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The role of crop insurance in an integrated risk management system

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by

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CHAPTER I. INTRODUCTION

The Problem

Since the early 1930s, the federal government has been providing disaster assistance programs to farmers. Examples of these are the Federal All-Risk Crop Insurance (FCI) program, the Agricultural Stabilization and Conservation Service (ASCS) low yield disaster assistance program, and the Farmer Home Administration Emergency Loan program. More recently, there has been a tendency to concentrate government efforts on a less costly and self-sustaining federal disaster assistance program. In fact, this trend began with the passage of the Federal Crop Insurance Act of 1980. As a consequence, the ASCS low yield assistance program is now virtually banned and emergency loans have been reduced.

If the expanded FCI program is to be cost effective, James Deal, former Director of the Federal Crop Insurance Corporation, estimates that 68 percent of eligible acres should be insured. However, past experience has shown that only 14 percent of eligible acres have been insured steadily; in fact, with few exceptions, farmers have been unwilling to participate in all-risk crop insurance programs.

Crop insurance is relevant when yield risks are the primary source of fluctuations in income. A well-designed insurance program would spread risks among many farmers, across diverse regions, across sectors of the economy, and over time. Like other risk-sharing arrangements, it enables the individual farmer to focus more aggressively on average profits, thereby mitigating many of the effects of risk. It may also provide a more efficient alternative to traditional risk-sharing arrangements such as sharecropping.

Yet, there are two major deficiencies associated with crop insurance programs. First, they usually cover only yield variation and not price variation, so their contribution to income stability could be quite limited. Second, farmers may be less conscientious in trying to avoid damage from natural causes, because it is easy to rely on insurance compensation.

Crop and price risks play an important role in determining the well-being of farmers and their productivity. For these reasons, farmers look for ways to manage their resources efficiently in a risky environment.

Price risk occurs because crop prices are not set by the farmer but are set by supply and demand in the commodity markets--although price fluctuations may be limited by government intervention. Hence, the product price at harvest time may not equal the price the farmer expected months earlier when he made his planting decisions. The crop production risk is that of a reduced yield or crop failure caused by natural hazards of two kinds: (1) adverse weather--hail, wind, frost, drought, excessive moisture or flooding, and "late spring", and (2) pests--insects, plant diseases, and weeds.[1]

The next section briefly discusses the nature of crop production

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[1]"Late spring" refers to cool weather and other conditions that interfere with germination and emergence of seedling plants.

hazards, the beginnings and evolution of crop insurance, the extent of present participation and the characteristics of current crop insurance contracts--i.e. crop, hail, and all-risk types.

With the information required from the description of crop insurance, the next step is to establish hypotheses on farmers' attitudes toward all-risk crop insurance. Objectives and methodology of the study are given in the same section.

General Considerations

The nature of crop production hazards

Hail may damage a growing crop at any time up to harvest. Hail storms occur across much of the United States, with the chief hail insurance areas extending from central Montana to Virginia and North Carolina, reaching south to Kansas, Missouri, southern Illinois, and Kentucky. The hazard of drought is greatest in the Grain Plains where wheat, barley, and grain sorghum are the main insured crops and in the western Corn Belt where those crops as well as corn and soybeans are insured. Frost is a hazard to wheat and barley in the northern part of Montana, North Dakota and Minnesota and to corn and soybeans throughout the Corn Belt. Excess moisture and flooding are hazards to all crops in all areas. Unfavorable weather seasons may affect seed germination or seedling emergence and hence lower the eventual yield, particularly of crops like corn and cotton.

Although man has little control over the weather, the risk of crop losses due to drought has been lessened. We now have varieties of crops that are more resistant to droughts. And through the use of summer fallow, conservation tillage, and more timely operations, we are able to conserve more soil moisture for the use of crops. The use of the fallow has been greatly encouraged by the crop allotment and acreage diversion programs. Nevertheless, drought remains a serious hazard annually in the Great Plains and seasonally (late summer) in the more humid East and South.

Evolution of crop insurance

The present description concentrates on the two principal kinds of crop insurance--crop-hail and all-risk. Crop-hail insurance is sold chiefly by private insurance companies, whereas all-risk crop insurance is sold chiefly by the federal crop insurance corporation.

Crop-hail insurance[1] Crop insurance was first used to protect against losses due to hail damage and is still widely used for that purpose. In 1880, tobacco growers in Connecticut organized a mutual hail insurance company that continued in business for seven years. In 1883, some fire insurance stock companies first offered hail insurance to crop farmers. These early attempts at offering crop insurance were sporadic and short-lived. Little was known about the frequency or the severity of hail damage within an area. By 1919, of the 121 mutual hail insurance companies that had operated at one time

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[1]The historical development of crop-hail insurance is taken from Valgren (1922, pp. 2-11).

or another, 80 had been discontinued.

During the 1915-20 period, crop insurance received new impetus with the organization of several new companies. In addition to 43 stock companies and several mutual companies then in business, the state legislatures of Montana, Nebraska, North Dakota, and South Dakota established State crop-hail insurance systems. In 1919, the total volume of crop-hail insurance reached $559 million. Of this, the stock companies held almost half, and the remainder was about equally divided between the mutual companies and the State crop-hail insurance systems. During the 1920s, the amount of crop-hail insurance used by farmers declined and by 1934, it totaled only $87 million. Since the mid-1930s, crop-hail insurance has expanded rapidly, mainly via the commercial mutual and commercial stock companies, as all of the State-sponsored crop-hail insurance systems except Montana's have been discontinued.

Crop-hail is generally available in all areas of the country where hail risk is significant. It is widely used on tobacco in the mid-Eastern states, on corn and soybeans in the Corn Belt, and on wheat, barley, and grain sorghum in the Great Plains. In 1982, crop-hail insurance with coverage estimated at $8.9 billion was bought by $362.9 million premium income. Total indemnities ($190.4 million) averaged 52 percent of premium income (CHIAA, 1982).

All-risk crop insurance   Although commercial insurance companies have become firmly established in the crop-hail insurance business, they have not yet developed a significant program of all-risk or weather-peril insurance, mainly because of large losses incurred because of drought. The first recorded attempt (and failure) to offer all-risk insurance was that of a company organized in 1899 to sell weather-peril insurance in North Dakota and Minnesota. Almost two decades later in 1917, three companies attempted to offer all-risk insurance in the Dakotas and Montana, but they soon discontinued the operation. Again in 1920, several larger insurance companies attempted to insure grains and cotton, but without success. During the 1920s and 1930s, only a few attempts were made by commercial companies to offer all-risk crop insurance, and all were soon discontinued.

These attempts by pioneer insurance companies failed for the following reasons: (1) there was no proper actuarial calculation of risk because of inadequate data; (2) premium rates were too low compared to the coverage offered; (3) risks were not well-spread because of limited area of operation; and (4) applications were accepted when high probability of crop failure existed (Ray, 1981).

Federal crop insurance   Because of these unhappy results by private crop insurance companies and an extended drought in the Great Plains, President Roosevelt appointed a "President's Committee on Crop Insurance" in 1936. After meetings with government officials, the commercial insurance industry, and various farm groups, the President's Committee recommended a plan for crop insurance to Congress in 1937. After a year of legislative activity and hearings, Congress passed the Federal Crop Insurance Act in 1938 as Title V of the

Agricultural Adjustment Act.

The original Act provided only for insurance on wheat, beginning with the 1939 crop; insurance on cotton began in 1942. Both were very large programs in which the insurance was offered nationwide. Losses exceeded premiums on both wheat and cotton in each of the first five years, 1939-43 (Table I.1). Although heavy losses resulted directly from droughts, winterkill, and other causes, there were also some defects in the insurance plan and administrative operations. Because of the disappointing experience of the early years, Congress passed legislation withdrawing the insurance in the 1944 crop year.

The crop insurance program was revived by Congress in 1945 with insurance on wheat, cotton, and flax to be made available generally. Experimental work also was started on corn and tobacco insurance in a few counties. Experience improved with wheat and was satisfactory with flax, corn, and tobacco. However, large program losses occurred on cotton in both 1945 and 1946, primarily because of widespread drought in the Southwest. In 1946, total indemnities for all crops exceeded premiums by \$28 million--a loss ratio of 1.80 (Table I.1). More than 75 percent of FCIC's original capital stock of \$100 million had been used to pay losses not covered by premiums in that year.

