be an attractive option for farmers.

Going beyond the single-crop case, Musser and Stamoulis (1981) attempt to evaluate the ASCS programs without federal crop insurance as an alternative. Using quadratic programming and a representative farm model, they derive efficiency frontiers (i.e., loci of trade-offs between expected net returns and variance of net returns) with and without participation in farm programs. Under a set of arbitrary risk aversion coefficients, their results indicate that risk averse farmers would prefer participation to non-participation in farm programs. Musser and Stamoulis (p. 453) claim, consequently, that their study "has provided empirical support for the widely held view that government agricultural commodity programs reduce the risks faced by farmers." A notable deficiency in their analysis is that different sets of values of the risk aversion coefficient are used under participation and no participation. Also, in their own concluding notes, Musser and Stamoulis observe that their results seem to be inconsistent with actual crop-mix in the area of study (South Central Georgia).

A question worth asking with respect to the above empirical studies relates to their theoretical underpinning. Apart from Pope and Gardner's hint within a stochastic dominance theory framework that participation in farm programs is preferred to non-participation in the simple case where there is no cost to participation (1981), the theoretical literature on the impact of farm programs in general and the FCI program in particular seems to be lacking. A possible reason for the paucity of literature on the FCI is that it tends to be associated with private insurance in general. The arguments put forward to defend private insurance are certainly not lacking and are quite convincing. At the individual level, it is argued that a contract freely arrived at between two rationally behaving private economic agents must be necessarily beneficial to both parties. To substantiate that idea, an argument originating from Friedman and Savage (1948) is usually offered: it is indicated that if an individual is averse to risk, the maximum premium he would be willing to pay (i.e., the premium where the individual would just be indifferent between coverage and no coverage) is greater than the actuarial value of the loss he would suffer; it follows that, if administrative costs are sufficiently small, the insurance firm will have an opportunity to make a profit without the buyer of insurance being worse off as compared with the precontract situation. At a broader level, Arrow (1964) and Debreu (1959) show that in a context of risk, contingent markets such as insurance can help achieve Pareto optimality. In the Arrow-Debreu world each economic agent selects a strategy where a market exists for delivery of each commodity at each date conditional on each state of nature and there is a price for delivery of each commodity conditional on each state of nature. Given such a framework, Arrow and Debreu demonstrate that there exists an equilibrium and that the provision of insurance is Pareto-optimal. Two basic limitations of the Arrow-Debreu model are that it requires the existence of too many contingent markets and, as Radner (1968) suggests, it breaks down if individuals have limited computational abilities. Also, the analysis assumes that insurance reduces risk to zero. As will be made explicit in the ensuing chapter, federal crop insurance is probabilistic in nature; i.e., it involves a choice between two uncertain prospects instead of a choice between an uncertain prospect and a safe one. In addition, since the FCI program is based upon law, the motives of the seller (the government in this case) can be quite distinct from those of a private insurance firm. The problem needs to be examined more closely before agreeing with Arrow (1963, p. 961) that "the welfare case for insurance policies of all sorts is overwhelming. It follows that the government should undertake insurance in those areas, where this market, for whatever reason, has failed to emerge."

A theoretical model is developed in the chapter that follows that explicitly incorporates some of the features of the FCI program. Under the premise that the purpose of the program is to induce risk shifting, an attempt is made to determine the impact of FCI on crop-mix and risk-taking behavior. In addition, the relationship between the cost of insurance and the demand for coverage is studied. Furthermore, some observations are made on compulsory crop insurance. Although there are no compulsory provisions in the FCI program, they have been suggested from time to time to alleviate the problem of low participation in the current program. At the empirical level the aim is to determine the implications of federal crop insurance availability on output-mix and risk taking for selected Arizona farmers and to evaluate the social desirability of the FCI program. Procedures of estimation are presented in that regard in the third chapter, and the fourth chapter analyzes the results derived therefrom. Implications of this study, as well as suggestions for further work, are presented in the fifth chapter.

CHAPTER 2

ASPECTS OF THE THEORY OF FEDERAL CROP INSURANCE

General Framework

Since the federal crop insurance program is aimed at altering the risk environment faced by farmers, a framework of completely known outcomes would obviously be inadequate. It will be assumed that a farmer maximizes the expected value of a von Neuman-Morgenstern utility function of returns above variable costs, hereafter referred to as profits.

Let

$$E[U(\pi)|\alpha] \equiv \int_{\pi} U(\pi)d\alpha(\pi) \qquad (2.0)$$

where

E = the expectation operator

$U(\pi)$ = a real-valued function defined on profits, π

$\alpha(\pi)$ = a probability distribution defined on profits.

Letting $\alpha_1, \alpha_2, \ldots, \alpha_n$ denote n such probability distributions, the expected utility hypothesis asserts that the preferred distribution, α^*, is the one which yields the highest value of $E[U(\pi)]$ in Equation (2.0) (McCall, 1971).

Let > and = indicate "preferred to" and "indifferent to" respectively and consider three probability distributions: α_1, α_2 and α_3. Then, the axioms underlying the expected utility theorem are as follows:

1. completeness in the preference ordering and transitivity of the ordering; that is,

   either $\alpha_1 \geq \alpha_2$ or $\alpha_2 \geq \alpha_1$ and if $\alpha_1 \geq \alpha_2$ and $\alpha_2 \geq \alpha_3$, then $\alpha_1 \geq \alpha_3$,

2. continuity of the preference ordering; that is, if $\alpha_1 > \alpha_2$ and $\alpha_2 > \alpha_3$, then there exists a constant c, $0 < c < 1$, such that $c\alpha_1 + (1-c)\alpha_3 = \alpha_2$; and

3. independence; that is, if $\alpha_1 > \alpha_2$, then $c\alpha_1 + (1-c)\alpha_3 > c\alpha_2 + (1-c)\alpha_3$, given $c > 0$.

The adequacy of the above axiomatic system has been questioned by various researchers. Tisdell (1968, p. 26), for instance, claims that "the utility axiom of continuity is dubious" and that a given individual "may, if he has the choice, be unprepared to participate in a lottery in which a possible outcome could involve him in starvation, bankruptcy, or a tremendous fall in social status." Others critical of the expected utility hypothesis have focused their attention almost exclusively on the independence axiom, i.e., the axiom which asserts that there is independence between beliefs and values. Allais (1953), for example, contends through empirical studies that there is a systematic deviation between individual observed choices and the pattern suggested by von Neumann and Morgenstern.

Refutations of the expected utility maxim make it only improbable and not false with uncertainty (Kemeny, 1959). In addition, from a positivistic standpoint, a test of the implications of the theory would be desirable. Studies by Mosteller and Nogee (1951), Davidson, Suppes and

Siegel (1957), for instance, would seem to indicate that people behave as if they maximized expected utility. Furthermore, recent works by Machina demonstrate that "while the independence axiom (and hence the hypothesis of expected utility maximization) may not be empirically valid, the implications and predictions of those theoretical studies which use the expected utility analysis in general will be valid, provided preferences are smooth" (1979, p. 5).

Alternatives to the expected utility hypothesis are numerous and include Allais' new foundation of utility theory (1953), Handa's certainty-equivalence theory (1977), Kahneman and Tversky's prospect theory (1979) and a number of rules of thumb known as safety-first models (e.g., Mao, 1970), some of which have been shown to be special cases of the expected utility hypothesis (Fishburn, 1977). In Allais' theory, an individual maximizes a preference function given by:

$$V = h(M, \sigma^2) \tag{2.1}$$

where

$M = \sum_i \alpha_i \, S(g_i)$

$\sigma^2 = \sum_i (S(g_i)-M)^2$

α_i = the probability associated with the ith state of nature

S = a utility function

g_i = the outcome resulting from the ith state of nature

h = a weakly constrained psychological function

In prospect theory, the individual maximizes,

$$V = \sum_i f\,(\alpha_i)\; U(g_i) \tag{2.2}$$

where

g_i = defined above

U = a utility function

f = generally a non-linear function of probabilities, α_i

It should be obvious from the above formulations that the expected utility hypothesis is a special case of (2.1) and (2.2) where $h(M, \sigma^2) = M$ and $f(\alpha_i) = \alpha_i$, respectively. Although more general in that sense, the predictive power of the above alternatives to the expected utility maxim remains to be seen. As Ahmihud (1979a) contends, Allais' theory only describes _ex post_ why choices are made in a certain way but fails to predict those choices _ex ante_. The same observation applies to Kahneman and Tversky's theory. Given that the function h is left unspecified in (2.1), Ahmihud (1979b, p. 186) suggests: "Thus, the harmony of the theory with reality is guaranteed under any circumstances; the theory cannot be put to test against reality, and can never be refuted." In Handa's certainty-equivalence theory, the preference function is linear in the outcomes but non-linear in the probabilities. As such, it could be viewed as a special case of (2.2).

The above remarks are intended to suggest that the expected utility hypothesis remains an acceptable theory in a framework of risk. It is worth recalling Kuhn's words in that context: "The act of judgment that leads scientists to reject a previously accepted theory is always based upon more than a comparison of that theory with the world. The decision to reject one paradigm is always simultaneously the decision to accept another and the judgment leading to that decision involves the comparison of both paradigms with nature and with each other" (1970).

Before specifying a model of federal crop insurance in the ensuing sections, it is worth sketching the general framework of analysis. It is assumed that there are two states of nature resulting in low and high yields, respectively. Although the model to be described could readily incorporate other farm programs, the framework includes only federal crop insurance. The feasible acts for a given farmer are:

- Select a crop-mix with the purchase of insurance.
- Select a crop-mix with no insurance.

The consequences under each set of decisions are profits in the low- and high-yield states of nature. The probability of occurrence of a given state of nature is assumed to be given. The latter assumption rules out problems associated with the moral hazard factor, i.e., where the purchase of an insurance policy induces the holder of the policy to alter the probability of occurrence of a given state of nature (e.g., arson in the case of fire insurance or careless driving under car insurance).

An attempt is made at deriving the theoretical implications of federal crop insurance availability within an expected utility framework in the ensuing sections. The first variant of the model focuses on the case of a constant marginal cost in acreage while the second variant assumes a non-linear cost function. The main objective throughout the theoretical discussion will consist in generating, when feasible, refutable hypotheses regarding the effect of federal crop insurance availability on crop-mix and risk taking.

Introductory Model

Single-Crop Case

Consider a competitive farmer who grows a single crop whose yield is random and suppose that the price is given. If the farmer purchases a federal crop insurance policy, his profit can be expressed as:

$$\pi_L = PY_LA + I_BA - I_PA - vA$$

and

$$\pi_H = PY_HA - I_PA - vA \tag{2.3}$$

with probabilities α and $(1-\alpha)$, respectively, where

π_L and π_H = profit in the low- and high-yield states of nature, respectively

P = the known product price

Y_L = the low yield

Y_H = the high yield

v = the constant marginal cost in acreage

I_P = the premium paid per acre

I_B = the insurance benefit received in the low-yield state of nature

A = the acreage assigned to the crop

The simple assumption that costs of production are related to acreage only may be derived from the supposition that the cost of producing a given crop is a function of both yield and acreage, i.e.,

$$C = \phi(Y_L, Y_H, A)$$

but that the function ϕ is homogeneous of degree zero in yield in every state of nature. Under the federal crop insurance program, the insurance benefit received in case of disaster can be expressed on a per-acre basis as:

$$I_B = \overline{P}(\lambda\overline{Y}-Y_L)$$

where

$\overline{P}$ = a payment rate used to compute insurance benefits to farmers

λ = a percentage coverage with $0 \leq \lambda \leq 1$

$\overline{Y}$ = normal yield determined by the Federal Crop Insurance Corporation

Denote the price of insurance, i.e., the cost per unit of coverage, by γ.

Then,

$$\gamma = I_P/I_B$$

It follows that the insurance premium can be expressed as

$$I_P = \gamma I_B = \gamma\overline{P}(\lambda\overline{Y}-Y_L)$$

As a result, profit under federal crop insurance availability can be rewritten as:

$$\pi_L \equiv PY_LA + (1-\gamma)\overline{P}(\lambda\overline{Y}-Y_L)A-vA$$

$$\pi_H \equiv PY_HA - \gamma\overline{P}(\lambda\overline{Y}-Y_L)A-vA \qquad (2.3')$$

with probabilities α and $(1-\alpha)$ respectively.

A number of methods have been used in the literature to introduce insurance in a given model. Whereas Smith (1968) and Mossin (1968) define insurance in terms of the liability coverage of losses and Ehrlich and Becker (1972) define it in terms of the net addition to income in the unfavorable state of nature, insurance in the above model is explicitly identified with $\overline{P} > 0$.

The case of no insurance in (2.3') is associated with $\overline{P} = 0$, in which case both I_P and I_B are zero. In addition, free insurance is identified with $\gamma = 0$, in which case a farmer does not pay any premium but receives an insurance benefit. Such a program is provided by the Agricultural Stabilization and Conservation Service as disaster assistance. For $\gamma = \alpha$ in (2.3'), the insurance premium is offset by the expected insurance benefits. Under usual circumstances, $\gamma > \alpha$, due to administrative costs.

It will be assumed that λ, the coverage percentage, is given. Denoting the utility of profit by $U(\pi)$, where it is assumed that more profit is desirable, i.e., $U'(\pi) > 0$ and given a fixed coverage level, the farmer will select under the expected utility hypothesis that level of acreage, A, which maximizes the expression:

$$E[U(\pi)] = \alpha U(\pi_L) + (1-\alpha)U(\pi_H) . \tag{2.4}$$

The first- and second-order conditions for an interior maximum to the above problem are, respectively:

$$\frac{\partial E[U(\pi)]}{\partial A} = \alpha U'(\pi_L)(PY_L + (1-\gamma)\overline{P}(\lambda\overline{Y}-Y_L)-v) + (1-\alpha)U'(\pi_H)(PY_H - \gamma\overline{P}(\lambda\overline{Y}-Y_L)-v) = 0 , \tag{2.4'}$$

$$D \equiv \frac{\partial^2 E[U(\pi)]}{\partial A^2} = \alpha U''(\pi_L)(PY_L + (1-\gamma)\overline{P}(\lambda\overline{Y}-Y_L)-v)^2$$
$$+ (1-\alpha)U''(\pi_H)(PY_H-\gamma\overline{P}(\lambda\overline{Y}-Y_L)-v)^2 < 0 \,, \qquad (2.4'')$$

where the primes denote differentiation. Condition (2.4') reflects the balancing of the loss in utility from paying a premium in the high-yield state of nature and receiving no benefit against the gain in utility from receiving a net benefit in the low-yield state of nature. Condition (2.4") is satisfied for a farmer whose utility function exhibits risk aversion, i.e., $U''(\pi) < 0$.

What is the impact of lowering the cost of insurance on planned acreage in this basic model? Totally differentiating (2.4') and using (2.4"), one obtains:

$$\frac{D}{\overline{P}(\lambda\overline{Y}-Y_L)} \frac{\partial A}{\partial \gamma} = \alpha U''(\pi_L)(PY_L + (1-\gamma)\overline{P}(\lambda\overline{Y}-Y_L)-v)A$$
$$+ (1-\alpha)U''(\pi_H)(PY_H- \overline{P}(\lambda\overline{Y}-Y_L)-v)A$$
$$+ \alpha U'(\pi_L) + (1-\alpha)H'(\pi_H)$$
$$\equiv D_1 \,. \qquad (2.5)$$

By the assumption of positive marginal utility, the last two terms of D_1 are positive. Nonetheless, without further restrictions on the utility function, there is no forthcoming unambiguous result for the effect of a premium subsidy on planned acreage and expected output.

Two particular restrictions that will be considered are associated with the hypotheses of nonincreasing absolute risk aversion and nondecreasing relative risk aversion. Absolute risk aversion and relative risk aversion are measures of attitudes toward risk, devised independently by Pratt (1964) and Arrow (1971), which have the appealing property that they are invariant under a linear transformation of the utility function. In what follows, they will be denoted by $R_a(\pi)$ and $R_r(\pi)$ and they are defined respectively as:

$$R_a(\pi) = \frac{-U''(\pi)}{U'(\pi)}$$

and

$$R_r(\pi) = \frac{-U''(\pi)}{U'(\pi)}\pi.$$

Regarding absolute risk aversion, Arrow has suggested that it is non-increasing in income or wealth,

> . . . which would reflect the hypothesis that as a decision maker becomes wealthier (in terms of income, profit, etc.), his risk premium for any risky prospect, defined as the difference between the mathematical expectation of the return from the prospect and its certainty equivalent, should decrease, or at least not increase (Sandmo, 1971, p. 68).

Concerning relative risk aversion, Arrow has also conjectured that it increases with profit.

Consider the case where a farmer's utility function is characterized by constant relative risk aversion; that is,

$$R_r(\pi) = -U''(\pi)\pi/U'(\pi) = b$$

where b is a constant. Then,

$$\alpha U''(\pi_L)\pi_L = -b\alpha U'(\pi_L)$$

and

$$(1-\alpha)U''(\pi_H)\pi_H = -b(1-\alpha)U'(\pi_H) .$$

Thus, D_1 in Equation (2.5) can be rewritten as:

$$(1-b)[\alpha U'(\pi_L) + (1-\alpha)U'(\pi_H)]$$

Under positive marginal utility of profit, the impact of a premium subsidy on planned acreage is therefore directly related to the sign of 1-b. The range of b, in turn, can be determined by examining utility functions which are consistent with constant relative risk aversion and positive but diminishing marginal utility. As shown by Pratt (1964, p. 126), any utility function under risky choices can be approximated by:

$$U(\pi) = \int e^{-\int R_a(\pi)d\pi} d\pi ,$$

where $R_a(\pi)$ demotes the absolute risk aversion function. Since $R_r(\pi) = R_a(\pi)\pi = b$, the above function can be rewritten as:

$$U(\pi) = \int e^{-b\int \frac{1}{\pi}d\pi} d\pi = \int e^{\ln|\pi|^{-b}} d\pi$$

where

$|\ |$ and ln denote absolute value and natural logarithm, respectively. When b = 1, $U(\pi) = \ln|\pi|$. For b different from one, and disregarding the constants of integration (since the preference function is invariant to a linear transformation of the utility function), the utility function is of the form:

$$U(\pi) = |\pi|^{1-b}$$

In order to have positive and diminishing marginal utility, profit must be strictly positive in the above utility functions and the parameter b must be such that $0 < b \leq 1$.[1] When $b = 1$, $D_1 = 0$ in (2.5), implying that a premium reduction has no effect on expected output. Expected output increases, however, as a result of reducing the premium if $b < 1$. The assumption of strictly positive profit, however, severely limits the plausibility of the hypothesis of constant relative risk aversion.