As a result of the heavy losses in 1946, federal crop insurance was limited to an experimental basis in 1948, and the corporation was directed to develop a sounder basis for its all-risk insurance. In 1948,

Table I.1. Summary of Federal Crop Insurance Corporation experience 1939-1980[a]

Year	Liability	Premiums	Indemnities	Pre-miums	Indem-nities	Loss ratio
	-------thousands of dollars-------			As % of liability		
1939	$ 34,475	$ 3,411	$ 5,603	9.9	16.3	1.64
1940	67,029	9,155	13,869	13.7	20.7	1.51
1941	101,700	11,279	18,924	11.1	18.6	1.68
1942	197,613	16,694	24,937	8.4	12.6	1.49
1943	244,394	18,236	33,231	7.5	13.6	1.82
1944	(No insurance offered)					
1945	148,161	9,360	23,246	6.3	15.7	2.48
1946	350,623	35,329	63,489	10.1	18.1	1.80
1947	420,921	43,777	35,244	10.4	8.4	.81
1947 & prior	1,564,916	147,241	218,543	9.4	14.0	1.48
1948	153,997	12,684	6,780	8.2	4.4	.53
1949	163,495	11,862	15,531	7.3	9.5	1.31
1950	240,448	14,104	12,799	5.9	5.3	.91
1951	317,463	19,111	21,338	6.0	6.7	1.12
1952	350,216	21,200	20,609	6.1	5.9	.97
1953	437,514	27,098	31,057	6.2	7.1	1.15
1954	354,279	22,655	28,030	6.4	7.9	1.24
1955	309,924	22,330	25,505	7.2	8.2	1.14
1956	306,743	22,139	27,890	7.2	9.1	1.26
1957	242,200	17,407	12,004	7.2	5.0	.69
1958	242,712	17,617	4,505	7.3	1.9	.26
1959	270,828	18,461	14,138	6.8	5.2	.77
1960	265,885	17,797	10,316	6.7	3.9	.58
1961	271,709	18,149	16,092	6.7	5.9	.89
1962	356,354	21,854	24,022	6.1	6.7	1.10
1963	496,669	30,374	23,524	6.1	4.7	.77
1964	542,117	33,852	30,362	6.2	5.6	.90
1965	590,393	36,015	40,753	6.1	6.9	1.13
1966	635,523	36,828	25,198	5.8	4.0	.68
1967	773,010	43,485	55,112	5.6	7.1	1.27
1968	875,054	48,966	51,280	5.6	5.9	1.05
1969	918,520	48,816	52,780	5.3	5.7	1.08
1970	852,086	44,387	41,850	5.2	4.9	.94
1971	946,005	47,878	28,553	5.1	3.0	.60

[a]Source: Federal Crop Insurance Corporation, Annual Report to the Congress, 1980.

Table I.1. (Continued)

Year	Liability	Premiums	Indemnities	Pre-miums	Indem-nities	Loss ratio
	---------thousands of dollars--------			As % of liability		
1972	$ 854,971	$ 42,063	$ 25,266	4.9	3.0	.60
1973	1,007,412	47,537	28,305	4.7	2.8	.60
1974	1,148,812	53,984	63,336	4.7	5.5	1.17
1975	1,570,493	73,377	63,385	4.7	4.0	.86
1976	2,082,486	90,838	142,328	4.4	6.8	1.57
1977	2,205,628	101,776	149,011	4.6	6.8	1.46
1978	2,094,120	93,860	47,367	4.5	2.3	.50
1979	2,224,718	103,347	67,205	4.6	3.0	.65
1980	3,040,197	157,553	347,130	5.2	11.4	2.20
1948-80	$27,141,981	$1,419,404	$1,553,361	5.2	5.7	1.09

insurance was authorized in only 200 wheat counties, 56 cotton counties, and a smaller number of counties for other crops. Previously, insurance had been available in about 2,500 counties.

Between 1948 and 1980, insurance protection under FCI increased from $154 to $3,040 million (Table I.1). The number of crops eligible for insurance expanded to 28, and the number of counties in which insurance was available increased from 324 to 1928.

The loss experience of FCIC was better for the 1948-80 period than in years prior to 1948. Indemnities paid out during 1948-80 were equal to 1.09 percent of the premiums paid in by farmers (Table I.1).

With a combination of losses and successes, the insurance program was restructured by the Federal Crop Insurance Act of 1980. Crop insurance is now offered to nearly all of the 3,000 agricultural counties in the U.S., covering 30 crops with 15,321 county programs.

The new program moves toward a crop insurance based on a farmer's actual production and loss figures. The program permits farmers to purchase hail and fire coverage from private companies and receive a premium reduction from the "all-risk" federal policy. It also authorizes the federal payment of the first 30 percent of a farmer's premium for coverage up to and including 65 percent of the average yield, and enables the private insurance industry through licensed agents and brokers to offer federal crop insurance, all in an effort to expand the sources from which farmers can obtain insurance.[1] Another objective of the new program is to become the primary form of federal disaster protection for farmers.

Extent and area of participation in crop insurance

Commercial crop-hail insurance Insurance against crop-hail damage to growing crops is available and is used in all areas of the country where the risk is significant. Participation in crop-hail insurance depends not only upon the incidence of hailstorms but also upon the value of the crop grown and its susceptibility to hail damage. In years of drought, for example, growers feel less need for hail protection.

About two-thirds of the crop-hail insurance coverage is sold in seven states--four in the Corn Belt plus Minnesota, Kansas, and North Dakota. Cropwise, wheat, corn grain, soybeans, cotton, and tobacco

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[1] Details of these changes are given in "Characteristics of Crop Insurance."

account for about 85% of the crop-hail insurance sold in 1982 (Table I.2).

Federal crop insurance In 1982, about 60% of all eligible acreage for federal crop insurance was located in nine states, where only 15.8% of the acres were insured. Illinois and Indiana accounted for the lowest participation rates, with Nebraska the highest among the nine leading states. Similarly, only 18.2 of the eligible acres in other states were insured (Table I.3).

Five crops--wheat, corn, soybeans, cotton, and tobacco--accounted for about 80% of the total eligible acreage in 1982. Only 20% of such acres were insured. Overall, 16.8% of the total eligible acreage in the United States was insured in 1982 (Table I.3). In the last decade, participation has been at a fairly constant rate of 14% per year. It seems that even with the improved 1980s FCI program, the participation rate has not significantly improved.

Characteristics of the two main types of crop insurance

Commercial crop-hail insurance Commercial crop-hail insurance protects against crop loss due to hail or combination of hail and wind; some policies also cover crop loss due to fire. Insurance coverage is offered in dollar amounts per acre up to the reasonable value of a full yield, with the premium scaled accordingly.

The premium charge per acre is based not only on the amount of insurance coverage per acre, but also on the probability of occurrence

Table I.2. Crop-hail insurance: Coverage, premiums, indemnities, and loss ratio in leading states and crops, 1982 (CHIAA, United States Statistics, 1982)[a]

States	Insurance coverage (000)	Premiums (000)	Indemnities (000)	Loss ratio percent
Illinois	1,699,513	26,078	4,940	19
Indiana	470,133	6,874	1,477	21
Iowa	1,143,615	42,438	6,653	16
Kansas	450,833	28,380	20,201	71
Minnesota	601,551	37,603	7,324	19
Nebraska	501,070	34,583	18,841	54
North Dakota	650,914	42,418	20,426	48
Seven states	5,517,629	218,374	79,862	36
Other states	3,425,960	144,572	100,510	76
By crop:				
Wheat	1,869,890	96,186	66,565	69
Corn grain	2,993,497	72,899	21,267	29
Soybeans	1,732,404	82,901	20,246	24
Cotton	455,352	19,724	31,080	162
Tobacco	667,544	35,540	15,829	44
Five crops	7,718,687	306,800	154,987	50
Other crops	1,224,902	56,146	35,385	63
United States	8,943,589	362,946	190,372	52

[a]About 90 percent of all crop-hail insurance contracts are written with CHIAA members and subscribers.

Table I.3. Percentage of eligible acreage insured by the Federal Crop Insurance Corporation (1982)

States	Eligible acreage (000)	Percentage insured (percent)
Illinois	20,630	4.6
Indiana	11,118	5.8
Iowa	22,314	17.3
Kansas	17,699	15.5
Minnesota	18,949	15.7
Nebraska	13,454	19.4
North Dakota	19,409	35.4
South Dakota	11,313	13.7
Texas	18,405	10.9
Nine states	153,295	15.8
Other states	110,892	18.2
By crop:		
Wheat	62,583	24.7
Corn	74,918	19.3
Soybeans	61,438	16.5
Cotton	11,821	9.6
Tobacco	966	41.3
Five crops	211,728	19.6
Other crops	52,459	8.0
United States	264,188	16.8

of hail, and the probable degree of damage--factors which in combination indicate the probable indemnities. In addition to covering the probable indemnities, premiums are set to cover operating costs and to return a profit. Actuarial data are mainly statistics on hail-loss adjustments pooled from the experience of insurance companies.

The indemnity is based on the percentage of the crop damaged by hail. Damage is measured in terms of stand reduction of percentage of grain heads or corn ears lost, and so on. The damage is assessed by the insurance company soon after the event, so it can be isolated from other causes. The indemnity is computed as the percentage of damage times the insured value (per acre damaged). For example, assume a farmer insures an acre of corn for a total value of $360. Also assume, he experienced a damage evaluated as 10 percent below potential yield. Without deductible, he expects to receive indemnities equal to $36 (360 x .10 = 36).

<u>Federal all-risk crop insurance</u>[1] The purpose of federal all-risk crop insurance (FCI) is "to promote the national welfare by improving the economic stability of agriculture through a sound system of crop insurance . . . ."[2] The purpose is simply to enable farmers to recover their production expenses (their investment in the crop) rather than compensate them for the full value of the crop. Hence,

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[1]Appendix A contains a more detailed description of federal all-risk crop insurance features.

[2]Federal Crop Insurance Corp. (1980), p. 1.

FCI coverage is limited by the usual expense of crop production, not to exceed 75 percent of the county (or area) average normal yield. Owner-operators, tenants, renters, crop-share landlords, partnerships, corporations, and states can insure their share of an insurable crop that is produced on insurable land. Since the Crop Insurance Act of 1980, FCI is now available through private insurance companies which in turn have reinsurance agreements with the FCIC. Reinsurance private companies write multiple peril crop insurance policies containing the same terms, rates, and coverages as FCI.

The insured select a yield coverage among three percentages of yield protection (50, 65, or 75 percent). The percentage selected times the average yield in the area where the farm is located gives the crop yield guarantee per acre insured. The insured can also choose a price level among three price options established by the Corporation for each crop. This level is used to calculate premiums and possible indemnities. It is not the purpose of the price options to guarantee a minimum market price for the insured farmer's crop. Price options are established so that the insured can recover variable costs of the crop losses experienced.

The premium charge per acre is based on the price option selected and on the probability of the yield falling below the yield guarantee. The premium is set to cover only the anticipated indemnities and to build up a reserve. In computing premiums, the operating expenses of the Corporation may not be included. The FCI premium of a farmer may be reduced after his policy has been in effect for two years and he has filed no claims. The following schedule shows premium discounts earned by consecutive years (up to seven years) without a loss claim.

Percent premium rate reductions	Consecutive years with no loss
5% after	1 year
5% after	2 years
10% after	3 years
10% after	4 years
15% after	5 years
20% after	6 years
25% after	7 years and over

The possibility of earning reduced premium rates discourages farmers from reporting inconsequential small losses.

Indemnities are based upon the difference between the yield guarantees and the harvested yield (if any). For this purpose, the yield is averaged on all acres of the same insured crop on the farm. Thus, even though the crop on some acres might fail totally, there would be no indemnity if the average yield on all acres insured equals the yield guarantee per acre.

The indemnity is computed at the price option originally selected by the purchaser. For some crops, the indemnity may be increased to compensate for cost of harvesting, but not in the case of total loss when there is no harvest.

FCI must be purchased before a specified closing date, at seeding time or before. Cancellation must precede a specified date. A reinstated policy is a new policy with respect to the premium rate discount.

Comparisons of crop-hail insurance and federal all-risk insurance

Crop-hail insurance and federal all-risk insurance differ significantly in several ways:

(1) Insurance coverage. Private crop-hail insurance can be bought with the yield and dollar coverage preferred by the user up to the full value of the expected crop. FCI coverage is limited to up to 75 percent of area yield (or farm proved yield if qualifying); the user may have up to three unit price options with his guarantee. The crop-hail is flexible in that it can be readily used as supplemental coverage to other insurance such as FCI or to supplement other strategies used to combat risk.

(2) Premium revenue. Private crop-hail expects premium revenue to pay indemnities, build reserves, pay operating costs, and return a profit. FCI expects premium revenue only to pay indemnities and to build reserves; the federal Government finances FCIC operation expenses.

(3) Indemnities. Crop-hail indemnifies the farmer for that portion of his growing crop that is lost because of hail and fire. Loss adjustment is a matter of determining that percentage of the crop lost and is not concerned with the average yield as such. Indemnities are based on the loss percentage times the contracted insurance coverage. In contrast, FCI indemnifies for the amount

by which the actual yield falls below the insured or guaranteed yield. Adjustment is a matter of determining the actual yield, proof of which is the harvested yield. FCI computes indemnities on the average yield for the entire farm (acres insured), whereas crop-hail computes and pays indemnities on individual acres damaged or destroyed.

(4) Date of purchase. Crop-hail can be purchased at any time up to harvest whereas FCI must be purchased at or before crop planting time--as it must, since it insures against all risks.

Study Considerations

The general overview of crop insurance serves, along with the problem statement, to established hypotheses on the desirability of crop insurance from the farmer's standpoint and to establish objectives and methodology of the research study.

Hypotheses statements

In addressing the problem of farmers' low participation in all-risk (multiperil) crop insurance, we have developed the following hypotheses:

(1) Farmers reject multiperil crop insurance because of their perception of risk exposure, awareness of yield variability or attitudes toward production risk--particularly low probability disasters.

(2) Farmers reject multiperil crop insurance because alternative risk management strategies make insurance unnecessary.

Possible competitors with insurance include government farm commodity programs, marketing options, enterprise diversification, leverage, internal capital reserves, or farm size.

(3) Farmers reject multiperil crop insurance because the premiums and/or protection (coverage) levels are not set correctly. This implies premiums may be too high; they do not provide a sufficient protection because of low yield guarantees. Perhaps premiums are not adjusted downward rapidly enough to reflect satisfactory loss experience. Alternatively, the premium structure may not be actuarially sound.

These hypotheses attempt to capture the farmer's perception of production risk and his bearing-ability to cope with it, and the economic aspects of multiperil crop insurance working along with other risk-reducing strategies.

Research objectives and methodology

The objectives of the research study are directly related to the hypotheses on crop insurance participation. In brief, they are:

(1) a review of most recent and relevant literature on farmers' awareness of risk and risk exposure. The review also includes relevant studies dealing with FCI as a risk management strategy.

(2) a development of a crop insurance theoretical model of decision making under risk. Although the theoretical model is

a model directly related to production risk, price risk is also managed in the theoretical model.

(3) based upon the theoretical model, the final objective is to have an empirical estimate of the role and desirability of all-risk crop insurance in decisions under risk by developing a farm firm level computer model which analyzes alternative risk-bearing strategies other than crop insurance.

In regard to the last two objectives, the principal procedures involved in meeting these objectives include establishing costs and net returns from a set of risk management strategies where crop insurance is compared against different leverage positions, farm sizes, farm programs, and marketing alternatives. The theoretical model (Chapter II) is developed within this framework of strategies which does not try to exhaust all possible ways that farmers may bear production and price risks, nor consider other sources of risk.

A farm level computer version of the theoretical model is written to generate empirical evidence on the assertions of hypotheses 2 and 3. Crop yields and yield variability play an important role in crop insurance relevance as a risk management tool. Good estimates of yield distributions are crucial. Basically, yield distributions can be elicited from farmers' beliefs (subjective approach) or from historical data (historical approach). The computer model and yield distributions are the main themes of Chapter III.

Actual estimation and discussion of results are found in Chapter IV. Stochastic dominance procedures (Anderson et al., 1977) are used to evaluate crop insurance and performances of alternative strategies. Stochastic dominance searches for an efficient set of strategies that are undominated and hence admissible.

Finally, concluding comments are given in Chapter V.

CHAPTER II. THEORETICAL MODEL

Literature Review

A common point in the literature of insurance in general is the frequent use of expected utility models as a tool to measure decision makers' preferences under risk. In regard to agricultural insurance decision analysis, the Expected Utility Hypothesis (as developed by Von Neumann and Morgenstern (1947)) has been, among the group of expected utility models, the most widely applied in the field. Given the frequent use of that utility model in crop insurance, a description of the model is first presented, followed by a review of the literature in insurance.

Expected Utility Hypothesis

Expected utility can be seen as a method useful to measure human responses to uncertain events. "Event" is defined as the situation an individual is confronted with. "Human response" is defined as the decision demanded by the event.

In regard to the measurement of expected utility, Bernoulli was one of the pioneers who developed mathematical forms of the expected utility model. Bernoulli's motivation was to explain the so-called St. Petersburg Paradox. The Paradox asks "why people would pay only a small sum for a game of infinite mathematical expectation" (Schoemaker, 1980, p. 11). Bernoulli's answer was that people maximize the "moral expectation" of the event rather than its expected monetary value. Moreover, Bernoulli related the moral expectation (or expected utility) to the concept of wealth (also expressed in utilities). In particular, Bernoulli suggested that the utility resulting from any small increase in wealth will be inversely proportionate to the quantity of goods previously possessed. Thus, Bernoulli's concept led to a concave utility function which has important implications in the theory of risk aversion.