Assume now that absolute risk aversion is nonincreasing in profit; that is, $R_a'(\pi) \leq 0$. Let the returns per acre be specified as:

$$r_L = PY_L + (1-\gamma)\overline{P}(\lambda\overline{Y}-Y_L)-v$$

and

$$r_H = PY_H - \gamma\overline{P}(\lambda\overline{Y}-Y_L)-v$$

respectively under the low- and high-yield states of nature.

Then, $\pi_L = r_L A \geq 0$ when $r_L \geq 0$ given positive acreage A under the first-order condition (2.4'). It follows from the assumption that $R_a'(\pi) \leq 0$ that:

$$R_a(\pi_L) \leq R_a(0)$$

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1. When $\pi>0$ and $b\neq 1$, $U(\pi)=\pi^{1-b}$, implying that $U'(\pi)=(1-b)\pi^{-b}$ and $U''(\pi)=-b(1-b)\pi^{-(1+b)}$. For $0<b<1$, $U'(\pi)>0$ and $U''(\pi)<0$ while for $b>1$, $U'(\pi)<0$ and $U''(\pi)>0$. When $b=1$ and $\pi>0$, $U(\pi)=\ln\pi$, implying that $U'(\pi)=\frac{1}{\pi}>0$ and $U''(\pi)=\frac{-1}{\pi^2}<0$. If $\pi<0$ and $b\neq 1$, $U(\pi)=(-\pi)^{1-b}$, implying that $U'(\pi)=(b-1)(-\pi)^{-b}$ and $U''(\pi)=b(b-1)(-\pi)^{-(1+b)}$. In order to have $U'(\pi)>0$ given that $\pi<0$ and $b\neq 1$, b must be greater than one. If $b>1$, $U''(\pi)$ would have, however, been positive. For $b=1$ and $\pi<0$, $u(\pi)=\ln(-\pi)$; thus $U'(\pi)=\frac{-1}{\pi}>0$ and $U''(\pi)=\frac{1}{\pi^2}>0$. Consequently, only if profit is positive and $0<b\leq 1$ are the assumptions of positive and diminishing marginal utility satisfied.

or

$$R_a(\pi_L) \equiv -\frac{U''(\pi_L)}{U'(\pi_L)} \leq R_a(0) \,. \tag{2.6}$$

For positive marginal utility and $\alpha > 0$, it is clear that

$$-\alpha U'(\pi_L)r_L \leq 0 \,. \tag{2.7}$$

Hence, multiplying both sides of inequality (2.6) by $-\alpha U'(\pi_L)r_L$ yields:

$$\alpha U''(\pi_L)r_L \geq -R_a(0)\alpha U'(\pi_L)r_L \tag{2.8}$$

This last result is invariant to the sign of r_L. Indeed, if r_L were nonpositive, $\pi_L \leq 0$ and $R_a(\pi_L) \geq R_a(0)$. Since in that case $-\alpha U'(\pi_L)r_L \geq 0$, multiplying (2.6) by $-\alpha U'(\pi_L)r_L$ would again result in inequality (2.8).

Likewise, in the high-yield state of nature,

$$R_a(\pi_H) \equiv -\frac{U''(\pi_H)}{U'(\pi_H)} \leq R_a(0)$$

when the return per acre, r_H, is nonnegative. Using the same approach as above, one obtains:

$$(1-\alpha)U''(\pi_H)r_H \geq R_a(0)(1-\alpha)U'(\pi_H)r_H \tag{2.9}$$

Adding (2.8) and (2.9) and using the first-order condition (2.4') yields $D_1 > 0$. The immediate conclusion is that, under nonincreasing absolute risk aversion and constant marginal cost, a reduction of the premium induces an increase in the expected output of the single crop.

Two-Crop Case

Suppose now that there are two feasible crops, the first one having both nonrandom price and yield and the second one having a random yield and a nonrandom price. Profit is expressed here as:

$$\pi_L = P_1Y_1A_1 + P_2Y_2^L(\overline{A}-A_1) + (1-\gamma)\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L)(\overline{A}-A_1) - v_1A_1 - v_2(\overline{A}-A_1)$$

$$\pi_H = P_1Y_1A_1 + P_2Y_2^H(\overline{A}-A_1) - \gamma\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L)(\overline{A}-A_1) - v_1A_1 - v_2(\overline{A}-A_1) \tag{2.10}$$

with probabilities α and $(1-\alpha)$ respectively,

where

P_1 = the known price for the first crop

P_2 = the known price for the second crop

Y_1 = the nonstochastic yield of the first crop

Y_2^L = the low yield of the second crop

Y_2^H = the high yield of the second crop

$\overline{P}_2$ = the insurance payment rate on the second crop

γ = I_P/I_B where I_P is the insurance premium per acre and I_B is the insurance payout per acre

v_1 and v_2 = constant marginal costs

λ = the percentage coverage of normal yield

A_1 = the acreage assigned to the safe crop

$\overline{A}$ = the total endowment of land

It is doubtful that there exists in reality any crop that does not display any randomness in yield. Nevertheless, it seems adequate to work with such an assumption, since it allows one the use of a simple proxy for risk taking, namely the acreage assigned to the risky crop (see Mossin, 1968a for a similar approach in portfolio analysis).

The expected utility of profit is given by:

$$E[U(\pi)] = \alpha U(\pi_L) + (1-\alpha)U(\pi_H)$$

and the first- and second-order conditions for an interior maximum are, respectively:

$$\frac{\partial E[U(\pi)]}{\partial A_1} = \alpha U'(\pi_L)r_L + (1-\alpha)U'(\pi_H)r_H = 0 \tag{2.11}$$

$$D \equiv \frac{\partial^2 E[U(\pi)]}{\partial A_1^2} = \alpha U''(\pi_L)r_L^2 + (1-\alpha)U''(\pi_H)r_H^2 < 0\,, \tag{2.12}$$

where

$$r_L = P_1Y_1 - v_1 - (P_2Y_2^L + (1-\gamma)\overline{P}_2(\lambda\overline{Y}_2-Y_2) - v_2)$$

and

$$r_H = P_1Y_1 - v_1 - (P_2Y_2^H - \gamma\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - v_2)$$

represent the amount by which the gross margin per acre of the safe crop exceeds that of the risky crop in the low- and high-yield states of nature, respectively.

What is the impact of greater insurance availability on crop-mix and risk taking? Totally differentiating (2.11) with respect to $\overline{P}_2$, and using (2.12) yields:

$$\frac{\partial A_1}{\partial \overline{P}_2} = \frac{1}{D}\,[\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)](\lambda\overline{Y}_2 - Y_2^L)$$
$$+ \frac{1}{D}\,[\gamma(1-\alpha)U''(\pi_H)r_H - \alpha(1-\gamma)U''(\pi_L)r_L](\lambda\overline{Y}_2 - Y_2^L)A_2$$

Since r_L and r_H cannot have the same sign at the optimum for $U' > 0$ except where $r_L = r_H = 0$ (see (2.11)) and since r_L is greater than or equal to r_H when $\overline{P}_2 = 0$, it follows that $r_L \geq 0$ and $r_H \leq 0$ when

$\overline{P}_2 = 0$. As a result,

$$\frac{1}{D}\left[\gamma(1-\alpha)U''(\pi_H)r_H - \alpha(1-\gamma)U''(\pi_L)r_L\right] \leq 0$$

under risk aversion. In addition, when $\overline{P}_2 = 0$, the profit in the high-yield state of nature is unambiguously larger than the profit in the low-yield state of nature. Thus, $U'(\pi_L) > U'(\pi_H)$ under risk aversion. If $\gamma \leq \alpha$, in effect a premium subsidy, then $\alpha(1-\gamma) \geq \gamma(1-\alpha)$. Consequently,

$$\left.\frac{\partial A_1}{\partial \overline{P}_2}\right|_{\overline{P}_2=0} < 0 \qquad \text{and} \qquad \left.\frac{\partial A_2}{\partial \overline{P}_2}\right|_{\overline{P}_2=0} > 0\ ; \ (\text{where } A_2 = \overline{A} - A_1)$$

that is, making insurance available at a subsidized rate generates increased risk taking. The impact of insurance availability on the crop-mix is ambiguous where the premium exceeds expected benefits.

How does a reduction of the premium affect crop-mix in this two-crop case? Differentiating (2.11) with respect to γ and using (2.12) yields:

$$D_2 \equiv \frac{D}{\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L)}\frac{\partial A_1}{\partial \gamma} = [\alpha U''(\pi_L)r_L + (1-\alpha)U''(\pi_H)r_H]A_2 - [\alpha U'(\pi_L) + (1-\alpha)U'(\pi_H)]\,. \tag{2.13}$$

Suppose that absolute risk aversion is non-increasing in profit and let $\overline{\pi} \equiv (P_1Y_1 - v_1)\overline{A}$ be the level of profit when $r_L = r_H = 0$. Then, for nonnegative r_L and r_H,

$$R_a(\pi_L) = -\frac{U''(\pi_L)}{U'(\pi_L)} \geq R_a(\overline{\pi})$$

and

$$R_a(\pi_H) = -\frac{U''(\pi_H)}{U'(\pi_H)} \geq R_a(\bar{\pi}) .$$

Since when r_L and r_H are nonnegative, $-\alpha U'(\pi_L)r_L \leq 0$ and $-(1-\alpha)U'(\pi_H)r_H \leq 0$, it follows that:

$$\alpha U''(\pi_L)r_L \leq -R_a(\bar{\pi})\alpha U'(\pi_L)r_L \tag{2.14}$$

$$(1-\alpha)U''(\pi_H)r_H \leq -R_a(\bar{\pi})(1-\alpha)U'(\pi_H)r_H . \tag{2.15}$$

Adding (2.14) and (2.15) and using (2.11) yields $D_2 < 0$ so that:

$$\frac{\partial A_1}{\partial \gamma} > 0 \qquad \text{and} \qquad \frac{\partial A_2}{\partial \gamma} < 0 ,$$

where $A_2 = \bar{A} - A_1$ is the acreage assigned to the risky crop.

These results indicate that, under nonincreasing absolute risk aversion and constant marginal cost, a reduction of the premium entails a greater acreage of the risky crop.

Finally, how does a premium subsidy affect a risk averse farmer's welfare? Following Stiglitz (1969), the impact of a premium subsidy can be determined graphically as follows (Figure 2.1). Suppose that the percentage coverage of normal yield, λ, is again fixed. If a risk averse farmer grows the safe crop only, his profits are equal in the low- and high-yield states of nature; that is, $\pi_L = \pi_H = (P_1Y_1 - v_1)\bar{A}$. In Figure 2.1, the pair (π_L, π_H), when only the safe crop is produced, is represented by point S on the 45-degree line. If the farmer grows the risky crop only, in the absence of a subsidy of the premium, his profits in each state of nature are given, respectively, by:

$$\pi_L = [P_2Y_2^L + (1-\gamma)\bar{P}_2(\lambda\bar{Y}_2 - Y_2^L) - v_2]\bar{A}$$

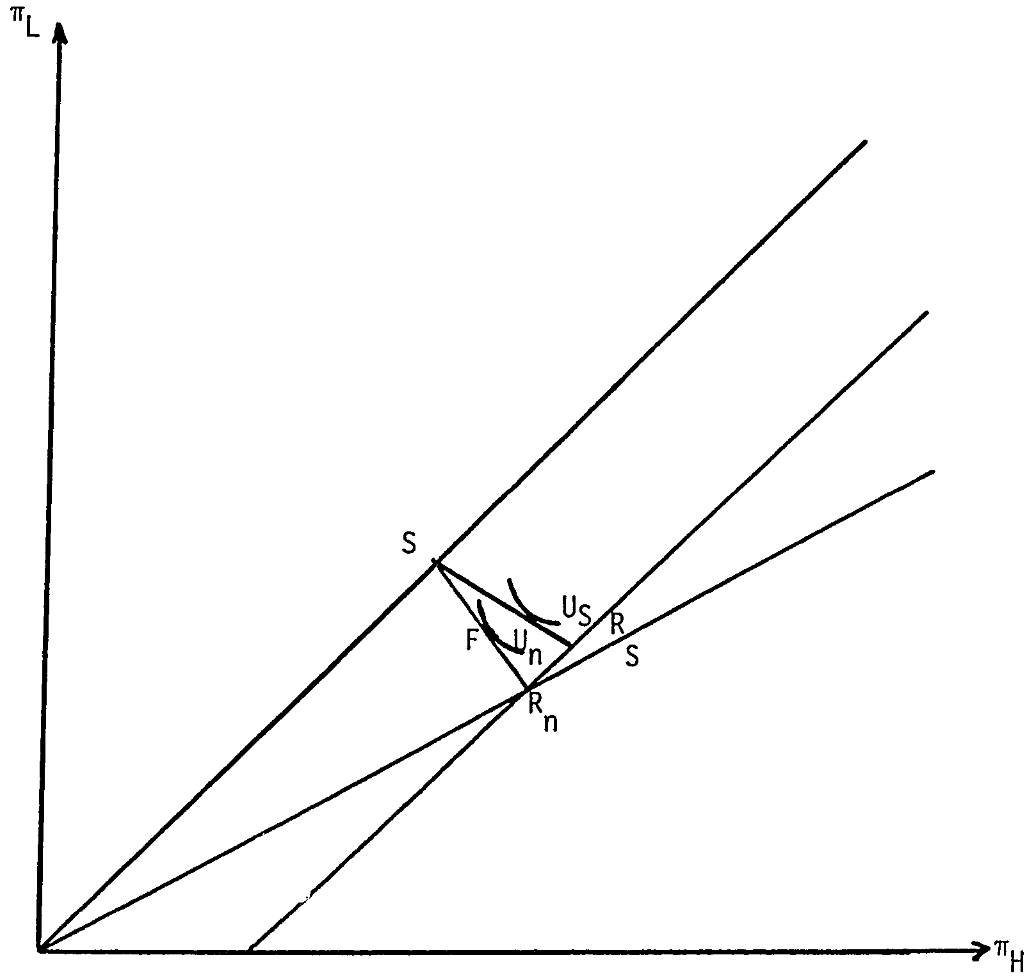

Figure 2.1. Welfare impact of a premium subsidy.

and

$$\pi_H = [P_2Y_2^H - \gamma\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - v_2]\overline{A}.$$

The pair (π_L, π_H) in that case is represented by the point R_n. Between the points S and R_n is a locus of combinations of profits in the low- and high-yield states of nature corresponding to different crop-mixes. That locus is a budget curve derived from (2.10) and given by the equation:

$$\pi_L = \frac{r_L}{r_H}[\pi_H - s_H] + s_L ,$$

where

$$s_L = [P_2Y_2^L + (1-\gamma)\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - v_2]\overline{A}$$

and

$$s_H = [P_2Y_2^H - \gamma\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - v_2]\overline{A}.$$

For a fixed endowment of land,

$$\frac{\partial\pi_L}{\partial\pi_H} = \frac{r_L}{r_H},$$

which is independent of A_1. Thus, the budget curve is linear under constant marginal cost. Since from (2.11) r_L and r_H cannot have the same sign at the optimum, the budget line is negatively sloped. At the point of tangency between the budget line SR_n (without a premium subsidy) and the convex indifference curve U_n, the marginal rate of substitution of π_L for π_H is equal to the slope of the budget line: F provides that equilibrium. Suppose now that a premium subsidy is introduced. If the farmer grows the safe crop only, his profits in the low- and high-yield states of nature are such that $\pi_L = \pi_H = (P_1Y_1 - v_1)\overline{A}$ as before, implying that the new budget line must rotate around point S. If, on the other hand, the farmer grows the risky crop only, π_L and π_H are greater as compared with the pre-subsidy case but they change by the same amount, suggesting that the endpoint of the new budget line, R_s, must be on a 45-degree line passing through the point R_n. It follows that a given farmer's welfare increases under a premium subsidy.

Non-Linear Cost Model

The profit function defined below differs from the foregoing in the sense that the cost function $C(A_1, A_2)$ is assumed to be non-linear in acreage. It is supposed, nonetheless, that C is separable in A_1 and A_2, the acreages assigned to the safe and risky crop, respectively. As before, $C(0) = 0$; i.e., fixed costs are assumed away and γ is the ratio of insurance premium to insurance payout. Given those premises, profit is now:

$$\pi_L = P_1Y_1A_1 + P_2Y_2^LA_2 + (1-\gamma)\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L)A_2 - C(A_1) - C(A_2)$$

$$\pi_H = P_1Y_1A_1 + P_2Y_2^HA_2 - \gamma\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L)A_2 - C(A_1) - C(A_2)$$

with respective probabilities α and $(1-\alpha)$, where $A_2 = \overline{A} - A_1$.

Crop specialization and crop diversification will now be examined in relation to federal crop insurance availability.

Federal Crop Insurance and Specialization

The study of the special case of specialization in the growing of a single crop owes its importance to the finding by Jones and Larson (1965) that insured farmers were, for the most part, specializing in a single crop. In an attempt to explain the above empirical result, it will be assumed that the farmer specializes in the growing of the risky crop and conditions will be determined under which he might opt for coverage.

As before, let $E[U(\pi)] = \alpha U(\pi_L) + (1-\alpha)U(\pi_H)$ denote the expected utility of profit. Letting:

$$r_L = P_1Y_1 - P_2Y_2^L - (1-\gamma)\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - C'(A_1) + C'(\overline{A}-A_1)$$

and

$$r_H = P_1Y_1 - P_2Y_2^H + \gamma\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - C'(A_1) + C'(\overline{A}-A_1),$$

define:

$$\frac{\partial E[U(\pi)]}{\partial A_1} = \alpha U'(\pi_L)r_L + (1-\alpha)U'(\pi_H)r_H \tag{2.16}$$

and

$$D \equiv \frac{\partial^2 E[U(\pi)]}{\partial A_1^2} = \alpha U''(\pi_L)r^2 + (1-\alpha)U''(\pi_H)r_H^2$$
$$- [\alpha U'(\pi_L) + (1-\alpha)U'(\pi_H)](C''(A_1) + C''(\overline{A}-A_1)) \,. \tag{2.17}$$

Assume that the marginal cost of growing both crops is increasing in acreage, i.e., $C''(A_1)$ and $C''(\overline{A}-A_1)$ are positive. Then, for a farmer who is either risk neutral or risk averse, $E[U(\pi)]$ is a strictly concave function of A_1 since (2.17) is negative. Hence, a necessary and sufficient condition for specialization in the growing of the risky crop with no insurance is that:

$$\left.\frac{\partial E[U(\pi)]}{\partial A_1}\right|_{\substack{A_1 = 0 \\ \overline{P}_2 = 0}} < 0$$

For $A_1 = 0$ and $\overline{P}_2 = 0$,

$$r_L = P_1Y_1 - P_LY_2^L + C'(\overline{A})$$

and

$$r_H = P_1Y_1 - P_2Y_2^H + C'(\overline{A}) \, .$$

Thus,

$$\alpha U'(\pi_L)r_L + (1-\alpha)U'(\pi_H)r_H < 0 \, . \qquad (2.18)$$

Since the marginal utility of profit is assumed to be positive, a sufficient condition to have the required sign in (2.18) is that

$$r_L = P_1Y_1 - P_2Y_2^L + C'(\overline{A}) < 0$$

and

$$r_H = P_1Y_1 - P_2Y_2^H + C'(\overline{A}) < 0 \, ;$$

that is,

$$P_1Y_1 < P_2Y_2^L - C'(\overline{A})$$

A sufficient condition therefore in specializing in the growing of the risky crop is that the marginal revenue from the safe crop be less than the marginal revenue from the risky crop (in the low-yield state of nature) net of its marginal cost.