Von Neumann and Morgenstern (1947) restated Bernoulli's work in a new utility theory which expanded economic theory into models of risk. Today this theory predominates among models of choice under risk. Rational[1] decision making under risk is contained in the theory, which assumes that no one would want to violate its axioms. On the other hand, the theory reaffirms the Bernoulli principle that people maximize expected utility rather than mathematical expectation.

The Von Neumann-Morgenstern (NM) utility theory (hereafter referred to as the Expected Utility Hypothesis (EUH)) establishes that a rational individual (decision maker) is said to maximize his utility if he accepts the following postulates:[2]

(1) Complete ordering and transitivity: For any two alternatives, A_1 and A_2, a person either prefers A_1 to A_2 or A_2 to A_1 or is indifferent between them. If a person is able to order alternatives, and let us say that the person prefers A_1 to A_2 and A_2 to A_3, then the transivity concept tells that the person must prefer A_1 to A_3.

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[1]In a broad sense, rational means to act according to some ordering of alternatives.

[2]For alternative set of postulates (P. C. Fishburn, 1970).

(2) Continuity: If A_1 is preferred to A_2, and A_2 to A_3, then some probability p (between 0 and 1) must exist so that the person is indifferent between A_2 and a lottery offering A_1 or A_3 with probability p and (1 - p), respectively.

(3) Independence: If a person is indifferent between A_1 and A_2, then two lotteries offering A_1 and A_3 in the first lottery and A_2 and A_3 in the second, with probabilities p and (1 - p) in each lottery should be indifferent to him for any A_3 and p value.

(4) Unequal probability: If A_1 is preferred to A_2, a lottery L_1 containing A_1 and A_2 is preferred to a lottery L_2 containing the same outcomes A_1 and A_2 if, and only if, the probability of A_1 is greater in L_1 than in L_2.

(5) Complexity: If lottery L_1 has L_3 and L_4 as outcomes, with L_3 and L_4 offering only alternatives A_1 and A_2, and if L_2 offers A_1 and A_2 only, then a person should be indifferent between L_1 and L_2 if, and only if, the expected values of L_1 and L_2 are identical. This postulate guarantees that the final probability p of A_1 and (1 - p) of A_2 are identical in either L_1 or L_2.

The above postulates are sufficient to prove that there exists a utility index, unique up to linear positive transformation, so that computing expected utilities will yield a preference ordering among alternatives or lotteries of alternatives.[1]

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[1]In terms of the theoretical model to be developed, alternative will mean a risky prospect that has a probability distribution of outcomes.

The EUH model proposes that decision makers maximize the expected utility of wealth plus income (or final asset position) from all possible choices. This is

$$\text{Maximize } E[U(W)] \tag{II.1}$$

where E stands for the expectations operator evaluated over all possible action alternatives, U represents the utility function, and W the decision maker's wealth plus income.

In the discrete case, U(W) is equal to $\sum p_i \, U(W_i)$ where p_i is the probability associated with an alternative that brings a wealth plus income position equal to W_i.

Finally, expected utilities are based on the individual's subjective distribution of outcomes. Higher moments of utility, e.g., its variance, are not relevant in the selection process. Utility can be scaled arbitrarily since utility is defined up to linear transformation. However, comparison of utility values between individuals is meaningless (Anderson et al., 1977).

Thus in utility theory, one needs first to determine preferences of the decision maker in order to derive his utility function. Such a utility function will reflect the decision maker's degrees of belief and his degrees of preference. Once a decision maker's utility function is derived, it is possible to lead him to the analysis, for example, of risk management strategies to cope with farm risks.

This idea will be brought up again in the presentation of the theoretical model. Several studies have been conducted to test the validity of the EUH's axioms, and some of the findings are discussed below.

In regard to the ordering axiom, Mosteller and Nogee (1951) carried out an experimental study with Harvard students and National Guardsmen as subjects. NM utility functions were constructed for each of the subjects. The major finding was that the estimated utility curves did respect the ordering rule of EUH.

Another similar experimental study by Davidson et al. (1957) using 19 Stanford business students had the following general conclusions: (1) people chose as if they attempted to maximize EU, (2) the utility functions were generally nonlinear, and (3) upon remeasurement, subjects appeared consistent.

Tversky (1969) showed that transitivity (considered in the ordering axiom) is likely to be violated when subjects use evaluation strategies involving comparisons within dimension, e.g. first comparing price, then quality, then size, etc.

By asking a group of people to rank three gambles A, B, plus a probability mixture of A and B called C in order of attractiveness, Coombs (1975) found that subjects ranked these three gambles in three basic groups, namely "monotone orderings" (ACB or BCA), "folded orderings" (CAB or CBA), and inverted ordering (ABC or BAC). Only the monotone ranking is consistent with EU. From 520 rank orderings reviewed by Coombs, 54 percent were monotone, 27 percent were folded, and 19 percent inverted. This suggests that nearly half the subjects violated the continuity axiom.

Tversky (1972) discussed the independence axiom in terms of a certainty effect and a reference effect that are sources of error in judgments. When confronting an individual with a situation with a certain outcome (p=1) and probabilistic outcomes (i.e. A_1 with p and A_2 with (1-p), where $0<p<1$), the certain outcome is seen larger than those that are uncertain. On the other hand, the reference effect states that people evaluate options in relation to their status quo, adaption level or expectations rather than to final asset positions, as EU theory assumes. Preferences might change because of differences in the formulation of a decision problem.

From the above review, it is apparent that the EUH's axioms are systematically violated by people in experimental studies. However, what seems also apparent is that the EUH (as developed by Von Neumann and Morgenstern) only established the general rules a rational individual should always follow, and not rules for conducting experimental studies. In spite of this, the validity of the EUH's axioms depends as much on a rational behavior as how well an experimental study is brought forth to cope with real situations.

Alternatives to EUH   A very complete classification of alternative methods is found in Schoemaker (1980, Chapter 3). In general, he classifies decision models as holistic and non-holistic, or sequential elimination, models. The holistic branch contains expected utility theory, EU models with probability transformations, mean-risk models, and additive models. The non-holistic models include comparisons against some standard, comparisons across attributes, and comparisons within attributes.[1] A brief discussion of the EU models with probability transformations follows.

EU models with probability transformations are further divided into two groups: subjective expected utility models and subjective weighted utility models. We will deal with each of them at this time.

Subjective expected utility (SEU) proposes that probability p_i of EUH be replaced by $f(p_i)$, so that $U(W) = \sum f(p_i) \cdot U(W_i)$. In this new expression, $f(p_i)$ is a mathematical probability symbol in which the sum of all p_i equals 1 (i.e., $\sum f(p_i) = 1$).

SEU models usually assume (1) independence between utility and subjective probability; (2) risk invariance of utility; and (3) the mathematical probability expression $\sum f(p_i) = 1$. In this sense, probability is regarded as a degree of beliefs, and it may differ from "the stated or objective ones assumed by the researcher" (Schoemaker, 1982, p. 537). In a review of empirical studies by Lee (1971), it is found that subjective probability curves overestimate low probabilities and underestimate high probabilities. However, subjective probabilities are higher when the outcomes are more desirable.

The subjective weighted utility (SWU) of transformed probability EU models differs from SEU models in that the mathematical probabilities

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[1]In the holistic approach, each alternative (or choice), X, is assessed independently of the others and assigned a utility value, U(X). Under the non-holistic approach, alternatives are usually compared to each other under certain standards or attributes, but they are never evaluated just by their own worth. Thus, an optimal choice may be reached by making comparisons "vis-à-vis" other alternatives.

do not possess characteristics shown in SEU models (e.g., $\sum f(p_i) = 1$). Three different approaches have recently been developed: certainty equivalence theory (Handa, 1977), subjectively weighted utility model (Karmarkar, 1978), and prospect theory (Kahneman and Tversky, 1979).

Handa (1977) developed a set of axioms for a certainty equivalent (CE) utility theory that differs from the traditional EUH theory. Handa states in his axioms that the outcomes and their respective probabilities are the relevant element of an individual's preferences among outcomes. Thus, using his terminology, the utility function in CE theory is:

$$U(X,p) = X_1 h(p_i) + \ldots + X_n h(p_n) \qquad \text{(II.2)}$$

where now U(X) is linear; i.e., $U(X_1) = X_1$ with a mathematical probability equal to $h(p_i)$. The expression $h(p_i)$ exhibits overweighting of low probabilities (risk seeking), and underweighting of high probabilities (risk aversion) when plotting $h(p_i)$ in the vertical axis and p_i in the horizontal axis (Handa, p. 113). However, in a comment on Handa's paper, Fishburn (1978) demonstrates that CE theory reduces to the expected monetary value model, where $h(p_i) = p_i$, for sufficiently rich prospects, i.e. a set of three outcomes only.

Karmarkar (1978) proposed a descriptive model that is an extension of the usual EUH model. It is the Subjective Weighted Utility (SWU) model, in which the only difference lies in how probabilities are expressed into the criterion. Normalized decision weights replace the probabilities p_i. Given a lottery ℓ with its outcomes X_i and probabilities p_i, a SWU function can be written as:

$$SWU(\ell) = \sum_{i=1}^{n} W_i U(X_i) \Big/ \sum_{i=1}^{n} W_i \qquad \text{(II.3)}$$

where W_i is a weighted function of p_i, explicitly

$$W(p) = \frac{p^{\alpha}}{p^{\alpha} + (1-p)^{\alpha}} \qquad \text{(II.4)}$$

If $\alpha=1$, then W(p) is linear and equal to p. For $\alpha>1$, W(p) distribution is S-shaped, which in turn, the understated low probabilities will show that a risk aversion position is taken. For $\alpha<1$, low probabilities are overstated and high probabilities understated. Karmarkar emphasized that a weighting function "does not represent a probability perception phenomenon." Given a perceived probability p by the decision maker, ". . . the transformation reflects a bias in the way the probability is incorporated into evaluating the associated lottery" (Karmarkar, 1979, p. 67).

With hypothetical choice problems presented to students and university faculty, Kahneman and Tversky (1979) demonstrate that in the generalized idea of concave utility function (risk aversion), the maximization of final wealth ($U(W + X_1, p_1, \ldots, W + X_n, p_n) > U(W)$), and that $U(X_1, p_1, \ldots, X_n, p_n) = p_1U(X_1) + \ldots + p_nU(X_n)$, the overall utility of a prospect equal to the utility of its outcomes of the EUH are systematically violated by several phenomena.

The phenomena found by Kahneman and Tversky are:

(1) Certainty effect. People's preferences (or weights) of outcomes

usually differ from their respective probabilities (as is assumed in EUH model). Instead, people "overweight outcomes that are considered certain, relative to outcomes which are merely probable. . ." (p. 265). This is the so-called certainty effect.

(2) Reflection effect. Between prospects with only positive outcomes (i.e. $X_i>0$), people have a certain order of preferences. However, when a negative sign is placed in front of the outcomes of the same prospects, people's preferences are reversed (mirror-image effect). This reflection effect implies that in the positive domain, people behave as risk averters while they behave as risk-seekers in the negative domain (i.e. losses only).

(3) Isolation effect. Frequently, people disregard components that are common between alternatives in order to simplify decision making. Instead, they focus on aspects that distinguish the alternatives. This effect can be the cause of inconsistent preferences since common and distinguishing aspects can be broken down in more than one way which may lead to different preferences.

Given the above effects that violate the EUH model, Kahneman and Tversky developed an alternative descriptive model called "prospect theory." The utility function of this theory is now composed of a value function $v(X_i)$ and a weighting function $\pi(p_i)$, explicitly

$$V(X_1, p_1; X_2, p_2) = v(X_1) + \pi(p_1)[v(X_1) - v(X_2)] \qquad \text{(II.5)}$$

when comparing two prospects with either $X_1>X_2>0$ or $X_1<X_2<0$ and if $p_1 + p_2 = 1$ (mathematical probabilities add to one).

For the case where $p_1+p_2<1$ and either $X_1 \geq 0 \geq X_2$ or $X_1 \leq 0 \leq X_2$, then

$$V(X_1, p_1, X_2, p_2) = \pi(p_1)v(X_1) + \pi(p_2)v(X_2) \quad \text{(II.6)}$$

where, now, $\pi(0) = 0$, $\pi(1) = 1$, and $v(0) = 0$ are linear and prospect theory is similar to expected monetary value ($\sum p_i X_i$) in this special case. However, $\sum p_i=1$ in the expected value model.

Kahneman and Tversky, as does Karmarkar, emphasize that "decision weights are not probabilities: they do not obey the probability axioms and they should not be interpreted as measures of degree or belief" (1979, p. 280). Finally, they state that $\pi(p)>p$ for low probabilities and $\pi(p)<p$ for high probabilities which implies that for all $0<p<1$, $\pi(p) + \pi(1-p) < 1$; thus, the weighting function is within the bounds of 0 and 1.

In brief, the properties of the probability weighting function $\pi(p)$ can be summarized as follows:

(1) $\pi(0) = 0$ and $\pi(1) = 1$.

(2) Subadditivity for small p (i.e., $\pi(\tau p)>\tau\pi(p)$ for $0<\tau<1$).

(3) Overweighting of small p (i.e., $\pi(p)>p$).

(4) Subcertainty: $\pi(p) + \pi(1-p)<1$ for $0<p<1$.

(5) Subproportionality: $\pi(pq)/\pi(p) \leq \pi(pq\tau)/\pi(p\tau)$ for $0<p,q,\tau\leq 1$.

The main differences between the EUH and prospect theory can be summarized as follows:

(1) Prospect theory defines a value function that is unique up to positive ratio transformations. EUH is unique up to linear transformations. The value function in prospect theory does not

measure attitudes toward risk, but only the value of outcomes under conditions of certainty. In general, it is convex for losses and concave for gains.

(2) While objective probabilities are used in EUH, decision weights, $\pi(p_i)$ are used in prospect theory. $\pi(p_i)$ reflect the impact of outcomes on "the prospect's attractiveness." Low probabilities are generally overweighted and high ones underweighted.

(3) Strictly positive or negative outcomes involved in prospects are treated separately from combinations of both in prospect theory. Such a distinction does not appear in EUH.

(4) To simplify choices, prospect theory performs various editing operations such as coding, combining, segregation and cancellation.

(5) Finally, prospect theory's value function is a subjective measure of outcomes relative to some reference point that may vary as a function of problem presentation. Changes in wealth or assets are emphasized instead of final asset position (as in EUH).

Insurance literature

Since farm management strategies normally involve crop insurance as a risk reducing strategy, the review of literature is concentrated on crop insurance and the natural type of insurance disasters (i.e., flood) with a two-fold purpose: (1) to gain insight into a method to measure preferences in risky situations, and (2) to improve understanding of human behavior under risk.

Optimal insurance purchase was discussed by Mossin (1968). Assuming an initial wealth (or net worth), Mossin studied the problems an individual faces in the purchase of property insurance: maximum acceptable premium for full coverage, optimal coverage at a given premium, optimal reinsurance quota, and optimal amount of deductible[1] in less than full coverage. He solved for these problems in a theoretical model where risk aversion is implicit since a premium exists. Mossin has demonstrated in his model that as wealth increases, an individual's risk aversion decreases and, therefore, premiums must be a decreasing function of wealth.

Using a model of rational insurance purchasing, Doherty (1975) establishes the basis of willingness to pay premiums given the individual's level of risk (prone, neutral, or averter). Given an actuarially fair premium, a risk-seeking individual who shows a convex utility function will not buy insurance (or he will self-insure) as long as the mean of the insurance prospect is lower than that of the non-insurance prospect. Under risk neutrality, the utility function is a straight line and the individual is indifferent between full insurance and self-insurance. The utility function is concave under risk aversion and full insurance is preferred by the risk averter.[2]

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[1]A deductible is a fixed sum of deduction for each claim so that the insured himself bears losses below this sum.

[2]The degree of risk aversion is measured by the coefficient of risk aversion. An absolute coefficient of risk aversion is given by U''/U' for each level of wealth (or any other criterion of analysis). See Pratt (1964).

Doherty also studied the Mossin and Smith theorem that less than full insurance is optimal where "proportional loading" is imposed. Proportional loading is a premium rating system where premiums are directly related to the size and probability of a loss and a coverage level (e.g. 80 percent, etc.). Doherty reached the same conclusion as Mossin and Smith. A final remark in his article notes that loss prevention by the insured is reduced by the purchase of insurance (the "moral hazard" argument).

In another study, Doherty (1977) evaluates deductible insurance and full insurance for risk averter individuals. He concluded that unless the savings in premium with deductible insurance is greater than the mean value of uninsured risk, risk averters will choose to have full insurance without deducting any fixed amount.

An experimental study on insurance decisions was conducted by Kunreuther and Schoemaker (1979) to assess the descriptive power of prospect theory and EUH. Their experiment focuses on four issues relevant to insurance.

The first issue addresses people's concern to protect themselves against high-probability, low-loss events, or against low-probability, high-loss events when expected values are equal. Both EUH and prospect theory agree that people prefer to be protected against low-probability, high-loss events when expected values are equal. The second issue considers the aspects of full coverage and coverage with deductible. Again, both theories agree that people prefer full coverage to an insurance policy with deductible.