Suppose now that the farmer is specializing in the risky crop. Under what conditions would he be willing to purchase insurance? Since $E[U(\pi)]$ is strictly concave in $\overline{P}_2$ under risk aversion, a necessary and sufficient condition is that:

$$\left. \frac{\partial E[U(\pi)]}{\partial \overline{P}_2} \right|_{\substack{A_1 = 0 \\ \overline{P}_2 = 0}} > 0$$

Now,

$$\left.\frac{\partial E[U(\pi)]}{\partial \overline{P}_2}\right|_{\substack{\overline{P}_2 = 0 \\ A_1 = 0}} = [\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)](\lambda\overline{Y}_2 - Y_2^L)\overline{A}$$

Since $\pi_L < \pi_H$ when $A_1 = 0$ and $\overline{P}_2 = 0$, it follows that $U'(\pi_L) > U'(\pi_H)$ under risk aversion. Given that the low yield of the risky crop is less than the guaranteed yield, a sufficient condition for the purchase of an insurance policy is:

$$\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H) > 0 \tag{2.19}$$

or

$$\frac{\alpha(1-\gamma)}{\gamma(1-\alpha)} > \frac{U'(\pi_H)}{U'(\pi_L)} \tag{2.20}$$

Since the right-hand side of (2.20) is less than one, it will be sufficient that:

$$\frac{\alpha(1-\gamma)}{\gamma(1-\alpha)} > 1 \qquad \text{or} \qquad \alpha > \gamma$$

recalling that γ is the cost per unit of coverage. Hence $\gamma < \alpha$ will induce a risk averter specializing in a risky crop to seek coverage. Likewise, if insurance is costless in the sense that the premium is equal to the expected insurance benefits, it will pay the farmer to insure against his probable losses. Finally, a risk averse farmer will always find it profitable to participate in a free insurance program (e.g., disaster assistance) since (2.19) is always positive in that case.

Federal Crop Insurance and Diversification

Special Cases of No Coverage and Full Coverage. Assume that there is diversification in the sense that a given farmer grows each of both crops, i.e., $A_1 > 0$ and $A_2 > 0$. Under what conditions would he be willing to buy no insurance or take full coverage? For this purpose, maximize:

$$E[U(\pi)] = \alpha U(\pi_L) + (1-\alpha)U(\pi_H)$$

subject to:

$$0 < A_1 < \bar{A} \qquad \text{and} \qquad 0 \leq \lambda \leq 1 .$$

The Lagrangean function for the above problem is:

$$L = E[U(\pi)] + \mu(1-\lambda) ,$$

where μ denotes a Lagrange multiplier. It can be easily verified that the bordered Hessian

$$H = \begin{vmatrix} L_{11} & L_{1\lambda} & L_{1\mu} \\ L_{1\lambda} & L_{\lambda\lambda} & L_{\lambda\mu} \\ L_{1\mu} & L_{\mu\lambda} & 0 \end{vmatrix}$$

where

$$L_{11} = \frac{\partial^2 L}{\partial A_1^2} ;$$

$$L_{1\lambda} = \frac{\partial^2 L}{\partial A_1 \partial_\lambda} ;$$

$$L_{1\mu} = \frac{\partial^2 L}{\partial A_1 \partial \mu} ;$$

$$L_{\mu\lambda} = \frac{\partial^2 L}{\partial \mu \partial \lambda} ;$$

$$L_{\lambda\lambda} = \frac{\partial^2 L}{\partial \mu^2},$$

is strictly positive and that accordingly a maximum is attainable here under both risk neutrality and risk aversion. The Kuhn-Tucker conditions are:

$$\frac{\partial L}{\partial A_1} = 0\,; \tag{2.21}$$

$$\frac{\partial L}{\partial \lambda} = [\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)]\overline{P}_2 A_2 - \mu \leq 0,\ \lambda \geq 0\,; \tag{2.22}$$

and

$$\frac{\partial L}{\partial \mu} = 1 - \lambda \geq 0,\ \mu \geq 0\,. \tag{2.23}$$

Consider now the risk neutral farmer. Since $U'(\pi_L) = U'(\pi_H)$ in that case, (2.22) and (2.23) can be rewritten as:

$$\frac{\partial L}{\partial \lambda} = (\alpha-\gamma)U'(\pi_L)\overline{P}_2\overline{Y}_2 A_2 - \mu \leq 0\,,\ \ \lambda \geq 0 \tag{2.22'}$$

and

$$\frac{\partial L}{\partial \mu} = 1 - \lambda \geq 0,\ \mu \geq 0\,. \tag{2.23'}$$

Suppose now that $\lambda = 1$ (full coverage), implying that μ is strictly positive. Then,

$$\frac{\partial L}{\partial \lambda} = 0 \qquad \text{or} \qquad (\alpha-\gamma)U'(\pi_L)\overline{P}_2\overline{Y}_2 A_2 = \mu$$

and since $\mu > 0$ and $A_2 > 0$, it follows that γ must be strictly less than α (that is, there must be a premium subsidy) in order for a risk neutral farmer to take full coverage. In the risk neutral case also, the case of no coverage is compatible with $\gamma > \alpha$, i.e., an actuarially unfavorable insurance policy. The risk averse farmer would want to take full coverage if there is a free or costless insurance program. In opposition to the risk neutral case, however, full coverage is compatible with an actuarially unfavorable insurance under risk aversion. Finally, for the risk averse farmer not to take insurance requires that the ratio of marginal utility of profit in the high- and low-yield states of nature be greater than

$$\frac{\alpha(1-\gamma)}{\gamma(1-\alpha)}.$$

Results pertaining to the risk averse case would seem to be at variance with Mossin's conclusion that "if the premium is actuarially unfavorable, then it will never be optimal to take full coverage" (1968b, p. 577) even though he acknowledges that some people do in fact take full coverage.

Optional Coverage under Diversification. The necessary and sufficient conditions for a farmer to produce both crops under the assumption that the coverage percentage, λ, is continuous and $0 < \lambda < 1$ are:

$$\frac{\partial E[U(\pi)]}{\partial A_1} = \alpha U'(\pi_L)r_L + (1-\alpha)U'(\pi_H)r_H = 0 \qquad (2.24)$$

$$\frac{\partial E[U(\pi)]}{\partial \lambda} = [\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)]\overline{P}_2\overline{Y}_2(\overline{A}-A_1) = 0 \qquad (2.24')$$

$$D = \begin{vmatrix} E_{A_1A_1} & E_{A_1\lambda} \\ E_{A_1\lambda} & E_{\lambda\lambda} \end{vmatrix} > 0 \qquad (2.24'')$$

where

$$r_L = P_1Y_1 - P_2Y_2^L - (1-\gamma)\overline{P}_2(\lambda\overline{Y}_2 - Y_2^L) - C'(A_1) + C'(\overline{A}-A_1);$$

$$r_H = P_1Y_1 - P_2Y_2^H + \gamma\overline{P}_2(\lambda\overline{Y}_2-Y_2^L) - C'(A_1) + C'(\overline{A}-A_1) ;$$

$$E_{A_1A_1} = \alpha U''(\pi_L)r_L^2 + (1-\alpha)U''(\pi_H)r_H^2$$

$$- [\alpha U'(\pi_L) + (1-\alpha)U'(\pi_H)](C''(A_1) + C''(\overline{A}-A_1)) ;$$

$$E_{A_1\lambda} = [\alpha(1-\gamma)U''(\pi_L)r_L - \gamma(1-\alpha)U''(\pi_H)r_H]\overline{P}_2\overline{Y}_2(\overline{A}-A_1)$$

(using (2.24')); and

$$E_{\lambda\lambda} = [\alpha(1-\gamma)^2U''(\pi_L) + \gamma^2(1-\alpha)U''(\pi_H)](\overline{P}_2\overline{Y}_2(\overline{A}-A_1)^2 .$$

Under risk aversion and increasing marginal cost, $E_{A_1A_1}$ and $E_{\lambda\lambda}$ are both negative. When the second-order condition, as reflected in expression (2.24"), is satisfied (2.24) and (2.24') are sufficient conditions for a maximum and the impact of a premium subsidy can be assessed by totally differentiating them to obtain:

$$E_{A_1A_1}\frac{\partial A_1}{\partial\gamma} + E_{A_1\lambda}\frac{\partial\lambda}{\partial\gamma} = H_1 \tag{2.25}$$

$$E_{A_1\lambda}\frac{\partial A_1}{\partial\gamma} + E_{\lambda\lambda}\frac{\partial\lambda}{\partial\gamma} = H_2 \tag{2.25'}$$

where

$$H_1 = -[\alpha U'(\pi_L) + (1-\alpha)U'(\pi_H)]\overline{P}_2(\overline{Y}_2-Y_2^L)$$

$$+ [\alpha U''(\pi_L)r_L + (1-\alpha)U''(\pi_H)r_H]\overline{P}_2(\overline{Y}_2-Y_2^L)(\overline{A}-A_1) ;$$

and

$$H_2 = [\alpha U'(\pi_L) + (1-\alpha)U'(\pi_H)]\overline{P}_2\overline{Y}_2A_2$$

$$+ [\alpha(1-\gamma)U''(\pi_L) - \gamma(1-\alpha)U''(\pi_H)]\overline{P}_2^2\overline{Y}_2(\overline{Y}_2-Y_2^L)A_2^2 .$$

Applying Cramer's rule to the system of equations represented by (2.25) and (2.25') yields:

$$\frac{\partial A_1}{\partial \gamma} = \frac{1}{D}\,[H_1 E_{\lambda\lambda} - H_2 E_{A_1\lambda}] \tag{2.26}$$

$$\frac{\partial \lambda}{\partial \gamma} = \frac{1}{D}\,[H_2 E_{A_1 A_1} - H_1 E_{A_1\lambda}]\,. \tag{2.27}$$

Since $E_{A_1A_1}$ and $E_{\lambda\lambda}$ are both negative, it remains to determine the signs of H_2, $E_{A_1\lambda}$ and H_1. Consider the case where absolute risk aversion is constant; that is,

$$R_a(\pi) \equiv -U''(\pi)/U'(\pi) = b$$

where b is a positive constant. Then,

$$\alpha U''(\pi_L)r_L = -b\alpha U'(\pi_L)r_L\,; \tag{2.28}$$

$$\alpha(1-\gamma)U''(\pi_L) = -b\alpha(1-\gamma)U'(\pi_L)\,; \tag{2.28'}$$

$$\alpha(1-\gamma)U''(\pi_L)r_L = -b\alpha(1-\gamma)U'(\pi_L)r_L\,; \tag{2.28''}$$

$$(1-\alpha)U''(\pi_H)r_H = -b(1-\alpha)U'(\pi_H)r_H\,; \tag{2.29}$$

$$\gamma(1-\alpha)U''(\pi_H) = -b\gamma(1-\alpha)U'(\pi_H)\,; \tag{2.29'}$$

and

$$\gamma(1-\alpha)U''(\pi_H)r_H = -b\gamma(1-\alpha)U'(\pi_H)r_H\,. \tag{2.29''}$$

Adding (2.28) to (2.29) and using (2.24) yields:

$$\alpha U''(\pi_L)r_L + (1-\alpha)U''(\pi_H)r_H = -b[\alpha U'(\pi_L)r_L + (1-\alpha)U'(\pi_H)r_H] = 0\,.$$

Hence, H_1 is negative. Subtracting (2.29') from (2.28') yields:

$$\alpha(1-\gamma)U''(\pi_L) - \gamma(1-\alpha)U''(\pi_H) = -b[\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)]$$

$$= 0 \quad \text{from (2.24')}\,.$$

Hence, H_2 is positive. Finally, subtracting (2.29") from (2.28") and using (2.24'), one obtains:

$$\alpha(1-\gamma)U''(\pi_L)r_L - \gamma(1-\alpha)U''(\pi_H)r_H = -b[\alpha(1-\gamma)U'(\pi_L)r_L - \gamma(1-\alpha)U'(\pi_H)r_H]$$
$$= -b\gamma(1-\alpha)U'(\pi_H)(r_L - r_H) \, ,$$

which is negative if the price election $\overline{P}_2$ is less than the market price and the guaranteed yield is less than the actual yield in the favorable state of nature, as would be expected in practice. Hence, $E_{A_1\lambda}$ is negative. It follows from the results above that:

$$\frac{\partial A_1}{\partial \gamma} > 0 \qquad \text{and} \qquad \frac{\partial A_2}{\partial \gamma} < 0$$

where $A_2 = (\bar{A} - A_1)$ and

$$\frac{\partial \lambda}{\partial \gamma} < 0 \, .$$

These results suggest that, under constant absolute risk aversion, a premium subsidy induces greater risk taking. Also, a premium subsidy results in a greater coverage level so that the demand for federal crop insurance protection is negatively sloped. It should be emphasized that the above results are predicated on the assumptions that marginal cost is increasing in acreage and that constant absolute risk aversion characterizes the preference function of a given farmer. Under decreasing absolute risk aversion for instance, the signs of H_2 and $E_{A_1\lambda}$ are ambiguous so that a premium subsidy may have perverse effects on risk-taking behavior.

It is often suggested that the demand for coverage is positively related to risk. In Arrow's view, "Clearly, from the risk aversion point of view, insurance is more valuable, the greater the uncertainty in the risk being insured against" (1963, p. 963). Adds Pauly (1974, p. 61), "Still, if we assume that the distribution of attitudes toward risk is independent of the distribution of probabilities of loss, people who buy more insurance will tend, on the average, to have larger expected losses than those with less insurance." It is shown below that if the decisions to purchase federal crop insurance and to grow crops are considered jointly and if farmers' risk preferences exhibit constant absolute risk aversion, then the impact of increased risk on the demand for coverage is ambiguous. To do so, totally differentiate (2.24) and (2.24') with respect to α, the probability of loss, to obtain:

$$E_{A_1A_1}\frac{\partial A_1}{\partial\alpha} + E_{A_1\lambda}\frac{\partial\lambda}{\partial\alpha} = H_3\,; \tag{2.30}$$

$$E_{A_1\lambda}\frac{\partial A_1}{\partial\alpha} + E_{\lambda\lambda}\frac{\partial\lambda}{\partial\alpha} = H_4\,, \tag{2.30'}$$

where

$$H_3 = U'(\pi_H)r_H - U'(\pi_L)r_L$$

and

$$H_4 = -[(1-\gamma)U'(\pi_L) + \gamma U'(\pi_H)]\overline{P}_2\overline{Y}_2A_2\,.$$

Applying Cramer's rule to the system represented by Equations (2.30) and (2.30') yields:

$$\frac{\partial A_1}{\partial\alpha} = \frac{1}{D}\,[H_3E_{\lambda\lambda} - H_4E_{A_1\lambda}]$$

and

$$\frac{\partial\lambda}{\partial\alpha} = \frac{1}{D}\,[H_4E_{A_1A_1} - H_3E_{A_1\lambda}]\,.$$

From (2.24'), $H_4 = -\frac{1}{\alpha}\gamma U'(\pi_H) < 0$. Also, from a previous proof, $E_{A_1\lambda}$ is negative under constant absolute risk aversion. Since at the optimum, r_L and r_H cannot have the same sign (see Equation (2.24)) and since $r_L > r_H$, it follows that $r_L > 0$, $r_H < 0$ and $H_3 < 0$. Given that $E_{A_1A_1} < 0$, as indicated earlier, it follows that the impact of a higher probability of loss on the demand for coverage is indeterminate.

<u>Insurance Availability and Risk Taking</u>. To determine the impact of federal crop insurance availability on risk taking, it is sufficient to derive the response of the acreage assigned to the safe crop to an increment in the price election and to evaluate the result at a zero level of the price election to obtain:

$$\text{sign}\ \frac{\partial A_1}{\partial \overline{P}_2}\bigg|_{\overline{P}_2 = 0}$$

From (2.24) and (2.24') and at $\overline{P}_2 = 0$, one obtains:

$$\frac{\partial A_1}{\partial \overline{P}_2}\bigg|_{\overline{P}_2 = 0} = \frac{1}{D} H_5 E_{\lambda\lambda}\,, \tag{2.31}$$

where

$$H_5 = [\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)](\lambda\overline{Y}_2 - Y_2^L)$$
$$+ [\gamma(1-\alpha)U''(\pi_H)r_H - \alpha(1-\gamma)U''(\pi_L)r_L](\lambda\overline{Y}_2 - Y_2^L)A_2\,.$$

From a previous proof, under constant absolute risk aversion, H_5 reduces to:

$$H_5 = [\alpha(1-\gamma)U'(\pi_L) - \gamma(1-\alpha)U'(\pi_H)](\lambda\overline{Y}_2 - Y_2^L) = 0$$

from (2.24'). Thus,

$$\left.\frac{\partial A_1}{\partial \overline{P}_2}\right|_{\overline{P}_2 = 0} = 0 \quad \text{and} \quad \left.\frac{\partial A_2}{\partial \overline{P}_2}\right|_{\overline{P}_2 = 0} = 0 ;$$

that is, insurance availability does not induce greater risk taking under constant absolute risk aversion.

Mandatory Insurance. Ray (1958) distinguishes between two main types of compulsory insurance:

- In the first case, there is obligatory insurance and the private sector is completely excluded (USSR).
- In the second case, private insurance companies may engage in crop insurance for values of coverage above a minimum level established by the State (United Kingdom).

Compulsory insurance is associated here with the case where every farmer growing an insurable crop has no other choice but to insure his crops. An advantage of compulsory insurance relates to the ease with which it can be administered. Notable disadvantages of mandatory insurance are that it interferes with the free will of the insured and that it may benefit some individuals while hurting others (e.g., risk neutral decision makers when insurance is offered on an actuarially unfavorable basis). In that context, it is worth contrasting, graphically, the cases of optional and compulsory insurance (Figure 2.2).

Suppose, to start with, that there is no crop insurance. In that case, if the farmer grows the safe crop only, his profits in both low-yield and high-yield states of nature are equal, i.e., $\pi_L = \pi_H = P_1Y_1A_1 - C(A_1)$ and (π_L^n, π_H^n) is represented by point S in Figure 2.2.

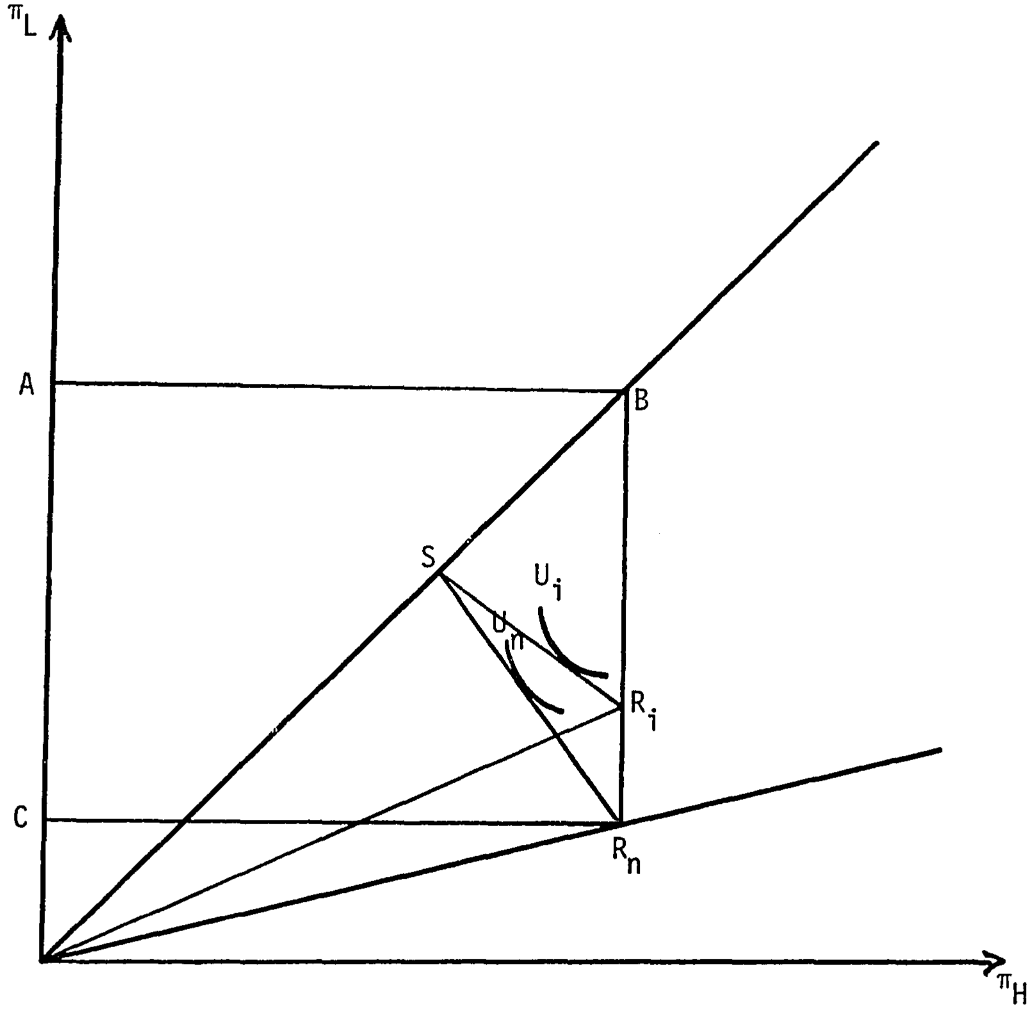

Figure 2.2. Welfare impact of compulsory insurance.

If, on the other hand, the farmer grows the risky crop only, i.e., $A_1 = 0$, then:

$$\pi_L^n = P_2 Y_2^L \overline{A} - C(\overline{A}) < P_2 Y_2^H \overline{A} - C(\overline{A}) = \pi_H^n ,$$

the superscript n denoting "no insurance." The point (π_L^n, π_H^n) is represented by R_n, and the line SR_n constitutes the budget line without insurance (in the special case of constant marginal cost).

Suppose now that insurance is introduced. If the farmer grows the safe crop only, $\pi_L = \pi_H$ as before and if he grows the risky crop only, then:

$$\pi_L^i = P_2 Y_2^L \overline{A} + (1-\gamma)\overline{P}_2(\lambda \overline{Y}_2 - Y_2^L)\overline{A} - C(\overline{A}) > \pi_L^n ;$$

and

$$\pi_H^i = P_2 Y_2^H \overline{A} - \gamma_2^{\overline{P}}(\lambda \overline{Y}_2 - Y_2^L)\overline{A} - C(\overline{A}) < \pi_H^n ,$$

where the superscript i denotes "with insurance." It follows that the second point of the new budget line can be anywhere in the area ACR_nB. While under optional crop insurance the farmer will purchase a policy if and only if that act increases his welfare from, say, U_n to U_i, under mandatory insurance the new budget line is not necessarily in the area bounded by SR_n, SB and BR_n. The farmer's welfare may be reduced by the mandatory insurance program.

CHAPTER 3

EMPIRICAL FRAMEWORK

Setting of the Study

The empirical study of the Federal Crop Insurance program focuses on irrigated farms in Pinal County, Arizona. The choice of that particular area is motivated by the availability of relatively adequate data on the crop-mix of individual farms (Firch, 1980). Each year farmers report the acres planted of different field crops to the Agricultural Stabilization and Conservation Service (ASCS) to establish eligibility for governmental farm programs. The ASCS data used cover the period 1973-1979 and they constitute the primary input in the empirical study.

The major crops reported are cotton (both upland and Pima varieties), wheat, barley, grain sorghum and alfalfa. Occasionally some acres of safflower, sugarbeets, vegetables and melons were reported to the ASCS.

Farms growing Pima cotton were not considered since the latter crop is included in a government allotment program and information had not been collected on the acreage allotment. Data for years prior to 1976 were also omitted since government price support programs were in effect during those years which could influence crop-mixes; price supports were well below market prices in the 1976-1979 period. Farms whose net acreage had varied substantially during the period 1976-1979 were not considered in this study owing to the hypothesis that there was a change in resource base for which information was not available. Land, machinery and water are assumed to be the only limiting factors. As a result of the inclusion of a water constraint, farms located in relatively low water cost areas such as Casa Grande and Coolidge-Florence were also excluded from the original ASCS sample.

Applying the above criteria left 35 farms, 14 of which are located in the Maricopa-Stanfield subarea, one in the Queen Creek subarea and 20 in the Eloy subarea. Among the remaining 35 farms, 22 are fully-owned, 2 are partly owned and there are 22 farms where the operator is a tenant. The characterization of farms on the basis of the tenure of the operator is based on data provided by ASCS on individual farm gross and net acres owner-operated and/or leased. This typology derives its importance from the plausible hypothesis that, ceteris paribus, full owners will tend to exhibit less risk averse behavior than either part-owners or tenants.

Data on the crop-mix of the 35 farms were used in conjunction with county-wide data on monthly water requirements of upland cotton, wheat, barley, grain sorghum and alfalfa, obtained from Arizona Field Crop Budgets (Hathorn, Little and Steadman, 1978) to determine for each farm and for the years 1976-1979, the approximate monthly water use. Water usage was estimated by multiplying acres reported by the monthly water requirements per acre of each activity and summing them up across activities. The monthly usage of machinery was also computed using hours per acre of machinery (power units), the number of times a given operation was performed each month on each crop and the crop-mix of the different farms. The data on hours per acre of machinery use and the number of times an operation is performed are provided in the Arizona Field Crop Budgets. Water and machinery capacities were identified using the highest monthly water and machinery usages, respectively. Tables 3.1 and 3.2 report data on hours of machinery and acre inches of water required per acre in Pinal County based on 1976-1979 data.

The purpose of determining water and machinery capacities is twofold. First, since water is expected to be a limiting factor, there is a need to estimate its availability level (water capacity, as defined earlier, is the obvious proxy); in addition, water and machinery capacities provide additional elements for eliminating another set of farms from consideration. Of the 35 farms mentioned above, 13 were retained on the basis of stable water and machinery capacities over the period 1976-1979. Table 3.3 reports data on the resource restraints of the 13 farms.

Empirical Procedures

E-V Approach

This empirical study of federal crop insurance hinges upon the use of an expected profit-variance of profit (E-V) framework. The E-V approach defines the efficiency frontier as one yielding maximum expected value of profit for each level of the variance of profit or, equivalently, minimum variance of profit for a given expected value of profit.

Table 3.1. Tractor hours required per acre in Pinal County.

	Upland Cotton	Wheat	Barley	Grain Sorghum	Alfalfa
December	1.21	.37	.37	.24	
January	1.50	.12	.12		
February	.91				
March	.32				
April	.67				
May	.32	.02	.02		
June		.48	.30	.84	
July	.26			.10	
August					.82
September					2.30
October	.02			.02	.33
November	.60	.24	.24	.24	

Note: Derived from representative farm data provided in the Arizona Field Crop Budgets (Hathorn et al., 1978).

Table 3.2. Water required per acre in Pinal County (acre inches).

	Upland Cotton	Wheat	Barley	Grain Sorghum	Alfalfa
December		4.00	1.60		
January	3.60	4.00	4.80		
February	6.00	3.00	4.80		5.00
March	2.40	6.00	6.00		5.00
April		9.00	9.00		10.00
May	6.00	12.00	6.00		10.00
June	12.00			4.00	12.00
July	12.00			10.00	12.00
August	12.00			12.00	6.00
September	6.00			12.00	11.00
October				6.00	7.00
November					7.00

Note: Data are from Arizona Field Crop Budgets (Hathorn et al., 1978).

Table 3.3. 1976-1979 average land cultivated and estimated machinery and water capacity.

Farm #	Land (net acres)	Machinery (tractor hours)	Water (acre feet)
1	774.00	504.71	330.00
2	675.00	502.33	334.00
3	475.00	526.40	350.00
4	2,522.00	1,661.92	1,105.00
5	1,245.00	627.16	417.00
6	1,245.00	293.28	195.00
7	601.00	319.10	230.00
8	867.00	624.16	448.00
9	305.00	140.32	91.00
10	212.00	151.90	101.00
11	854.00	261.32	163.00
12	1,610.00	503.56	339.00
13	603.00	325.50	226.00

Note: Estimated machinery and water capacities are based on data provided by Arizona Field Crop Budgets (Hathorn et al.).

Subject to the efficiency frontier, the optimal portfolio is determined by maximizing an index of utility which is a function of expected profit and variance of profit (Markowitz, 1959). A theoretical justification for E-V analysis is provided by the assumptions that profit is normally distributed and that a given farmer's utility function is of the form:

$$U(\pi) = K - ae^{-r\pi} \tag{3.1}$$

where

π = profit

r = risk aversion parameter (a positive value being associated with aversion to risk)

e = an exponential function

a and K = positive constants

As shown by Freund (1956), maximization of the expected value of the above utility function, under the assumption that profit is normally distributed, is equivalent to maximization of the expression:

$$W = E(\pi) - (r/2)V(\pi) \tag{3.2}$$

where E and V denote the expectation and variance operators respectively. Under the Markowitz approach, the decision maker selects the portfolio which maximizes (3.2) subject to:

$$V(\pi) = F(E(\pi)) , \tag{3.3}$$

where the function F represents the efficiency frontier (Figure 3.1). To derive the efficiency frontier in Figure 3.1, use is made of quadratic programming to minimize:

$$Z = X'\Omega X \tag{3.4}$$

subject to:

$$AX \leq b$$

and

$$\mu'X = k ,$$

where

X = a vector of activities

μ = a vector of expected returns

Ω = a variance-covariance matrix of returns

A = a matrix of resource requirements

b and k = constants

Assuming the vector X is exogenous in the model, $\mu'X = k$ is expected returns for a selected activity-mix and the constraint k is

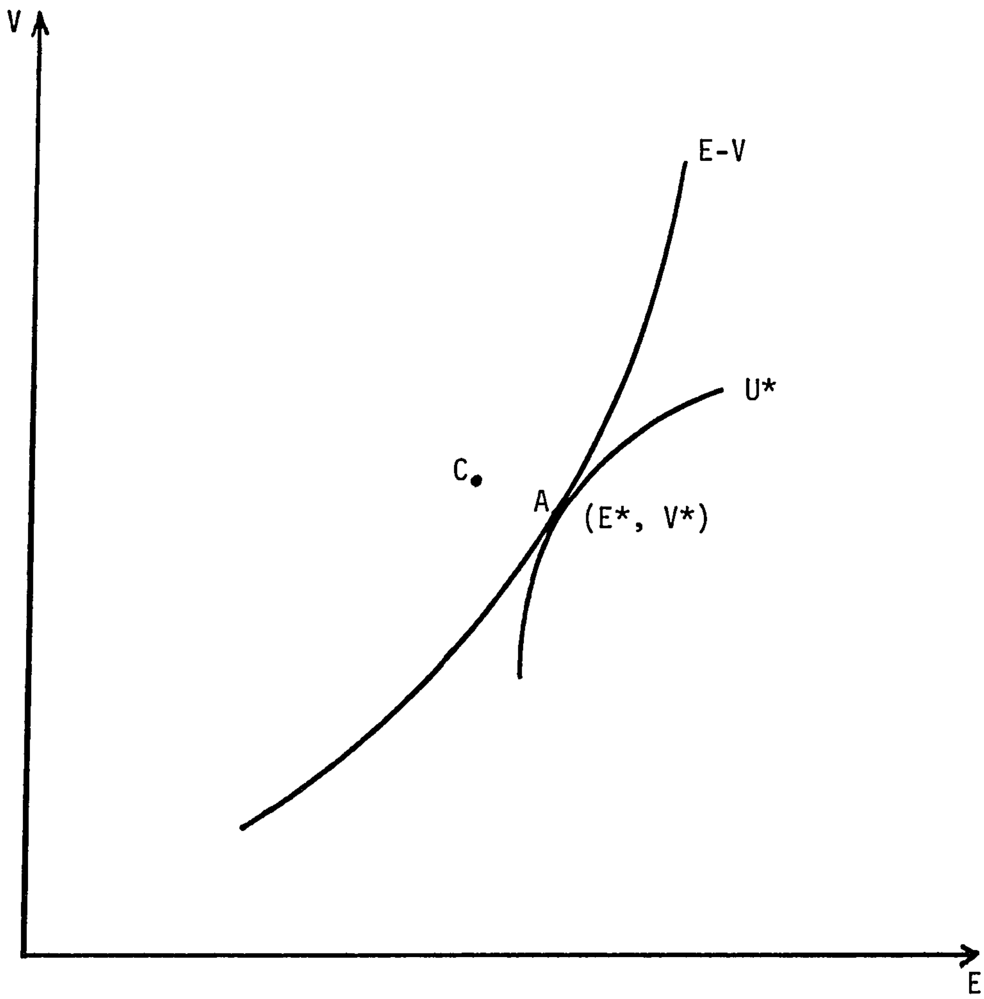

Figure 3.1. Optimal portfolio choice in E-V framework.

varied parametrically to derive the E-V frontier. The optimal activity-mix in such a framework is obtained by selecting the maximum expected utility point and observing the corresponding activity-mix, e.g., the activity-mix corresponding to the pair (E^*, V^*) in Figure 3.1, where U^* represents an indifference curve which is tangent to the efficiency frontier. To do so, however, requires an estimate of the risk aversion parameter, r, in (3.2).

Risk Aversion Estimation

Various methods have been used by researchers to evaluate risk aversion parameters. Young et al. (1979) distinguish three main such procedures. The first method, which features prominently in many works, relies on interview procedures and the use of hypothetical lotteries to elicit farmers' attitudes toward risk. As noted by Young et al., this procedure suffers from possible biases arising from different interviewers and the plausible lack of "representativeness of choices involving hypothetical gains and losses in a parlor game setting" (p. 5). A second and closely related method, which has been used only sparingly, differs from the previous one in that use is made of actual financial compensations rather than hypothetical ones. Economic considerations obviously lessen the practicability of this experimental method. Finally, the third method discussed by Young et al., and termed "observed factor demand and output supply behavior," encompasses two variants:

1. In the first case, the risk aversion coefficient is varied parametrically and the coefficient that minimizes the difference

between observed and predicted behavior is selected as representing individual decision makers' preferences.

2. The second variant of the "observed factor demand and output supply behavior" centers around estimating the risk aversion coefficient from first-order conditions given a postulated behavioral hypothesis. In Moscardi and de Janvry's approach, for instance (1977), given a generalized power production function, first-order conditions with respect to input demands are derived from a safety-first model to obtain:

$$MVP_i = \frac{P_i}{(1-\rho r)}, \quad i = 1, \ldots, n \tag{3.5}$$

where

P_i = the price of the ith input

ρ = a yield coefficient of variation

r = a risk aversion parameter

MVP_i = the marginal value product of the ith input, presumably at the optimum.

In principle, r should be the same in all equations in (3.5).

Estimation of the risk aversion coefficient in this study follows closely the first variant of the "observed factor demand and output supply behavior" procedure. As emphasized by Young et al., this procedure suffers from the tendency to attribute deviations between observed and predicted behavior to risk aversion alone. Using the vector notations introduced earlier, rewrite (3.2) and (3.3), respectively, as:

$$W = \mu' X - (r/2) X' \Omega X \tag{3.6}$$

$$X' \Omega X = F[\mu' X] \tag{3.7}$$

where $\frac{dF}{d\mu' X}$, which is the slope of the E-V frontier, is positive when a farmer is risk averse. Substituting $X'\Omega X$ of (3.7) into (3.6) and maximizing the latter, the first-order conditions are:

$$\mu - (r/2) \frac{\partial F}{\partial \mu' X} = 0 \, . \tag{3.8}$$

For a non-zero vector μ, (3.8) is equivalent to:

$$1 - (r/2) \frac{\partial F}{\partial \mu' X} = 0$$

or

$$r = 2/(\partial F / \partial \mu' X) \, . \tag{3.9}$$

To estimate the risk aversion coefficient for a given farmer, one first determines the farm plan on the E-V efficiency frontier which is closest to the observed crop-mix. Suppose that the closest farm plan is represented by point A in Figure (3.1); that is, the sum of the absolute deviations between the predicted crop-mix represented by A and the observed crop-mix represented by C is at a minimum. Then, a slight movement from A consistent with remaining on the frontier would provide the slope of the E-V frontier. The inverse of that slope would be set equal to r/2 in (3.9), where r denotes again the risk aversion parameter.