Willingness to pay for comprehensive protection against potential monetary losses is the third issue studied by Kunreuther and Schoemaker. Separate insurance policies may lead to higher total coverage than grouping policies together; small but likely loss may attract people to buy single coverage policy than a combined policy with a large but unlikely loss and a likely small loss. They proved that individual policy maximum bids will equal the maximum bid for the comprehensive policy in both EUH and prospect theory. However, interpretation of how the problem would be structured may lead to a difference between prospect theory and EUH.

The final issue is a hypothetical case in which premium and maximum coverage (liability) are increased by a factor ($K>1$) and leaving the probabilities the same. Kunreuther and Schoemaker found that people prefer insurance as K increases when using the EUH approach. The opposite holds true for prospect theory unless p were excessively low to induce risk-aversion (overweighting effect where $\pi(p)>p$).

A study of expected utility theory as a descriptive model was conducted by Kunreuther (1978) on insurance coverage against floods and earthquakes. Kunreuther assessed homeowners' subjective values of the probability of a disaster occurring, the cost per dollar of insurance, and the dollar loss resulting from the disaster. The assessments on these features were done by interviewing 2000 floodplain homeowners and 1000 living in earthquake areas. The general conclusions of Kunreuther's study are that people seldom have enough information to comply with Expected Utility theory and that if they do, their decisions are often not consistent with the assumption of risk aversion or even more relaxed Expected Utility interpretations.

In the same vein, Attanasi and Karlinger (1979) specified a model characterizing the individual's decision to purchase flood insurance. Using the EUH, their model solves for the optimal insurance coverage as a function of risk preferences, premium structure, a physical "damage function", and the probability distribution governing the occurrence of floods. They based the model on information from four towns in New Jersey exposed to floods. The risk preferences were obtained by using Arrow-Pratt measures of absolute risk aversion (Arrow, 1974) since their study assumed a bounded, monotone increasing, and concave (with respect to wealth) utility function. Their findings suggest that the behavior of the sampled individuals who purchased flood insurance was not inconsistent with the EUH. Their estimated risk-aversion coefficients were all positive and greater than zero (risk aversion). Finally, they suggested that efforts to inform residents of the damage of floods may influence risk preferences and increase participation in flood insurance programs.

Ahsan et al. (1982) studied the capability of competitive markets to provide crop insurance. Imperfect information, specifically that on farmers' risk position, was hypothesized as the main reason a competitive crop insurance market may not exist. If farmers have reasonable knowledge of their own risk position, insurance agencies, not having access to such information, may be unable to distinguish among customers. In this case, only high-risk farmers may buy crop insurance, and, hence, insurance companies may incur heavy losses. Thus, agricultural policy makers are forced to consider public crop insurance.

Premium rate-making in crop insurance programs is usually based on a normal yield distribution assumption. Yeh and Sun (1980) developed Pearson probability distributions of actual wheat yields for 14 crop districts of the province of Manitoba in Canada. The purpose was two-fold: (1) to compare Pearson yield distributions to those of normal curve theory and (2) to obtain pure premium rates from the Pearson estimations.

To examine the first purpose, they compared chi-square and F-statistics of both normal and Pearson distributions. Nine out of the fourteen Pearson distributions showed a lower dispersion than their corresponding normal distributions. In general, the statistical tests suggest that Pearson wheat yield distribution was better than estimated normal distribution in those 14 districts. Based on these results, Yeh and Sun estimated pure (no subsidied) premium rates assuming both a normal and a Pearson distribution. In general, premium rates are underestimated when an estimated normal distribution is used. From the results of their study, they conclude that a normal distribution of yields may occur as a special case. Pearson distributions have the great advantage that an algebraic form of the distribution does not need to be specified a priori. Thus, a sound crop insurance program should evaluate yield distributions with the higher accuracy possible. More specifically, it might prevent under- or overestimation of premium rates in multiperil crop insurance policies.

Farmers' subjective probabilities were elicited by Grisley and Kellogg (1983) in Northern Thailand. They looked at farmers' perceptions of yield, price, and net income expected next season by using an elicitation process with monetary rewards. They surveyed rice, tobacco, and soybean farmers. The subjective elicitation revealed that 43 percent of farmers' predictions were between -10 to +10 percent different from actual results; 33 percent of the predictions were under -20 percent; and 23 percent were over +20 percent of actual yield, price, and net income. Farmers were more accurate in their rice predictions than for tobacco and soybeans. It was also found that surveyed farmers behaved as risk averters.

The selected literature is presented below with the purpose of reviewing what has been written in regard to the Federal Crop Insurance (FCI) and selected risk management strategies in recent years.

In a 1982 study, Kramer and Pope evaluated the performance of FCI. They showed that the subsidized FCI program would be preferred by risk averse farmers. With 17 years of historical data from a farm in Loudoun County, Virginia, they have demonstrated that actual yields were below 75 percent of the 10-year average in three years; only once did the actual yield fall below 65 percent of the average. If the farmers in Loudoun County had bought FCI at the 75 percent coverage level during the 17-year period, indemnities would be higher than possible premiums paid during the same period. Their analysis suggests that crop insurance "can be an attractive option for managing risk."

However, farmers' assessment of yield probabilities below 75 percent of their normal yields will determine, in general, their participation decision.

Miller and Walter (1977) evaluated alternative options for the Federal Government to cover crop losses due to natural hazards. FCI, Disaster Payments Program (DPP)[1], and the private insurance industry were the institutional instruments considered in their study. There are four not mutually exclusive options. The first option is to continue with current programs--the DPP and the FCI program--without modification. The DPP extends coverage mainly in high-risk areas where FIC is not available. However, the trend has been that disaster payments were made in counties where FCI was available, thus suggesting that DPP was a "free-insurance" policy to farmers and that the FCIC and DPP overlapped their functions. Miller and Walter remarked here that this overlapping could be a possible cause of farmers' low participation in the FCI program (17 percent of eligible acreage in 1976).

A subsidy to the private crop insurance industry is their second option. From a superficial analysis, Miller and Walter suggest that this option might be more costly than providing crop insurance through the FCIC.

Their third option is to subsidize premiums of the FCI program and discontinue the DPP. They estimated that with a 25 percent of premium

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[1]DPP was introduced by the Agriculture and Consumer Protection Act of 1973. This program lasted until the 1981 crop year and was mainly replaced by the FCI program as amended in 1980.

subsidy, farmers' participation in the FCI program would be increased up to 40 percent of the eligible acreage. The idea of this option was undertaken when the FCI program was restructued in the 1980 Act.

Modification in the DPP is their fourth option. This includes lower yields guarantees for payments, elimination of the prevented planting coverage, increments in the payments rate, and other minor alternatives.

Finally, Miller and Walter have concluded that the FCI program should concentrate its functions in low-risk areas and that the DPP is a better option to cover high-risk areas in agriculture.

With a sample of ten dry land wheat farmers in Colorado, King and Oamek (1983) evaluated the effects of the elimination of DPP and the possible expansion of farmers' participation in the FCI program as amended in 1980. Evaluating different alternatives under the adjusted gross income criterion, they demonstrated that the elimination of DPP and the subsidization of FCI premiums may attract farmers to purchase FCI. However, farmers' "participation rates did not rise substantially in eastern Colorado for the 1982 crop year." They allude to the fact that FCI premiums account for up to 30 percent of variable costs for some of the farmers in the sample. It forces farmers to operate without any protection against low yields.

Although the results of King and Oamek's study cannot be used on an aggregate level, they conclude that the policy decision taken on the DPP and FCI programs in 1980-81 does not insure higher farmer participation in the latter.

In another study of FCI and DPP, Lemieux et al. (1982) compare the effects of (a) participation in the FCI program, (b) participation in the DPP, and (c) nonparticipation on a typical Texas High Plains cotton farm over a 10-year planning horizon. By establishing boundaries for four risk preference classes (prone, neutral, moderately risk averse, and risk averse), they compare programs' benefits on the present value of ending net worth of the 10-year period. Their conclusions based on stochastic dominance efficiency analysis show that for risk prone producers, DPP is as efficient as the highest level of FCI coverage (high yield) and high price selection). A risk neutral producer should be indifferent among any FCI yield and price level of protection and DPP except for the low and medium price options of FCI. For a moderately risk averse producer, the results are similar except that low coverage (50 percent) and low price coverage of FCI is the only prospect on the risk averse's efficiency set.

Farmers' choice of participating in government programs is better investigated under the EU theory (Kramer and Pope, 1981). By using intervals of risk levels (prone, neutral, and averter), Kramer and Pope studied the impact of 10 hypothetical cases of government programs[1] and farm size. Their analysis was done under stochastic dominance to rank farmers' choices. Low risk averse and risk prone farmers selected nonparticipation in 7 out of the 10 alternatives. Reduction in the

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[1]The government programs considered in their study were price support loans, disaster payments and deficiency payments programs.

requirements for farmers to participate in the disaster and deficiency payments programs and loan rates seem to result in a higher participation by low risk averters.