To determine points such as C and A requires knowledge of the moments of net returns distributions. The derivation of such moments is described in what follows.

Gross Margin Distributions
Without the FCI Program

The derivation of the variance-covariance matrix of gross margins (returns above variable costs) and the expected gross margins per acre of the five field crops considered in this study hinges on an estimation of farmers' subjective distributions of gross margins; subjective distributions of gross margins per acre in turn depend on the distributions of the components of gross margins per acre; that is, prices, yields and variable costs of production. It is assumed that, just prior to the decision-making period, the farmer formulates his subjective distribution of a given variate on the basis of both an expected component and a random component.

Price Distributions. The expected component of a price variate is assumed to be reflected in the harvest time delivery futures price at planting time and the expected basis, where the basis is defined as the difference between the harvest month futures price quoted at planted time and the cash price received at harvest time. More formally, the expected component of the price distribution, denoted $\hat{P}_i$, is defined as:

$$\hat{P}_i = FP_{pi} - E(FP_{pi} - P_i), \quad i = 1, \ldots, n \tag{3.10}$$

where

E = the expectation operator

FP_{pi} = the harvest futures price at planting time i

P_i = the cash price received during the ith harvest period

$FP_{pi} - P_i$ = the basis in the ith year

The random component ε_i (in the ith state of nature) is obtained by subtracting the expected price from the cash price in the ith year. Thus, the outcomes of the random component of the price distribution are given by:

$$\varepsilon_i = P_i - \hat{P}_i , \tag{3.11}$$

where $\hat{P}_i$ refers to the expected price at the start of the ith planting period. The outcomes of the farmer's subjective distribution about a given price are subsequently obtained by adding the series of price deviations from Equation (3.11) to the price expected just prior to decision making.

For cotton, both the price of cotton lint and the price of cottonseed are required. The lint equivalent price of seed receipts was obtained by multiplying the price of cottonseed by an average ratio of lint yield and cottonseed yield; the estimate of that ratio was based on representative farm yield data for Pinal County which were given in the Arizona Field Crop Budgets. A single price distribution was then obtained by adding the price of cotton lint to the lint equivalent price of cottonseed. The futures price of cottonseed was approximated by that of soybean using typical upland cotton planting and harvesting dates for Pinal County. Likewise, the futures price for grain sorghum was based on that of corn. For alfalfa, the harvest futures price at planting was approximated by the cash price received in September of the year prior to decision making while the basis is given by the difference between the average cash price during the harvest period and the cash price received at the end of the harvest period.

The period 1973-1980 was considered in the derivation of the price distribution of the different field crops. The starting year of 1973 was selected because of the belief that effective price support programs prior to that year had the effect of dampening considerably natural market price fluctuations. Data on harvest futures prices at planting time obtained from various issues of The Wall Street Journal are given, respectively, in Table 3.4, while data on cash prices and estimated basis are given in Tables 3.5 and 3.6, respectively. Finally, data on expected prices and the random component of prices, as defined in Equation (3.11), are presented in Tables 3.7 and 3.8.

To illustrate the computation of the expected component of the price distribution of a given crop, consider the case of wheat in 1977. The harvest futures price of that crop during the 1977 planting period was 5.78¢ per pound (Table 3.4) while the expected basis is .05¢ per pound (Table 3.6). Hence the expected price of wheat at the beginning of the planting period in 1977 is estimated as: 5.78 - .05; that is, 5.73¢ per pound. To obtain the farmer's subjective distribution about the price of wheat in 1977, the series of wheat price deviations (Table 3.8) is added to the 1977 expected price.

Finally, all data were subsequently expressed in current year dollars using an USDA index of prices paid for production items (1967 base year).

Yield Distributions. The estimation of the expected component of the yield distribution of upland cotton was based on both individual farm yield data provided by the ASCS for the years 1973 through 1979 and

Table 3.4. Harvest month futures prices quoted at planting time.

Harvest Year	Soybean (Chicago)	Cotton Lint (New York)	Wheat (Kansas City)	Barley (Winnipeg)	Corn (Chicago)	Alfalfa
	- - - - - - - - - - -	- - - - -	(¢/lb)	- - - - -	- - - - - - -	($/ton)
1974	11.86	82.90	7.91	4.97	4.46	40.00
1975	12.48	55.15	7.25	6.37	6.16	58.00
1976	9.96	53.85	7.08	5.41	5.39	58.50
1977	11.45	74.20	5.78	4.06	5.18	68.00
1978	9.03	54.60	4.07	3.64	3.25	55.00
1979	10.88	65.80	5.20	3.59	3.82	59.00
1980	12.26	69.19	7.17	5.35	5.12	79.00

Note: All data except alfalfa are derived from various issues of The Wall Street Journal. Futures prices of soybean and corn are used as proxies for those of cottonseed and sorghum, respectively. For alfalfa, the cash price prevailing in September of the previous year was used as a proxy for harvest futures price at planting time.

Table 3.5. Cash prices received (season average).

Year	Cottonseed	Cotton Lint	Wheat	Barley	Sorghum	Alfalfa
	- - - - - - - - - - - - -	- - - - -	(¢/lb)	- - - - -	- - - - -	($/ton)
1974	7.35	44.10	6.24	5.37	6.12	56.75
1975	5.05	53.10	5.28	5.52	5.21	58.45
1976	5.25	64.20	6.52	5.66	4.28	69.58
1977	3.75	56.10	4.45	4.39	3.68	65.79
1978	5.00	57.40	4.89	4.98	4.60	60.79
1979	5.75	64.10	6.28	5.41	5.55	69.33
1980	5.62	74.44	6.74	6.31	6.06	91.33

Source: Arizona Crop and Livestock Reporting Service.

Table 3.6. Estimated price basis and expected (mean) basis.

Year	Cottonseed	Cotton Lint	Wheat	Barley	Sorghum	Alfalfa
	- - - - - -	- - - - - -	(¢/lb)	- - - - -	- - - - -	($/ton)
1974	4.51	38.80	1.67	-.40	-1.66	-16.75
1975	7.43	2.05	1.97	.85	.95	-.45
1976	4.71	-10.35	.56	-.25	1.11	-11.08
1977	7.70	18.10	1.33	-.33	1.50	2.21
1978	3.93	-2.80	-.82	-1.34	-1.35	-5.79
1979	5.13	1.70	-1.08	-1.82	-1.73	-10.33
1980	6.64	-5.25	.43	-.96	-.94	-12.33
Mean	5.72	6.03	.58	-.60	-.30	-7.78

Notes: The price basis is defined as harvest futures price at planting time minus cash price received at harvest. It is derived from Tables 3.5 and 3.6.

Table 3.7. Estimated expected prices.

Year	Cottonseed	Cotton Lint	Wheat	Barley	Sorghum	Alfalfa
	- - - - - -	- - - - - -	(¢/lb)	- - - - -	- - - - -	($/ton)
1974	6.14	76.87	7.33	5.57	4.76	47.78
1975	6.76	49.12	6.67	6.97	6.46	65.78
1976	4.24	47.82	6.50	6.01	5.69	66.28
1977	5.73	68.17	5.20	4.66	5.48	75.78
1978	3.31	48.57	3.49	4.24	3.55	62.78
1979	5.16	59.77	4.62	4.19	4.12	66.78
1980	6.54	63.16	6.59	5.95	5.42	86.78

Note: Estimated expected prices are derived from Tables 3.5 and 3.7.

Table 3.8. Distribution of price deviations.

Year	Cottonseed	Cotton Lint	Wheat	Barley	Sorghum	Alfalfa
	- - - - - - - - - - - - - - - -					
1974	1.21	-32.77	-1.09	-.20	1.36	8.97
1975	-1.71	3.98	-1.39	-1.45	-1.25	-7.33
1976	1.01	16.38	.02	-.35	-1.41	3.30
1977	-1.98	-12.07	-.75	-.27	-1.80	-9.99
1978	1.79	8.83	1.40	.74	1.05	-1.99
1979	.59	4.33	1.66	1.22	1.43	2.55
1980	-.92	11.28	.15	.37	.64	4.55
Mean	.00	.00	.00	.00	.00	.00

Note: These data represent deviations of cash prices from expected prices (Tables 3.5 and 3.7). The prices of cottonseed and cotton lint were thereafter combined by multiplying the price of cottonseed by 1.645.

estimated relative frequencies of those years based on countywide average yield data from the Arizona Crop and Livestock Reporting Service (1965-1980).

Using the countywide average yields for upland cotton, class limits were first defined and their associated relative frequencies were determined (Table 3.9). For a specific year, the countywide average yield was observed and the relative frequency for that average yield was used as a proxy for the relative frequency of the year. For the years 1975 through 1978 the average yields in Pinal County were 829, 1101, 1049 and 902 pounds per acre, respectively; therefore, from Table 3.9, the relative frequencies associated with those years were 1/16, 2/16, 2/16 and 1/16, respectively. Those weights were, however, normalized before estimating individual farm yield data.

Table 3.9. Average yield distribution of upland cotton in Pinal County (1965-1980).

Class Limits (in lbs per acre)	Relative Frequency
829-879	1/16
880-904	1/16
905-929	1/16
930-979	1/16
980-1,004	1/16
1,005-1,029	1/16
1,030-1,054	2/16
1,055-1,079	1/16
1,080-1,104	2/16
1,105-1,129	2/16
1,130-1,179	1/16
1,180-1,204	1/16
More than 1,204	1/16

Note: The raw data were taken from the Arizona Crop and Livestock Reporting Service (1980). Class intervals of 25 pounds per acre were used to determine class limits.

No individual ASCS farm data on the yields of wheat, barley, grain sorghum and alfalfa was available. Hence, an alternative procedure of estimation was called for to derive the expected component of the yields of those field crops. As a first step, based on data from the Statistical Reporting Service (SRS) for the 1975-1978 period, the yields of wheat, barley and grain sorghum were each regressed on the yield of upland cotton. The general hypothesis was that the yields of feed grains would tend to be positively associated with the yield of upland cotton on a given farm. Apart from upland cotton as an independent variable, dummy variables were introduced to account for possible year effects. The following equations were obtained:

$$\underset{}{\text{Wheat}} = \underset{(2.16)}{5.145} + \underset{(1.98)}{7.12}\ \text{Cotton} - \underset{(-1.76)}{1.93T_2} - \underset{(-1.94)}{4.62T_3}, \quad R^2 = .17$$

$$\text{Barley} = \underset{(1.98)}{32.17} + \underset{(2.33)}{23.45}\ \text{Cotton} + \underset{(2.12)}{3.24T_2} - \underset{(-1.61)}{2.07T_3}, \quad R^2 = .28$$

$$\text{Sorghum} = 1.14 + .44\ \text{Cotton} + .15T_2 - .85T_3 + .01T_4, \quad R^2 = .29$$

where T_2, T_3 and T_4 are dummy variables corresponding to the years 1976, 1977 and 1978 with their associated estimated coefficients indicating how the effects of those years differ from the year 1975; and the t statistics are given in parentheses below the estimated coefficients.

Given the above estimated equations, the ASCS individual farm yield data for upland cotton were used to estimate the feed grain yield data for each farmer and each year. As in the case of upland cotton, the weights to apply to those data were based on countywide average yield data from the Arizona Crop and Livestock Reporting Service. For alfalfa, there were not enough degrees of freedom to justify the use of regression techniques; the expected component of the yield of that crop was based on a simple arithmetic mean of data provided by the Statistical Reporting Service. The estimated average yields of all field crops for each of the selected farmers are given in Table 3.10.

Before deriving the distribution of the random component of the yield of each field crop, a test was performed to determine whether cotton yield deviations for all thirteen farms come from the same population. The null hypothesis was that the individual farm cotton yield deviations from their means were drawn from the same population while the alternative hypothesis was that at least one sample (i.e., an individual farm set of data) was drawn from a different population. The cotton yield deviations from the mean were based on the ASCS data (Table 3.11). Using the Chi-Square approximation of the Kruskal-Wallis test (given that the samples had unequal size), the calculated χ^2 was found to be 19.01 compared with a table χ^2 of 21.02 at the 5% level of significance with 12 degrees of freedom. Hence, the null hypothesis could not be rejected. Given the positive association between the yield of upland cotton and that of feedgrains, the above hypothesis was assumed to hold for all field crops. The distribution of the random component of the yield of a given field crop was therefore assumed to be the same for all selected farms.

The estimation of the distribution of the random component of yield was based primarily on the data provided by the Statistical

Table 3.10. Estimated average yields of field crops for selected farms.

Farm	Cotton	Wheat	Barley	Sorghum	Alfalfa
	- - - - - - - - -	-(lbs/acre)-	- - - - - - - - -		(tons/acre)
1	1,320	3,736	4,496	4,300	6.8
2	1,535	4,060	5,200	3,747	6.8
3	1,603	4,121	5,361	3,874	6.8
4	1,593	4,112	5,338	3,855	6.8
5	884	3,481	3,674	3,545	6.8
6	770	3,380	3,408	2,535	6.8
7	573	3,204	2,945	1,970	6.8
8	948	3,538	3,826	2,664	6.8
9	711	3,327	3,269	2,226	6.8
10	1,019	3,601	3,991	2,794	6.8
11	858	3,458	3,613	2,496	6.8
12	850	3,451	3,594	2,482	6.8
13	896	3,491	3,702	2,566	6.8

Notes: These estimates are based on data from both ASCS and SRS and the derived weights in Table 3.10. All data are rounded values.

Table 3.11. Cotton yield deviations around individual farm mean yield (1974-1979).

Farm	1974	1975	1976	1977	1978	1979
1	29.67	280.67	-213.33	189.68	118.67	-405.33
2	8.50	396.50	-515.50	224.50	- 27.50	- 26.50
3	-127.83	360.17	-124.83	190.17	-253.83	- 43.83
4	36.34	12.34	-297.66	236.34	32.34	- 19.66
5	203.20	-385.80	240.20	22.20	- 79.80	
6	293.00	18.00	-313.00	468.00	-318.00	-148.00
7	-114.66	33.34	232.34	95.34	- 24.66	-221.66
8	168.67	280.67	- 93.33	23.67	-121.33	-258.33
9	192.34	56.34	3.34	- 91.66	- 81.66	- 78.66
10	- 80.00	5.00	-208.00	391.00	8.00	-276.00
11	134.17	- 94.83	-177.83	138.17	- 50.83	51.17
12	- 26.84	104.84	- 99.16	69.84	22.84	-125.16
13	294.75	19.75	-262.25	- 7.25		

Notes: These derived data are based on individual farm yield data provided by the ASCS. Each set of data for a given farm was treated as a sample in order to perform the Kruskal-Wallis test. Missing data indicates years the farms did not grow cotton.

Reporting Service. To derive the outcomes of the distribution of yield for a given field crop, only farmers who had reported data for at least two years (from 1975 to 1980) were considered. Individual SRS average farm yields were computed for a given field crop along with the deviations between the reported yield and the average yield. The outcomes of the yield distribution for a given field crop were then associated, for a given year, with the set of yield deviations from all farms.

The derivation of the relative frequencies associated with the yield outcomes is illustrated with the following example. Assume that there is a sample of two farms with the following data on the individual farm yield deviations of alfalfa from the average yield over the period 1975 through 1977.

	Farm	Yield Deviations (in tons)
1975	1	-1.1
	2	- .7
1976	1	.3
	2	.9
1977	1	.8
	2	- .2

Suppose that, based on countywide average yield data for alfalfa, the states of nature associated with the years 1975, 1976 and 1977 have relative frequencies of 1/6, 1/2 and 1/3, respectively. For a given year, the relative frequency of a given outcome is then obtained by dividing the relative frequency of the state of nature by the number of observations reported by farmers. Thus, in 1975, the relative frequency associated with any outcome is 1/12 (i.e., 1/6 divided by 2). Using the above procedures, the following hypothetical distribution is obtained (after ordering the data for a given year).

Year	Yield Deviations (tons per acre)	Relative Frequency
1975	-1.1	1/12
	- .7	1/12
1976	.3	1/4
	.9	1/4
1977	- .2	1/6
	.8	1/6
	Total	1.00

More formally, let,

f_i = the relative frequency of the ith state of nature (year)

f_{ij} = the relative frequency associated with the jth observation in the ith state of nature, j = 1, n_i (where n_i is the number of observations reported in the ith state of nature).

Then, the relative frequency, f_{ij}, associated with the jth observation in the ith state of nature is estimated as:

$$f_{ij} = f_i \,/\, n_i \, . \tag{3.11'}$$

It is verified from (3.11') that:

$$\sum_i \sum_j f_{ij} = \sum_i \Big(\sum_j \frac{f_i}{n_i}\Big) = 1 .$$

The aforementioned procedures were applied to a sample of 34 SRS farms, to derive the distribution of the random component of yields for a given field crop. The yield distribution for a given farm was then obtained by adding the estimated average yield to the estimated distribution of the random component.

Cost Distributions. In is assumed that harvesting costs are the only random component among the variable costs of growing a field crop. In practical terms, the latter assumption enables one to associate the cost distribution with the yield distribution. It is supposed in that regard that harvesting operations are performed on a custom hiring basis. Prices of selected custom services are given in the Arizona Field Crop Budgets. To obtain the remaining variable costs (or preharvest costs), total harvest costs per acre are deducted from total variable costs based on representative farm yield and variable cost data provided also by the Arizona Field Crop Budgets.

The random cost component for feedgrains consists of a hauling cost per unit of yield and a combining cost per unit of additional yield when actual yield is above 2,000 lbs (.002¢ per lb.). The cost of harvesting upland cotton consists of picking and ginning costs per unit of yield of seed cotton (the latter incorporating cotton lint, seed and trash) including hauling and a rooding cost per lint unit. It was assumed that the rood cotton was 10% of cotton lint and that the gin turnout was 32% of seed cotton. Based on the above data, the lint equivalent costs of picking, ginning and rooding were added to derive harvesting costs per unit of yield for upland cotton.

Regarding alfalfa, it is assumed that the establishment of stands can last three years. Letting:

C_H = the harvesting cost of hay per unit of yield

C_{PH} = the preharvest costs of hay per acre

C_E = the stand establishment costs per acre

the discounted rental value of a standing crop, r_D, is first estimated. Using a replacement cost appraisal approach,

$$r_D = \frac{2/3\ C_E}{1 + r},$$

where r denotes a discount rate. The variable cost per acre of producing alfalfa, C, was then approximated in a given year by:

$$C = C_H Y_A + C_{PH} + C_E - r_D$$

or

$$C = C_H Y_A + C_{PH} + C_E \left(\frac{1/3 + r}{1 + r}\right),$$

where Y_A denotes the yield per acre of alfalfa.

<u>Derivation of Variances and Covariances of Gross Margins</u>. It is assumed that prices are independently distributed of yields. Under this premise, gross margin outcomes are obtained by multiplying each price outcome by each yield outcome and subtracting the variable costs per acre. Likewise, the relative frequency associated with a given gross margin outcome is obtained by multiplying each price relative

frequency by each yield relative frequency. Given the outcomes of gross margins with associated frequencies, the variances of gross margins per acre are derived for each farmer and for each field crop. A similar procedure was used in the estimation of the covariance of gross margins per acre of two field crops except that pairs of observations were considered in order to derive the underlying joint distributions of yields of two field crops.

Introduction of the FCI Program in the E-V Model

Since the FCI program was available in Pinal County both in 1977 and 1978 (the period of focus of this empirical study), activities associated with the purchase of crop insurance were included in the empirical model before estimating the risk aversion coefficients of the selected farmers.

Activities and Data

The federal crop insurance, as applied in Pinal County in 1977 and 1978, offered a given farmer a 75% coverage of normal yield for upland cotton, wheat, barley and grain sorghum, and three price elections on each of those crops, i.e., three alternative payment rates used to compute insurance benefits. No coverage was available for alfalfa. As a result, seventeen strategies were feasible for a given farmer in the selected sample: one strategy as regards alfalfa; that is, the growing of that crop without federal crop insurance; and four strategies for each of the other field crops; e.g., grow upland cotton without insurance or grow it with insurance and one of three price elections.

It is assumed that a given farmer can select a mix of policies even on a single crop; this assumption is not unreasonable since under the FCI program "The acreage of an insured crop under a contract may be combined into one insurance unit or divided into several units" (USDA, 1980, p. 10).

Under the FCI program a farmer who opts for coverage is classified into one of twelve yield classes for cotton and one of three yield classes for wheat, barley and sorghum. To each yield class corresponds a guaranteed yield. The guaranteed yield and the price elected by the farmer determine the premium per acre that he must pay. In practice, the guaranteed yield represents a weighted average of Pinal County average yields for a given crop. For cotton, a distinction is made as to whether the practice is "irrigated and solid planted" or "irrigated and skip-row planted." Solid plant was assumed to be representative of the area of study.

Data on the guaranteed yields, price election, as well as premium rates were provided by the Davis Regional Office of the Federal Crop Insurance Corporation (FCIC). For wheat, the 1975 data applied to the years 1976 through 1978 while for barley and sorghum the 1976 data applied to the years 1977 and 1978; in the case of cotton, separate 1977 and 1978 data were available.

In order to determine the appropriate data for the selected farms, guaranteed yields provided by the FCIC were divided by 70% to obtain the corresponding average yields. Use was then made of the estimated average yields of the individual farmers to infer their plausible area classification. The guaranteed yields for a selected farm were then obtained by referring to the class yield and observing the associated FCIC data. The premium rates corresponding to the different price elections were then obtained also from the FCIC. Data on the estimated guaranteed yields of the selected farms are given in Table 3.12 while data on the price elections are given in Table 3.13. Finally, data on the premium rates corresponding to the guaranteed yields and price elections (Tables 3.12 and 3.13) are given in Table 3.14.

Given all the data, the procedures described earlier to generate the expected returns above variable costs and the variance-covariance matrix of gross margins were applied.

In order to validate the derived data on the moments of the gross margins per acre under insurance availability, it seems helpful to indicate the likely effects of the FCI program on both the expected gross margins per acre and the variance-covariance matrix of gross margins per acre.

Impact of the FCI Program on Some Moments of Gross Margins Per Acre

Under federal crop insurance availability, the gross margins per acre of a given insurable crop is obtained by deducting the harvesting and preharvest costs as well as the premium per acre from the sum of the gross revenue and the insurance indemnities per acre to be received if actual yield falls short of the guaranteed yield. In the empirical setting adopted, harvesting costs include a cost per unit of yield and a cost per unit of additional yield (e.g., above 2,000 lbs. for feedgrains).

Table 3.12. Guaranteed yields for selected farms.

Farm	Cotton	Wheat	Barley	Sorghum
	-(lbs)-			
1	940	2,280	1,872	2,100
2	1,010	2,280	1,872	2,100
3	1,010	2,280	1,872	2,100
4	1,010	2,280	1,872	2,100
5	590	2,640	2,160	2,400
6	540	2,640	2,160	2,400
7	400	2,640	2,160	2,400
8	670	2,640	2,160	2,400
9	490	2,640	2,160	2,400
10	740	2,640	2,160	2,400
11	590	2,640	2,160	2,400
12	590	2,640	2,160	2,400
13	630	2,640	2,160	2,400

Notes: All the data above were derived from data provided by the FCIC. The assignment of a guaranteed yield to a given farmer was based on the approximate class yield of that farm. FCIC data were originally given in bushels per acre for wheat and barley and in hundredweights for sorghum.

Table 3.13. Price elections (1975-1978).

Price Election	Cotton	Wheat	Barley	Sorghum
	- - - - - - - - - -	(¢/lb)	- - - - - - - - - -	
1	28	2.50	2.08	2.00
2	30	3.33	2.60	2.50
3	35	4.16	3.33	3.00

Notes: Price elections are payment rates used to compute insurance indemnities. A farmer may opt for any of three levels offered by the FCIC. The data above were provided by the FCIC. Price elections for wheat and barley were originally given in dollars per bushel while those for grain sorghum were expressed in dollars per hundredweight.

Table 3.14. Premium rates per acre for selected farms (dollars).

	Crop and Price Election*											
	Cotton			Wheat			Barley			Sorghum		
Farm	1	2	3	1	2	3	1	2	3	1	2	3
1	7.8	8.4	9.8	2.6	3.5	4.4	2.2	2.7	3.5	2.4	3.0	3.6
2	8.3	8.8	10.3	2.6	3.5	4.4	2.2	2.7	3.5	2.4	3.0	3.6
3	8.3	8.8	10.3	2.6	3.5	4.4	2.2	2.7	3.5	2.4	3.0	3.6
4	8.3	8.8	10.3	2.6	3.5	4.4	2.2	2.7	3.5	2.4	3.0	3.6
5	6.0	6.4	7.4	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
6	5.7	6.1	7.1	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
7	5.1	5.5	6.4	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
8	6.4	6.8	7.9	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
9	5.6	5.9	6.9	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
10	6.8	7.3	8.5	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
11	6.0	6.4	7.4	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
12	6.0	6.4	7.4	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8
13	6.2	6.6	7.7	3.0	4.0	5.0	2.3	2.8	3.6	2.5	3.2	3.8

* 1, 2, and 3 refer to price elections 1, 2, and 3, respectively (see Table 3.14). These data are taken from the FCIC.

For the ith crop, let:

Y_i = the yield

P_i = the price per unit of yield

c_i = the cost per unit of yield

d_i = the cost per unit of additional yield above a fixed level of yield, Y_d (Y_d = 2,000 lbs for feedgrains and $d_i = 0$ for cotton and alfalfa)

F_i = the preharvest cost per acre

$\overline{P}_i$ = the price election

$\overline{Y}_i$ = the guaranteed yield

P_{mi} = the premium rate per acre

Then, the per-acre returns above variable costs depend on whether or not the actual yield, Y_i, is between the guaranteed yield, $\overline{Y}_i$ and the fixed level of yield, Y_d for feedgrains. For cotton, the only consideration is whether or not the actual yield is less than the guaranteed yield. Consider the case of feedgrains and assume that there exists some yield less than the guaranteed yield. Suppose also that the guaranteed yield exceeds 2,000 lbs. There are three mutually exclusive events in that case:

1. The actual yield is less than or equal to 2,000 lbs, implying that it is less than the guaranteed yield.
2. The actual yield is strictly greater than 2,000 lbs but strictly less than the guaranteed yield.
3. The actual yield is at least equal to the guaranteed yield and therefore larger than 2,000 lbs.

The per-acre returns above variable costs are thus defined as:

$$R_i = P_iY_i - c_iY_i - P_{mi} - F_i + \begin{cases} \overline{P}_i(\overline{Y}_i - Y_i) & \text{if } Y_i \leq Y_d \\ \overline{P}_i(\overline{Y}_i - Y_i) - d_i(Y_i - Y_d) & \text{if } Y_d < Y_i < \overline{Y}_i \\ -d_i(Y_i - Y_d) & \text{if } Y_i \geq \overline{Y}_i \end{cases} \tag{3.13}$$

Denoting probability by "P_r" and the conditional expectation of Y given X by $E(Y|X)$, expected gross margins per acre under insurance for the ith activity are:

$$\begin{aligned} E(R_i) = {} & E(P_iY_i) - c_iE(Y_i) - F_i - P_{mi} \\ & + \overline{P}_iE(\overline{Y}_i - Y_i | Y_i \leq Y_d)P_r(Y_i \leq Y_d) \\ & + \overline{P}_iE(\overline{Y}_i - Y_i | Y_d < Y_i < \overline{Y}_i)P_r(Y_d < Y_i < \overline{Y}_i) \\ & - d_iE(Y_i - Y_d | Y_d < Y_i < \overline{Y}_i)P_r(Y_d < Y_i < \overline{Y}_i) \\ & - d_iE(Y_i - Y_d | Y_i \geq \overline{Y}_i)P\ (Y_i \geq \overline{Y}_i)\,. \end{aligned} \tag{3.14}$$

Grouping terms, (3.14) can be rewritten as:

$$\begin{aligned} E(R_i) = {} & E(P_iY_i) - c_iE(Y_i) - F_i - P_{mi} \\ & + \overline{P}_iE(\overline{Y}_i - Y_i | Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i) \\ & - d_iE(Y_i - Y_d | Y_i > Y_d)P_r(Y_i > Y_d)\,. \end{aligned} \tag{3.14'}$$

Differentiating $E(R_i)$ in (3.14') with respect to $\overline{P}_i$, the price election on the ith activity, gives:

$$\frac{\partial E(R_i)}{\partial \overline{P}_i} = E(\overline{Y}_i - Y_i | Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i) - \frac{\partial P_{mi}}{\partial \overline{P}_i}, \tag{3.15}$$

remembering that the premium rate per acre is dependent on the price election (Table 3.14). It is clear from (3.15) that the expected gross margin per acre of an activity changes with $\overline{P}_i$ according to whether:

$$E(\overline{Y}_i - Y_i | Y_i < \overline{Y}_i) P_r(Y_i < \overline{Y}_i) \lesseqgtr \frac{\partial P_{mi}}{\partial \overline{P}_i} .$$

In particular, if the marginal change in insurance benefits is less than the marginal change in the premium rate as the price election increases, the expected gross margin per acre under insurance will be less than that without insurance.

The variance of gross margins per acre of the ith activity under insurance in the case where $\overline{Y}_i > Y_d$ and P_i and Y_i are independently distributed is, after grouping terms:

$$\begin{aligned} V(R_i) = {} & V(P_i Y_i) - c_i^2 V(Y_i) \\ & + (\overline{P}_i^2 - 2\overline{P}_i E(P_i) + 2c_i d_i) V(Y_i | Y_i < \overline{Y}_i) P_r(Y_i < \overline{Y}_i) \\ & + (d_i^2 - 2d_i E(P_i)) V(Y_i | Y_i > Y_d) P_r(Y_i > Y_d) . \end{aligned} \tag{3.17}$$

Differentiation of (3.17) with respect to $\overline{P}_i$, the price election, yields:

$$\frac{\partial V(R_i)}{\partial \overline{P}_i} = 2(\overline{P}_i - E(P_i) + c_i) V(Y_i | Y_i < \overline{Y}_i) P_r(Y_i < \overline{Y}_i) . \tag{3.18}$$

Hence, the direction of the change in the variance of gross margins per acre under insurance as the price election changes depends on the discrepancy between the expected price for the product and the sum of the price election and the harvesting cost per unit of yield, since the terms $V(Y_i | Y_i < \overline{Y}_i)$ and $P_r(Y_i < \overline{Y}_i)$ in (3.18) are nonnegative.

Derivation of the covariance of gross margins per acre for two activities is quite tedious and the analysis is limited to the case where the yield is below the level where an additional charge is added for harvesting. The gross margin per acre of the kth activity is:

$$R_k = P_k Y_k - c_k Y_k - F_k - P_{mk} + \begin{cases} \overline{P}_k(\overline{Y}_k - Y_k) \text{ if } Y_k < \overline{Y}_k \\ 0 \qquad\qquad \text{otherwise} \end{cases} \qquad (3.19)$$

where k = i, j for simplicity.

Denoting covariance by "cov," the covariance of gross margins per acre of two activities, i and j, is given by:

$$\begin{aligned} \mathrm{cov}(R_i, R_j) = {} & \mathrm{cov}(P_iY_i, P_jY_j) - c_i\mathrm{cov}(P_jY_j, Y_i) \\ & - c_j\mathrm{cov}(P_iY_i, Y_j) + c_ic_j\mathrm{cov}(Y_i, Y_j) \\ & - \overline{P}_i[\mathrm{cov}(P_jY_j, Y_i | Y_i < \overline{Y}_i) - c_j\mathrm{cov}(Y_i, Y_j | Y_i < \overline{Y}_i)] \\ & P_r(Y_i < \overline{Y}_i) \\ & + \overline{P}_i\overline{P}_j\mathrm{cov}(Y_i, Y_j | Y_i < \overline{Y}_i, Y_j < \overline{Y}_j)P_r(Y_i < \overline{Y}_i \\ & \text{and } Y_j < \overline{Y}_j) \,. \end{aligned} \qquad (3.20)$$

Consider the case where i and j are activities derived from two different crops. If there is coverage on the ith crop only, i.e.,

$$\overline{P}_i > 0 \qquad \text{and} \qquad \overline{P}_j = 0 \,,$$

then (3.20) reduces to:

$$\mathrm{cov}(R_i, R_j) = \mathrm{cov}(P_iY_i, P_jY_j) - c_j\mathrm{cov}(P_iY_i, Y_j) - c_i\mathrm{cov}(P_jY_j, Y_i) + c_ic_j\mathrm{cov}(Y_i, Y_j) - \overline{P}_i\mathrm{cov}(P_jY_j, Y_i | Y_i < \overline{Y}_i)P_r (Y_i < \overline{Y}_i) + \overline{P}_ic_j\mathrm{cov}(Y_i, Y_j | Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i) . \tag{3.21}$$

Taking the partial derivative of (3.21) with respect to $\overline{P}_i$ gives:

$$\frac{\partial\mathrm{cov}(R_i, R_j)}{\partial\overline{P}_i} = [c_j\mathrm{cov}(Y_i, Y_j | Y_i < \overline{Y}_i) - \mathrm{cov}(P_jY_j, Y_i | Y_i < \overline{Y}_i)] P_r(Y_i < \overline{Y}_i) . \tag{3.22}$$

If, in addition, P_j is independently distributed of the product of both yields, then (3.22) reduces to:

$$\frac{\partial\mathrm{cov}(R_i, R_j)}{\partial\overline{P}_i} = [c_j - E(P_j)]\mathrm{cov}(Y_i, Y_j | Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i)$$

If the expected gross margin per acre of the jth crop is positive, then the impact of the FCI program on the covariance of gross margins of two crops is indirectly related to the covariance of yields. In particular, if the covariance of yields of two crops is positive, insurance availability will reduce the covariance of gross margins under the above assumptions.

Assume now that i and j are activities associated with the same crop; then, by letting $P_i = P_j$ and $c_i = c_j$ with $\overline{P}_i \neq \overline{P}_j$, (3.20) simplifies to:

$$\begin{aligned}\mathrm{cov}(R_i, R_j) = {} & V(P_iY_i) - 2c_i\mathrm{cov}(P_iY_i, Y_i) + c_i^2V(Y_i) \\ & - (\overline{P}_i + \overline{P}_j)\ \mathrm{cov}(P_iY_i, Y_i|Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i) \\ & + c_i(\overline{P}_i + \overline{P}_j)V(Y_i|Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i) \\ & + \overline{P}_i\overline{P}_jV(Y_i|Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i)\,. \end{aligned} \tag{3.24}$$

Letting $\overline{P}_i = 0$ and $\overline{P}_j > 0$, (3.24) in turn reduces to:

$$\begin{aligned}\mathrm{cov}(R_i, R_j) = {} & V(P_iY_i) + (c_i^2 - 2E(P_i))V(Y_i) \\ & - \overline{P}_j(E(P_i) - c_i)V(Y_i|Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i)\,. \end{aligned} \tag{3.25}$$

Differentiating (3.25) with respect to $\overline{P}_j$ yields:

$$\frac{\partial \mathrm{cov}(R_i, R_j)}{\partial \overline{P}_j} = (c_i - E(P_i))V(Y_i|Y_i < \overline{Y}_i)P_r(Y_i < \overline{Y}_i) \tag{3.26}$$

If the expected price of a given crop is greater than the harvest cost per unit of yield of the same crop and if the probability of actual yield falling below the guaranteed yield is positive, then from (3.26) the covariance between gross margins per acre of an activity with insurance and an activity without insurance will decline as the price election increases.

Consider now the case where there is coverage of two crops, e.g., barley and cotton. To determine the impact of coverage of those crops on their covariance of gross margins per acre, differentiate Equation (3.20) with respect to both $\overline{P}_i$ and $\overline{P}_j$ (where i and j are treated as different crops) to obtain:

$$\frac{\partial \mathrm{cov}(R_i, R_j)}{\partial \bar{P}_i \partial \bar{P}_j} = \mathrm{cov}(Y_i, Y_j | Y_i < \bar{Y}_i, \bar{Y}_j < \bar{Y}_j)$$
$$P_r(Y_i < \bar{Y}_i \text{ and } Y_j < \bar{Y}_j) . \tag{3.27}$$

Thus, the impact of insuring against losses on two crops is directly related to the covariance of the yields of both crops given that those yields are below the respective guaranteed yields of the two crops.