Scott and Baker (1972) evaluated mean income under 10 states of nature, including from total idling of land to full participation in set-aside and price-support loan programs. It was demonstrated that risk aversion coefficients have no relationship to a person's leaving the decision of an optimal farm plan to the farmer's own perception of risk.

Calculating mean income and standard error for the 10 prospects, Scott and Baker conclude that a nonrisk averse farmer would not participate in government programs. The opposite is true for a high risk averse farmer. Their results show that a higher income is obtained with an open market corn price which also has a higher expected variance of income. Under government programs, mean income is lower but the variance is also lower.

In a study conducted in Deuel County, Nebraska, Smith et al. (1972) show that self-insurance strategies (i.e., storage of grain, financial reserves, etc.) are preferred to FCI and commercial hail and fire insurance if the opportunity cost is relatively low. At 10 percent and 11 percent of opportunity cost, hail insurance and FCI become more desirable, respectively, than the self-insurance strategies.

Farmers who cannot self-protect against crop losses have FCI as the best second alternative of protection. The Smith study suggests that farm size is not as relevant as liquid funds in crop insurance planning. It is important to note that this study was conducted ten years before the passage of the FCI Act of 1980, which is quite different from the program alluded to in their study.

Leverage and farm size also play an important role in farmers' risk preferences. Held and Helmers (1979) stress the impact of various land appreciation rates on farm growth and survival against net farm income and cash flow. The attractiveness of land appreciation to increase farm size (then, net worth) could bring low net farm incomes and disastrous negative cash flow because of increasing land taxes and higher interest costs of short term obligations. Again, prices in the near future and yield distributions greatly influence possible results of land appreciation and changes in farm size. Net return per owned acre might be diminished as farm size increases.

As a final comment on the literature reviewed, it should be stressed that crop insurance has not been considered as an alternative of a broader risk management system. Crop insurance has been isolated or, at most, considered with other disaster payment programs. On the other hand, expected utility theory is used in most of the literature on crop insurance and insurance in general, though it has been shown to be inconsistent with individual preferences.

Theoretical Model

In this section, the impacts of crop insurance and other risk management strategies on farm returns are individually considered in a flexible model with the following characteristics:

(1) It is a single-period farm level model where farm planning ends with marketing operations of the harvested crop.

(2) Planting and marketing of a single crop are the main source of revenue in the farm model. This ignores crop or livestock diversifications as an alternative management strategy.

(3) Since it is a single-period model (i.e., one year), cash flow after taxes and consumption is the maximization criterion selected to evaluate the worthiness of strategies.

(4) Finally, yields, crop prices, and cash flows are the stochastic variables in the maximization expression where input variables (i.e. production costs) are treated as known at the time the farmer makes activity decisions for the single-period plan.

Several risk management strategies were mentioned in Chapter I. These can be grouped in four general areas: insurance, production, marketing, and financial strategies. The model will include the following strategies:

(1) For insurance strategies, the model assumes the farmer carries property and life insurance which are considered as fixed cost items. The relevant insurance strategy is that directly related to crop production, specifically the Federal All-Risk Crop Insurance (FCI) as the strategy to be evaluated in the model.

(2) Farmers' participation in acreage reduction programs[1] (i.e. set-aside) of the federal government is the essential element of the model's production strategies. Other strategies implicitly assumed are good farming practices and flexible input uses.

(3) To deal with the risk of fluctuations in commodity prices, the model considers the use of hedging in futures markets as a feasible marketing strategy. Another marketing strategy is storage of the production when higher cash prices are expected sometime after harvest.

(4) Finally, farm leverage (debt to equity ratio) is included in the model as a financial tool that influences farmers' risk-bearing ability.

For purposes of model presentation, the model is first given alone with none of the risk management strategies acting. This will be called the base prospect. Then, the model allows the inclusion of one strategy at a time. Such prospects are identified by the strategy--i.e., marketing prospect. Finally, each strategy prospect is compared to the base prospect. The comparisons are made to assess how yield, price, and cash flow distributions are altered by the management options.

Stochastic dominance concepts are used as an expository device in prospect comparisons. The basic idea is that it is possible to rule

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[1]These federal farm programs normally compensate farmers by providing loan and target prices for their products. An exception to this was the payment-in-kind program where price support was not offered.

out as inefficient a prospect based only on broad characteristics of the decision maker, i.e. risk aversion (Anderson et al., 1977). The use of cumulative probability distribution (CPD) concepts supplies the analytical instrument for evaluating prospects under stochastic dominance. The graph of a CPD indicates the probability of receiving a given level of returns or less.

To rank CPDs of two prospects (i.e. CDPs of base and insurance prospects), two concepts of stochastic dominance are used: first- and second-degree stochastic dominance (FSD and SSD, respectively). FSD applies to all decision makers in regard to income maximization; i.e., at given probabilities, if the CPD of prospect "A" offers higher incomes than the CPD of prospect "B", it is said that "A" dominates "B" in FSD. The idea of FSD agrees with the broad assumption of a farmer's monotonically increasing utility function. Finally, SSD applies to all risk averters (this is consistent with the assumption of concave utility function). This is more difficult to explain intuitively, but it will be illustrated with the prospect comparisons to be presented below. Stochastic dominance will be important in this study for two reasons. First, it will be useful in deriving theoretical results in this chapter. Second, it will play a crucial role in the empirical investigation described in Chapter IV.

Base prospect

Assume a farmer tries to maximize his end-of-period cash flow by planting and harvesting a single crop, i.e., corn or wheat. Following Anderson et al. (1977, Chapter 6), we have in vectorial form,

$$\mathbf{CF_b} = [(\mathbf{P_y} \cdot \mathbf{Y} - P_v) \cdot V - D_p - C_d] \cdot [1 - T_x] + DIF \qquad (II.7)$$

where:[1]

$\mathbf{CF_b}$ = vector of cash flows after income tax in model's base prospect;

$\mathbf{P_y} \cdot \mathbf{Y}$ = price times yield vectors, both being assumed random and independent;[2] $P_y = (P-H)$; P=market price; and H=yield dependent costs;

P_v = yield independent costs, which are assumed fixed;[3]

V = total crop acreage, also assumed fixed;

D_p = Total assets depreciation;

C_d = interest on borrowed capital;[4]

T_x = income tax rate at given level of income; and

DIF = D_p - PP; add back depreciation, D_p, and subtract principal payment, PP, to obtain account for real cash flows.

---

[1]Variables in darker print are vectors of stochastic values for the respective variables.

[2]The assumption of independence between yields and prices appears reasonable in a micro-level model of decision making. This means individual farm production is uncorrelated with market production and, hence, price. If there exists a correlation between prices and yields, i.e., $cov(P_y, Y) \neq 0$, the analysis can still be carried out. However, the required algebraic manipulation becomes considerably more difficult. Although a single crop model is considered here, the essence of the results should also hold for the multi-crop case.

[3]This implies that costs are nonstochastic. This assumption makes the model more tractable, but it can be relaxed.

[4]Interest on borrowed capital, C_d, is obtained from the following expression:

$$C_d = FD \cdot i; \; FD = (a \cdot \ell/1+\ell) \cdot V = \text{farm debt};$$

where a = average asset value per acre, ℓ = leverage level; and i = capital interest rate.

From the expression in equation II.7, values of CF_b distribution can be obtained from vectors of independent values for prices, P_y, and yields, Y. One would expect that low (or negative) cash flows, CF_b, are caused by low yields, Y, and/or low prices, P_y. Figure II.1 portrays a hypothetical CPD of cash flows evaluated from given values of prices and yields at each point of the distribution.