Equations (3.23), (3.26) and (3.27), for instance, suggest that generalizations about the impact of the Federal Crop Insurance program on the variances and covariances of gross margins per acre across farms are not easily forthcoming. Consider the yield distribution again and let:

$$Y_{fi} = \bar{Y}_{fi} + e_i$$

represent actual yield if state i obtains, where

$\bar{Y}_{fi}$ = the average yield on a crop for farmer f

e_i = a common disturbance term across farmers

The variance of yield is:

$$V(Y_{fi}) = E(e_i - E(e_i))^2, \tag{3.28}$$

which is assumed to be the same for all farmers. It follows that the variances of gross margins are identical across farms only if there is no coverage and $P_r(Y_i > Y_d) = 0$ or $d_i = 0$ in Equation (3.18). The covariance of gross margins per acre between cotton and alfalfa should also be identical across farms if there is no coverage. Under coverage, however, variances of gross margins per acre (except for alfalfa) and covariances of gross margins would be expected to differ across farmers. Indeed, they all depend on average yield, the probability of actual yield falling below the guaranteed yield and the premium rates per acre which are, in general, farmer-specific. In addition, for feedgrains, the probability of actual yield being above 2,000 lbs will diverge, in general, across farms. As for expected gross margins per acre, they would be expected to diverge across farms for a given crop, even under no coverage, since they are directly dependent on farmer-specific average yields.

The derived data on the correlation matrix, the expected gross margins and the standard deviation of gross margins per acre for the five field crops are given in Table 3.15 for farm 10. The derived data for that specific farm indicate that insurance reduces both the expected gross margins per acre and the standard deviations of gross margins per acre. In addition, the correlation coefficient of gross margins per acre of alfalfa and other crops is lower when those crops are insured than when they are not. No clear pattern emerges, however, for the correlation coefficients among other crops. Table 3.15 suggests that insurance had very little effect on the correlating coefficient of gross margins per acre of cotton and barley. The impact of coverage was to reduce the correlation coefficient of gross margins per acre of sorghum with cotton and increase the correlation coefficient of sorghum with wheat. The correlation between cotton and barley is positive for no insurance and tends to be negative for insurance.

Table 3.15. Correlation matrix, expected value and standard deviation of field crop per acre gross margins for farm 10 (1978).

		Cotton				Wheat				Barley				Sorghum				Alfalfa
		0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0
										Correlation Matrix								
Cotton	0	1	.286	.286	.286	.036	.035	.035	.034	.000	.000	-.001	-.001	-.063	-.006	-.069	-.070	-.073
	1		1	.287	.288	.037	.037	.036	.036	.001	.000	.000	-.001	-.060	-.060	-.060	-.060	-.075
	2			1	.288	.037	.037	.036	.036	.001	.000	.000	-.001	-.060	-.060	-.060	-.060	-.076
	3				1	.037	.037	.036	.036	.001	.000	.000	-.001	-.059	-.060	-.060	-.060	-.076
Wheat	0					1	.160	.160	.960	.076	.080	.080	.084	.057	.058	.058	.058	-.020
	1						1	.160	.160	.076	.080	.080	.084	.062	.063	.063	.063	-.019
	2							1	.160	.076	.079	.080	.084	.063	.064	.064	.065	-.019
	3								1	.075	.079	.081	.083	.064	.065	.066	.066	-.018
Barley	0									1	.200	.200	.200	.018	.019	.020	.021	-.038
	1										1	.190	.200	.021	.022	.024	.024	-.038
	2											1	.200	.022	.023	.024	.024	-.038
	3												1	.023	.025	.026	.026	-.039
Sorghum	0													1	.210	.210	.200	.010
	1														1	.210	.210	.009
	2															1	.210	.008
	3																1	.008
Alfalfa	0																	1
										Dollars Per Acre								
Expected Value		69	63	62	61	-59	-61	-62	-62	22	20	20	19	-106	-108	-108	-108	107
Standard Deviation		215	213	213	212	58	57	57	57	33	33	33	32	84	81	77	76	83

Notes: 0 stands for "no insurance" while 1, 2, and 3 designate price elections 1, 2, and 3 for a given crop. All data are rounded values of those used in the quadratic programming runs.

The data in Table 3.15 show negative gross margins for wheat and sorghum for farm 10. These gross margins were positive for other farmers, depending upon their mean yield.

CHAPTER 4

EMPIRICAL RESULTS

Risk Aversion Coefficient Estimates

Following the empirical procedures outlined in the previous chapter, the risk neutral solution was obtained for each farmer for 1977. In a subsequent step, the expected gross margin for each farm was parametrized between the lowest expected gross margin for the actual crop-mix under insurance availability and the risk neutral expected gross margin to obtain points on the E-V efficiency frontier. To determine the risk aversion coefficient for a given farmer, the E-V point yielding the lowest discrepancy with reference to actual crop-mix was selected along with the next best point on the E-V efficiency frontier and the ratio of increments between the expected gross margins and variances of gross margins computed. The risk aversion parameter was then identified with twice that ratio.

A program to solve linear complementarity problems by Lemke's method (Tomlin, 1976) was used and the risk aversion parameters in Table 4.1 were obtained.

Table 4.1 shows relatively low risk aversion coefficients, at least as compared with previous studies (e.g., Brink and McCarl, 1978). Those risk aversion coefficient estimates were regressed on land (in net acres) and machinery and water capacities to determine whether the hypothesis of constant absolute risk aversion was tenable. The following

Table 4.1. Estimated risk aversion parameters.

Farm	Risk Coefficient
1	.000012
2	.000010
3	.000008
4	.000003
5	.000014
6	.000031
7	.000031
8	.000014
9	.000056
10	.000054
11	.000041
12	.000020
13	.000034

Notes: The estimates above are rounded. The risk aversion coefficient is the parameter r in Equation (3.2), i.e., $W = E(\pi) - (r/2)V(\pi)$.

regression equation was obtained:

$$\begin{array}{l} r = \underset{(5.33)}{.00004} + \underset{(.32)}{.39E - 08}L - \underset{(-.15)}{.25E - 07}M - \underset{(-.75E - 01)}{.18E - .07}W; \\ R^2 = .358 \end{array} \tag{4.1}$$

where

r = the estimated risk aversion coefficient

L = land rented

M and W = machinery and water capacities, respectively

The t-statistics shown in parentheses below the estimated coefficients of (4.1) indicate that the hypothesis that farmers' preference functions exhibit constant absolute risk aversion; that is, the coefficients on land, machinery and water are not significantly different from zero, could not be rejected at the 5% level of significance.

In order to insure the validity of the initial estimates of the risk aversion coefficients, a number of tests were performed. The estimated risk aversion coefficients were, first of all, applied to both 1977 and 1978 data to derive the model solution crop allocation under insurance availability. The data obtained from the risk averse model were then compared with the risk neutral predicted crop-mixes relative to the actual crop-mix reported by each farmer for both 1977 and 1978. Data on the actual crop-mix are given in Tables 4.2 and 4.3 for the years 1977 and 1978, respectively, while data pertaining to the predicted crop-mix from the risk averse model are given in Tables 4.4 and 4.5 for 1977 and 1978, respectively. The risk neutral solutions are presented in tables 4.6 and 4.7, respectively, for the years 1977 and 1978. Tables 4.2, 4.4 and 4.6 suggest that the risk neutral model performed quite well in 1977 for upland cotton relative to the risk averse model: the average absolute deviation of the risk neutral model predicted cotton acreage relative to the actual cotton acreage was 22 acres across farmers. As regards other crops, both models predicted quite inaccurately, suggesting a higher than normal acreage assigned to feedgrains and alfalfa as contrasted with upland cotton.

In order to assess the overall predictive power of both risk averse and risk neutral models, predicted errors were obtained for each crop and each farm and for a given farm, absolute deviations were summed up across crops (Tables 4.8 and 4.9). If the risk averse model performed

Table 4.2. Crop-mix of selected farms in Pinal County (1977), in acres.

Farm	Upland Cotton	Wheat	Barley	Sorghum	Alfalfa
1	330	68			
2	334				
3	350				
4	1,105				
5	417				
6	195				
7	207	63		23	
8	415				
9	91	29			
10	101				
11	157	102			
12	317	217			
13	200	200			

Source: ASCS.

Table 4.3. Crop-mix of selected farms in Pinal County (1978), in acres.

Farm	Upland Cotton	Wheat	Barley	Sorghum	Alfalfa
1	319	49		10	40
2	333				
3	350				
4	1,306				
5	434				
6	116			60	
7	209	120			
8	414	40		30	
9	102				
10	92				
11	174	83			
12	200	151	30		
13	201				

Source: ASCS.

Table 4.4. Predicted 1977 crop-mix from risk averse model, in acres.

Farm	Cotton	Wheat	Barley	Sorghum	Alfalfa
1	157		439	172	
2	153		429	78	14
3	166		308		
4	515		1,458	535	13
5	205		452		93
6	102		204		49
7	86		98		66
8	194		497		90
9	48		92		24
10	47		112		20
11	74		177		36
12	147		370		73
13	85		301		41

Note: These estimates are rounded values.

Table 4.5. Predicted 1978 crop-mix from risk averse model, in acres.

Farm	Cotton	Wheat	Barley	Sorghum	Alfalfa
1	122		260		162
2	133		287		142
3	130		189		155
4	463		953		469
5	35		363		173
6			95		83
7					82
8	58		407		171
9					39
10	20		87		42
11	8		147		62
12	14		312		125
13	17		269		77

Note: These estimates are rounded values.

Table 4.6. Predicted 1977 crop-mix from risk neutral model, in acres.

Farm	Cotton	Wheat	Barley	Sorghum	Alfalfa
1	309		342	16	4
2	307		341	14	11
3	350	11			
4	1,017		1,131	50	36
5	387		396		30
6	186		185		14
7	196		207		33
8	383		405		64
9	48		92		24
10	93		96		7
11	161		161		1
12	310		319		28
13	199		221		66

Table 4.7. Predicted 1978 crop-mix from risk neutral model, in acres.

Farm	Cotton	Wheat	Barley	Sorghum	Alfalfa
1	311		317		18
2	309		317		24
3	340		125		9
4	1,023		1,051		81
5			94		417
6			44		195
7					230
8			101		448
9					91
10			22		101
11			36		163
12			76		339
13			60		266

Table 4.8. Predicted errors from 1977 models, in acres.

Farm Rank[a]	Risk Averse Model	Risk Neutral Model
1	2,597	1,306
2	491	11
3	702	373
4	853	441
5	756	458
6	841	534
7	830	572
8	347	214
9	371	338
10	658	489
11	398	269
12	185	110
13	188	188

a. Farms are ordered by the degree of risk aversion (lowest to highest coefficient).

Table 4.9. Predicted errors from 1978 models, in acres.

Farm Rank[a]	Risk Averse Model	Risk Neutral Model
1	2,265	1,414
2	564	143
3	629	365
4	638	405
5	935	945
6	1,004	1,033
7	141	193
8	354	415
9	530	497
10	702	766
11	459	456
12	411	559
13	202	215

a. Farms are ordered by the degree of risk aversion (lowest to highest coefficient).

better than its risk neutral counterpart, one would expect the predicted errors from the risk neutral model to get larger and larger as the risk aversion coefficient increases; in addition, one would expect the predicted errors from the risk averse model to be fairly stable as the risk aversion parameter changes across farmers (the analogy with the concept of homoskedasticity in statistics would seem to be appropriate here). The relationship between the risk averse predicted errors and the risk aversion coefficient is indicated in equations (4.2) and (4.3), respectively for the 1977 and 1978 years:

$$PE_A = \underset{(5.20)}{1284.0} - \underset{(-2.80)}{.22E + 08r}; \quad R^2 = .363 \tag{4.2}$$

$$PE_A = \underset{(5.91)}{1213.2} - \underset{(-3.12)}{.21E + 08r}; \quad R^2 = .364 \tag{4.3}$$

Likewise, the relationship between the risk neutral predicted errors and the risk aversion coefficient is indicated in Equations (4.4) and (4.5) for the years 1977 and 1978, respectively:

$$PE_N = \underset{(4.50)}{644.1} - \underset{(-1.98)}{.93E + 07r}; \quad R^2 = .197 \tag{4.4}$$

$$PE_N = \underset{(5.20)}{858.3} - \underset{(-2.10)}{.11E + 08r}; \quad R^2 = .220 \tag{4.5}$$

where

PE_A = predicted error for the risk averse model

PE_N = predicted error for the risk neutral model

r = the risk aversion coefficient.

Given that the t-statistics in parentheses below the estimated coefficients are all significantly different from zero at the 10% level of significance, equations (4.4) and (4.5) indicate that the risk neutral predicted errors get lower and lower as the risk aversion coefficient increases while Equations (4.2) and (4.3) suggest that the predicted errors from the risk averse model decrease as the risk aversion coefficient increases and therefore are not stable across farmers. The above results would indicate that the estimation procedures for the risk aversion coefficient were inadequate or that the empirical model may have been incorrectly specified.

The specification errors hinted at above were traced back to the constraint matrix after reconsidering the assumptions of the model. This analysis suggested that a more careful specification of seasonal land use was in order. The constraint matrix was revised in two ways:

1. First, the land constraint was altered so as to explicitly allow for the seasonal pattern of the different field crops considered in this study. For instance, 1976 summer cotton and grain sorghum are followed by fall-planted winter wheat, barley or alfalfa or spring-planted cotton and sorghum. A schema of summer and winter acreage restrictions is given in Table 4.10.
2. In addition, the number of acres of cropable land inserted into the model was revised as follows. For each of the years 1976-1979, a distinction was made between summer and winter crops and the total acreage planted in each subperiod was determined using the actual crop-mix reported by farmers around July of a given year. The restraint on land was then identified with the highest acreage grown in the period 1976-1979 for a given farm.

Table 4.10. Land constraint matrix.

RHS	$Cotton_{t-1}$	$Sorghum_{t-1}$	$Cotton_t$	$Sorghum_t$	$Alfalfa_t$	$Wheat/Barley_t$
$Summer\ Acres_{t-1}$	1	1			1	
$Winter\ Acres_t$			1		1	1
$Summer\ Acres_t$			1	1	1	

Note: t-1 and t refer to past and current years, respectively. It is assumed that the acreage assigned to alfalfa in 1977 could not be larger than the difference between the summer acres of 1976 and the sum of cotton and sorghum acres. RHS refers to the right-hand side.

The revised data on cropable land for each of the selected farms are reported in Table 4.11.

The revised risk aversion coefficient estimates are given in Table 4.12 with associated predicted crop-mix and 1977 predicted errors in Table 4.13 and 4.14, respectively. The revised estimates of the risk aversion coefficients were quite an improvement over the previous estimates. Predicted errors were low for cotton: 4 acres on average in absolute value. Errors were relatively large on feedgrains but substantially less than with the previous estimates. The new estimates of the risk aversion coefficient were regressed on the new estimates of cropable land, and the previous estimates of machinery and water capacities and the following equation was obtained:

$$\underset{(2.0687)}{r = .0000003} - \underset{(-.46E-01)}{.27E-09L} - \underset{(-.91E-01)}{.11E-08M} + \underset{(.65E-02)}{.129E-09W}; \quad R^2 = .20 \tag{4.6}$$

where r, L, M and W are as defined previously. Equation (4.6) indicates as before that the hypothesis of constant absolute risk aversion is tenable at the 5% level of significance. Regression of the 1977 model predicted errors on the risk aversion coefficient resulted in the following equation:

$$PE = \underset{(4.07)}{90.90} - \underset{(-.599)}{.10E+08r}; \quad R^2 = .127 \tag{4.7}$$

where PE denotes predicted errors. Equation (4.7) suggests that the revised model has a higher predictive ability than the previous one (see Equation (4.3) for instance): the coefficient on the risk aversion

Table 4.11. Estimated cropable land (acres).

Farm	Land
1	406
2	447
3	354
4	1,306
5	529
6	200
7	329
8	484
9	170
10	153
11	276
12	534
13	400

Table 4.12. Reestimated risk aversion coefficients.

Farm	Risk Aversion Parameter
1	.0000005738
2	.0000000986
3	.0
4	.0
5	.0000002039
6	.0000006135
7	.0
8	.0
9	.0000019778
10	.0000035982
11	.0
12	.0
13	.0000012973

Table 4.13. Predicted crop-mix in 1977 (new estimates), in acres.

Farm	Cotton	Wheat/Barley	Sorghum	Alfalfa
1	329.91	76.08	.08	
2	325.62	113.00	.83	
3	350.00	4.00		
4	1,090.78	215.21	14.21	
5	409.04	112.00		7.96
6	194.93	5.00		.06
7	204.74	99.00		25.25
8	413.12	36.00		34.88
9	87.01	79.00		3.98
10	97.17	52.00		3.82
11	163.00	113.00		
12	319.73	195.00		19.26
13	205.94	134.00		60.05

Table 4.14. Predicted errors in 1977 (new estimates).

Farm	Cotton	Wheat/Barley	Sorghum	Alfalfa	Total[a]
1	+ .09	+ 8.08			8.25
2	- 8.38	+113.00			122.21
3	.00	+ 4.00			4.00
4	-14.22	+215.21			243.64
5	- 7.96	+112.00		+ 7.96	127.92
6	- .07	+ 5.00		+ .06	5.13
7	- 2.26	+ 36.00		+25.25	86.51
8	- 1.88	+ 36.00		+34.88	105.76
9	- 3.99	+ 51.00		+ 3.98	58.97
10	- 3.83	+ 52.00		+ 3.82	59.65
11	+ 6.00	+ 11.00			92.00
12	+ 2.73	- 22.00		+19.26	43.99
13	+ 5.94	- 66.00		+60.05	131.99

a. Total predicted errors for a given farm are given in absolute terms.

coefficient is not significantly different from zero at the 10% level of significance.

As Table 4.12 shows, seven out of thirteen farmers would seem to exhibit risk aversion although their estimated degree of risk aversion was very low. When those risk aversion estimates were applied to 1978 data, the predicted crop-mix was found to be quite close to the actual crop-mix for four out of the thirteen farmers. Among the remaining nine farmers, the model predicted no acreage assigned to cotton for three farmers. A look at the derived data on expected gross margins indicated that those three cases were associated with very low estimates of expected gross margins per acre of upland cotton as contrasted with barley or alfalfa. Data on the 1978 predicted crop-mix by farm as well as predicted errors, under insurance availability, are reported in Tables 4.15 and 4.16.

Comparative Study of Insurance and No Insurance

It was indicated earlier that among the selected thirteen farmers, estimated risk preferences were consistent with risk aversion for seven farmers. Among those seven farmers, 1978 data applied to the E-V framework indicated that four would have purchased federal crop insurance. The ensuing comparative study of federal crop insurance and no insurance focuses on those four farmers.

Crop-Mix Impact of Federal Crop Insurance

In testimony before the Committee of Agriculture of the House of Representatives, the U.S. Department of Agriculture stated in 1979

Table 4.15. Predicted crop-mix (1978), in acres.

Farm	Cotton	Wheat/Barley	Sorghum	Alfalfa
1*	329.92	76.00		
2*	325.62	113.00		8.37
3	350.00	4.00		
4	1,091.92	201.00		13.08
5	305.00	112.00		112.00
6		195.00		5.00
7				122.00
8	379.00	36.00		69.00
9				69.00
10*	49.00	52.00		52.00
11	44.00	84.46		119.00
12	105.14	211.85		217.00
13*	66.00	133.33		200.00

* Indicates that a given farmer purchased insurance.

Table 4.16. Predicted errors (1978), in acres.

Farm	Cotton	Wheat/Barley	Sorghum	Alfalfa	TOTAL Absolute Deviation
1	10.92	27.00	10.00	40.00	87.92
2	- 7.38	113.00		8.37	128.75
3		4.00			4.00
4	-214.08	201.00		13.08	428.08
5	-129.00	112.00		112.00	353.00
6	-116.00	195.00	-60.00	5.00	376.00
7	-209.00	-120.00		122.00	451.00
8	- 35.00	- 4.00	-30.00	69.00	138.00
9	-102.00			79.00	181.00
10	- 33.00	52.00		52.00	137.00
11	-130.00	1.46		119.00	250.46
12	- 94.86	30.85		217.00	342.71
13	-135.00	133.33		200.00	468.33

that one of its major objectives with respect to the federal crop insurance program was that the program should be "neutral" in its effects on the commodity-mix. Although it is not evident what the term "neutral" should be construed to mean, 1978 data on the predicted crop-mix of the four selected farmers, both under insurance availability and without insurance, suggest that the FCI program has no significant impact on crop-mix (Table 4.17). This result would imply that the insurance purchase decision is systematically divorced from the crop allocation decision. Table 4.17 also shows that, under insurance availability, farmers would have opted for coverage on cotton only, the insured acreage of cotton varying from 5% to 57%. Coverage of cotton only as contrasted with other field crops is consistent with the derived data on the variance-covariance matrix of returns above variable costs. Indeed, not only were the variances of gross margins of insured cotton substantially reduced under insurance availability as compared with the case of no insurance but also the covariances of gross margins of insured cotton with other activities were substantially less than those of wheat, barley and grain sorghum with other activities under insurance availability. Hence, the benefits from the FCI program were not sufficient for the four selected farmers to warrant the purchase of insurance for field crops other than cotton. Table 4.17 indicates also that there is no inherent bias in the Federal Crop Insurance program towards either diversification or specialization.

Table 4.17. Predicted risk averse crop-mix with and without insurance and risk neutral solution (1978).

Farm		Cotton	Wheat/Barley	Alfalfa
	INSURANCE			
	Acreage Covered	188.32		
1	Acreage Not Covered	141.60	76.00	
	Total	329.92	76.00	
	NO INSURANCE	329.92	76.00	.08
	RISK NEUTRAL	386.15	19.00	
	INSURANCE			
	Acreage Covered	16.47		
2	Acreage Not Covered	309.15	113.00	8.37
	Total	325.62	113.00	8.37
	NO INSURANCE	325.62	113.00	8.37
	RISK NEUTRAL	376.21	71.77	9.02
	INSURANCE			
	Acreage Covered	22.09		
10	Acreage Not Covered	26.91	52.00	52.00
	Total	49.00	52.00	52.00
	NO INSURANCE	49.00	51.00	52.00
	RISK NEUTRAL	82.21	22.78	48.00
	INSURANCE			
	Acreage Covered	7.26		
13	Acreage Not Covered	58.74	133.33	200.00
	Total	66.00	133.33	200.00
	NO INSURANCE	66.00	133.33	200.00
	RISK NEUTRAL	73.11	80.01	246.00

Welfare Impact of Federal Crop Insurance

In a comment on the concept of efficiency in economic analysis, Demsetz (1969, p. 1) contends that:

> The view that now pervades much public policy economics implicitly presents the relevant choice as between an ideal norm and an existing "imperfect" institutional arrangement. This nirvana approach differs considerably from a comparative institution approach in which the relevant choice is between alternative real institutional arrangements. In practice, those who adopt the nirvana viewpoint seek to discover discrepancies between the ideal and the real and if discrepancies are found, they deduce that the real is inefficient. Users of the comparative institutional approach attempt to assess which alternative real institutional arrangement seems best able to cope with the economic problem; practitioners of this approach may use an ideal norm to provide standards from which divergences are assessed for all practical alternatives of interest and select as efficient that alternative which seems likely to minimize the divergence.

Only two alternative institutional arrangements are examined here and the comparative institutional approach is adopted to determine whether federal crop insurance availability is preferable to the case of no federal crop insurance availability. Two possible approaches may be followed in providing an ideal norm to assess the desirability of the federal crop insurance program:

1. In the first approach, one may adapt the concept of net return to society, based on the Hicks-Kaldor notion of Pareto improvement to a framework of risk (Just, 1978, pp. 1-19). Under such an approach, derived demand and supply functions for a given input are derived under the assumptions of constant absolute risk aversion and nonstochastic factor prices and changes in welfare are associated as usual with the areas below the demand curve and above the supply curve. It should be noted that this

extension of the traditional welfare criterion to the case of risk could meet with serious difficulties if input prices are random.

2. The second approach is based on the work by Arrow and Lind on the evaluation of public investments in a framework of uncertainty (1970). According to these authors, since uncertainties on most governmental projects are publicly borne, the "cost" of risk is, in general, negligible for society as a whole. Thus, in evaluating the desirability of a given project, the government should act as if it were risk neutral. An implication of Arrow and Lind's argument is that "Positive social benefits of insurance occur, therefore, when the availability of insurance moves private resource allocation in the direction of the risk neutral optimum" (Roumasset, 1976, p. 223).

In what follows, the Arrow-Lind derived criterion is used as norm and the relative closeness of the risk averse optimum to the risk neutral optimum is used as the yardstick for evaluating the Federal Crop Insurance program.

Table 4.18 shows that, although expected gross margins at the whole farm level are lower under insurance availability as compared with no insurance, expected utility is higher for the four selected farmers under the former institutional arrangement. For a given risk aversion coefficient, both expected gross margins and variance of gross margins are lower under insurance availability. In Figure 4.1, EV_N and EV_I are

Table 4.18. Derived data on expected gross margins, standard deviation of gross margins (in dollars) and expected utility.

Farm		E	σ	U
	Risk Averse			
1	No Insurance	61,622	168,881	53,493
	Insurance	60,015	118,163	56,035
	Risk Neutral	69,460	172,779	69,460
	Risk Averse			
2	No Insurance	90,710	210,649	88,713
	Insurance	90,578	203,178	88,721
	Risk Neutral	100,603	213,121	100,603
	Risk Averse			
10	No Insurance	10,067	20,907	9,282
	Insurance	9,940	17,000	9,421
	Risk Neutral	11,310	21,518	11,310
	Risk Averse			
13	No Insurance	24,717	45,245	23,396
	Insurance	24,681	44,531	23,401
	Risk Neutral	29,245	47,427	29,245

Notes: E, σ and U designate expected gross margins, standard deviation of gross margins and expected utility, respectively. Under the hypotheses that gross margins are normally distributed and that there is constant absolute risk aversion, the expected utility is identical to the certainty equivalent. All data are rounded.

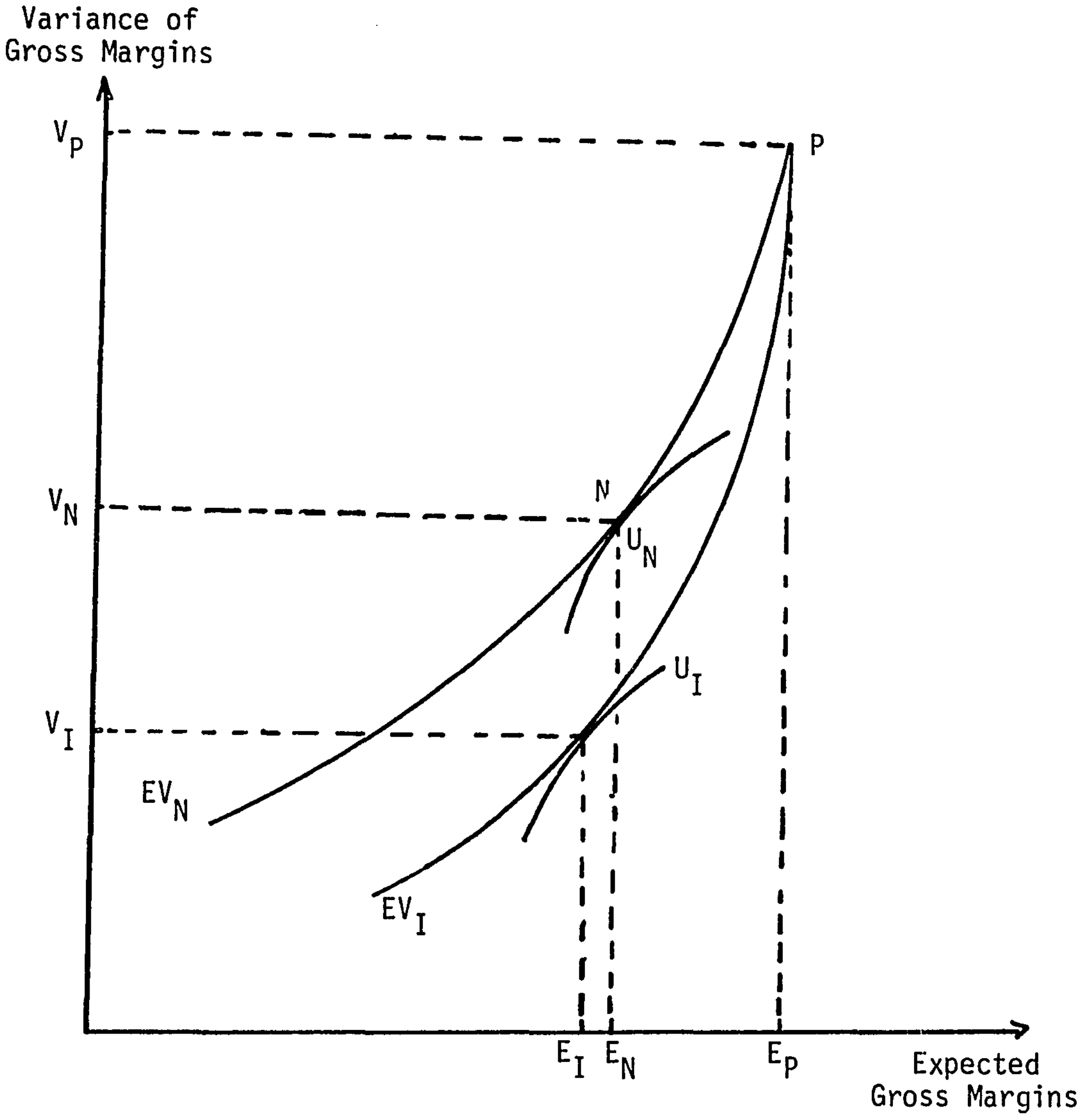

Figure 4.1. Comparison of insurance and no insurance availability.

efficiency frontiers without and with insurance with associated indifference curves U_N and U_I while the points:

$$N(E_N, V_N)\,,$$

$$I(E_I, V_I)\,,$$

and

$$P(E_P, V_P)$$

represent the risk averse optimum solutions under no insurance and insurance and the risk neutral solution, respectively (E and V denoting expected value of returns above variable costs and variance). Let the functions f and g represent the efficiency frontiers EV_N and EV_I, respectively. Then, since $E_I < E_N < E_P$, it follows that:

$$g(E_P) = f(E_P) > f(E_N) > f(E_I)\,.$$

Since f and g are monotonically increasing in the interval $(0, E_P)$ and $f > g$, for all values of expected gross margins less than E_P, it is the case that:

$$f(E_I) > g(E_I)\,.$$

Accordingly, $f(E_N) > g(E_I)$ and the risk averse optimum under insurance availability is farther away from the risk neutral point than the risk averse optimum without insurance.

The above analysis which attempts to capture the results of Table 4.18 would thus indicate that, although some farmers do benefit from the provision of federal crop insurance while none is worse off, the effectiveness of the program from a social standpoint is doubtful.

McCall (1971, p. 420) has argued in reference to the securities market that "Individuals can diversify their portfolio of stocks to achieve an acceptable level of expected return for a given risk. This ability to spread risks permits firms to engage in projects which otherwise would be unacceptable. Consequently, society is better off." Results above indicate otherwise with respect to the Federal Crop Insurance program based upon the Arrow-Lind criterion.

CHAPTER 5

SUMMARY AND SUGGESTED EXTENSIONS

This dissertation has illustrated an approach to public policy within a risk framework focusing on the Federal Crop Insurance program in the U.S. under 1978 provisions.

A number of results emerge from the expected utility hypothesis:

1. Under the assumptions of a single crop with stochastic yield and constant marginal cost in acreage, it is shown that a reduction of the insurance premium will induce an increase in planned acreage if nonincreasing absolute risk aversion characterizes farmers' preferences. This result holds also for the special case of constant relative risk aversion (assuming positive profit).
2. Assuming one crop with stochastic yield and another crop completely safe and marginal cost constant in acreage, it is shown that making Federal Crop Insurance available unambiguously alters the crop-mix in the direction of more risky ventures if the expected net returns from insurance coverage are positive. The only assumption about the farmer's utility function that is needed for this result is that the marginal utility of profit be positive and diminishing. The impact of the availability of insurance on risk taking is ambiguous if the expected net returns

from insurance are negative as would be the case for an unsubsidized insurance program. However, it is shown that under non-increasing absolute risk aversion a premium reduction for an insured farmer will encourage further risk taking and increase the farmer's expected utility even if expected net returns from insurance are negative.

3. Under nonlinear costs in acreage, conditions are established under which a farmer specializing in the growing of a risky crop will purchase insurance. It is shown that a risk averse farmer will always find it desirable to participate in the Federal Crop Insurance program if the expected net returns from coverage are positive. Enrollment in the program could occur also even if the expected net returns from coverage were negative.
4. Under a two-crop case and nonlinear cost in acreage and assuming a simultaneous choice of both insurance coverage and the crop-mix the theoretical analysis indicates that increasing insurance benefits through an increase in the price election has no effect on the crop-mix given that absolute risk aversion is constant. Higher exposure to risk has an ambiguous effect on the demand for coverage and a reduction of the insurance premium rate increases the demand for coverage under constant absolute risk aversion.

An empirical model is developed to predict the product mix for a sample of Arizona farms. Results derived within an expected value of income-variance of income framework under 1977 and 1978 Federal Crop Insurance provisions were as follows:

1. Making Federal Crop Insurance available results in a number of farms taking out insurance which reduces the variance of gross margins.
2. For farmers in the selected sample that would be expected to take out insurance, results of the empirical study indicate that the availability of the Federal Crop Insurance program has no significant impact on the product-mix under 1978 provisions.
3. A criterion derived from the work of Arrow and Lind on public investments under uncertainty was used to assess the social benefits of the availability of the Federal Crop Insurance program. That criterion evaluates the social desirability of a given public program by the extent to which its availability induces a reallocation of resources toward the risk neutral optimum. This criterion follows from the assumptions that all benefits and costs of a program accrue to the government and are then shared equally by all members of society and that the returns from the public program are independent of other components of national income. The empirical work undertaken here suggests that the crop insurance program generates negative social benefits in the sense that the risk averse optimum under insurance availability is farther away from the risk neutral optimum as compared with the risk averse optimum without insurance.

It was shown analytically that a premium reduction will, in general, increase risk taking. Is that result robust to a relaxation of the assumptions underlying the specification of profits? A number of extensions worth considering in that context are as follows:

1. The assumption of a binary distribution for profit could be discarded in favor of a continuous distribution.
2. The analysis could be broadened to encompass two risky crops with the proviso that one crop is unambiguously less risky than the other one.
3. An analysis where the production process allows for the possibility of substitution between at least two scarce inputs is needed to impart more generality to the results pertaining to the theoretical impact on product and factor mix of a premium reduction and insurance availability.

The analytical study could not yield refutable implications regarding the effect of insurance availability on risk taking when the expected net returns from coverage are negative. Research is needed to determine whether additional assumptions can obtain unambiguous hypotheses. For instance, assumptions may be made about the higher-order derivatives of the absolute risk aversion function.

Alternative specifications of the distributions of the components of gross margins are needed also in order to corroborate or invalidate the empirical results of this study.

Regarding prices, a simple linear function relating the expected price to both futures price and the expected basis was assumed to reflect the way farmers form their expectations. Two possible extensions are suggested below.

1. Based on historical data on average prices received and quantities demanded, one could estimate a demand function at the farm level. Using planned acreage and an estimate of normal yield for a given crop, one could then estimate expected output and the corresponding expected price.
2. Alternatively, one may still use both futures price at planting time and the expected basis with the added assumption, however, that farmers adjust their expectations according to whether the futures price at planting time is low relative to the normal price (the normal price being associated with the price equating demand and supply). For instance, if the futures price is below the normal price, the farmer may expect the quantity supplied in the market to decline,thereby entailing a higher price at harvest time. Thus, he may adjust his expectation upward, perhaps by a fraction of the gap between the futures price and the normal price.

The estimation of the yield distribution is also subject to modifications. For example, in the estimation of the distribution of the random component, SRS farmers who had not reported yield data for at least two years were not considered. An alternative estimation procedure which utilizes all available information could involve the use of the maximum entropy principle. According to Theil (1981, p. 1), in reference to that principle, "The basic idea is that the statistician knows something (but not everything) about this distribution and that it is rational to estimate this distribution by a fitted distribution . . . subject to the constraint of what he knows."

Additional alternatives should also be considered in the empirical model. In particular, other risk management alternatives such as hedging in futures markets and private insurance should be allowed.

Even within the empirical framework adopted in this study, further analysis is needed to test some of the theoretical results. For instance, how does a reduction of the premium rate affect the crop-mix under insurance availability? How much of a subsidy of the premium rate may be needed to alter the crop-mix in the direction of more risky alternatives? Sensitivity analysis pertaining to both the price election and the guaranteed yield levels should also be undertaken.

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