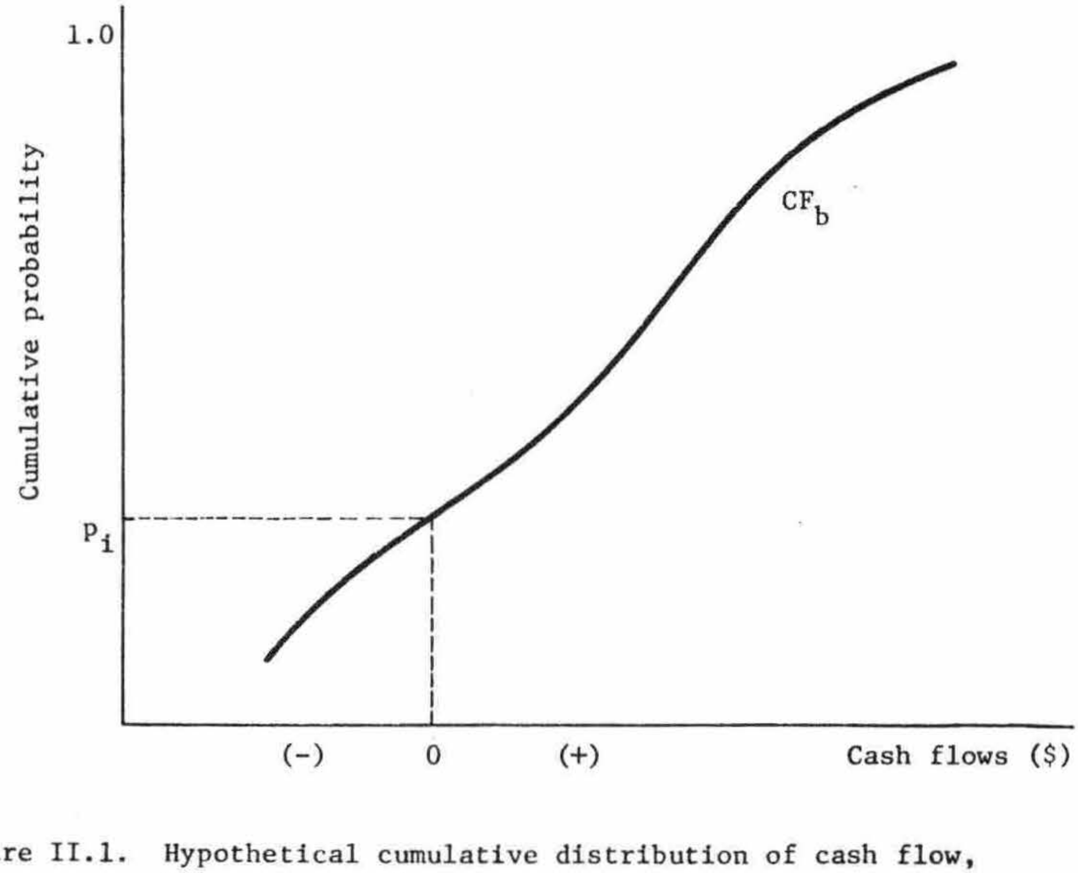

Figure II.1. Hypothetical cumulative distribution of cash flow, base prospect CF_b

CF_b=0+DIF when total revenue, $P_y \cdot Y \cdot V$, equals total costs, $P_v \cdot V$. At this point, income taxes are also equal to zero since $P_y \cdot Y - P_v \leq 0$; i.e., gross income ($P_y \cdot Y - P_v \cdot V$) is equal to or less than zero. Thus, we see that negative cash flows might occur with a combination of low yields and low prices, or "normal" yields with low prices or vice-versa. For instance, the probability of getting cash flows less than or equal to zero is p_i in Figure II.1. On the other hand, as revenues surpass costs, cash flows move into the domain of positive values up to a maximum feasible level, i.e., the highest price and yield possible.

Negative outcomes are of special concern to risk averse individuals who are willing to sacrifice higher outcomes in order to reduce the threat of potentially disastrous low outcomes. Let us now look at the impacts on CF distribution by the introduction of crop insurance into our original model.

<u>Crop insurance prospect</u>

With crop insurance, equation II.7 can be restated as

$$\mathbf{CF_I} = [(\mathbf{P_y} \cdot Y + I - P_v - E) \cdot V - D_p - C_d] \cdot [1 - T_x] + DIF \qquad (II.8)$$

where the new variables are:

I = indemnity per acre insured[1] when yields are below a guaranteed yield per acre, Y*, and

E = dollar value of insurance premium per acre, assumed fixed.

---

[1] For modeling purposes, acres insured are equal to acres planted which is equal to V in the equation. It is also assumed that I is subject to income tax.

Indemnities, I, are greater than zero whenever Y<Y* (guarantee yield). Otherwise, I=0.

Based on equations II.7 and II.8, the insure decision to insure can be characterized as a comparison of cash flows with insurance, CF_I, relative to cash flows without insurance, CF_b. Figure II.2 helps us to visualize a hypothetical comparison.

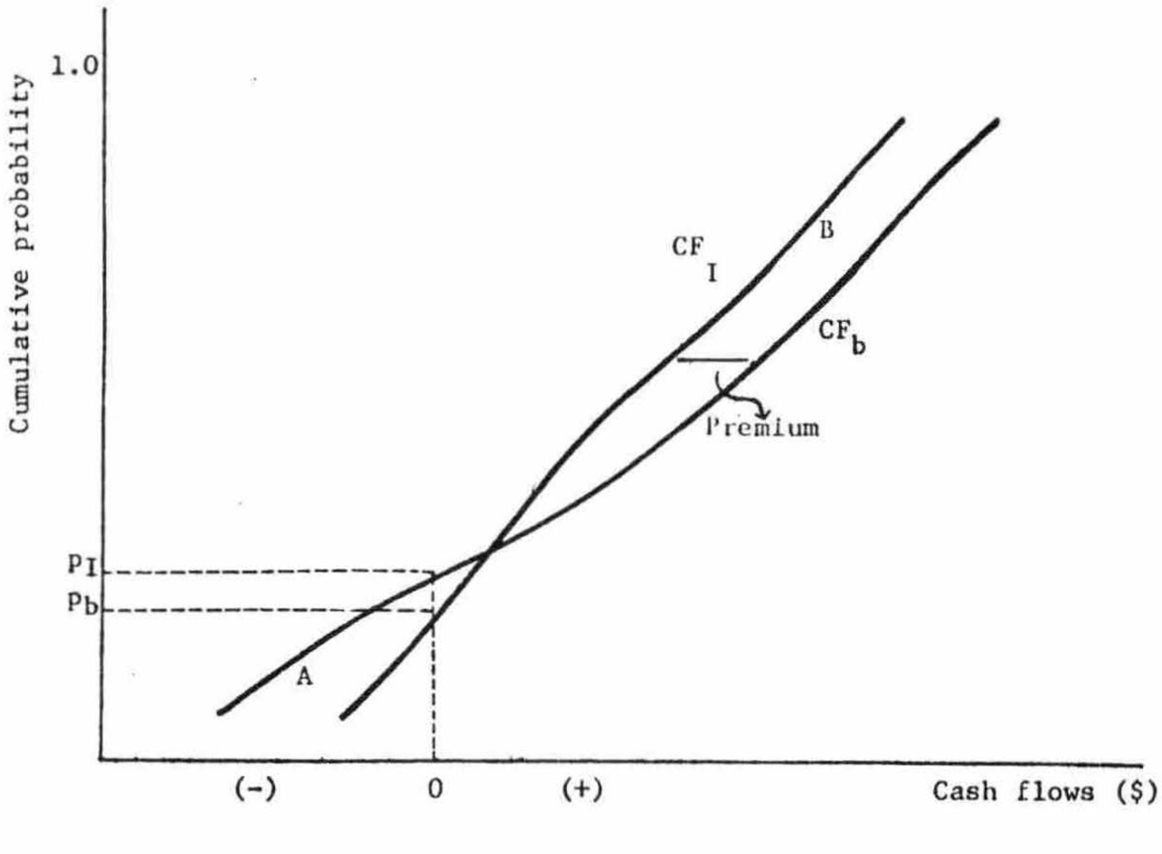

Figure II.2. CPDs of hypothetical crop insurance prospect, CF_I, and base product, CF_b

Purchase of crop insurance truncates the relevant yield distribution at a minimum equal to Y*. Price distribution remains unchanged. As a consequence, outcome distribution is pulled to the right at yields below Y* and bent back at values of $Y \geq Y^*$ by the absolute cost of the insurance premium--CF_I in Figure II.2. It is important to note that although insurance reduces the absolute amount of negative outcomes in the lower portion of the distribution of CF_I, the probability of such outcomes appears to be higher than without insurance whenever $0 \leq I \leq E$ and $CF_I < 0$, i.e., probability, p_I, compared to p_b at an outcome equal to zero. It also holds true for outcomes on the positive domain, or, more generally, whenever $Y \geq Y^*$ and $E > 0$.

Because CPDs of CF_I and CF_b cross once, crop insurance and base prospects are not dominated by each INFSD. Here, farmers' utility in each prospect is monotonically increasing. Assuming farmers' general risk aversion, we can apply the SSD concept to the insurance and base prospects' CPDs. In Figure II.2, SSD requires the evaluation of the areas under CF_b and CF_I's CPDs. The efficiency rule in SSD says that if the area under the $CF_b \leq$ the area under the CF_I, then CF_b dominates CF_I in SSD. From Figure II.2, if the area "A" is greater than area "B", then CF_I dominates CF_b. The size of these varies directly with insurance premium and protection levels. For example, if a higher premium is imposed on the same insurance protection, it will narrow area "A" and widen "B" and make insurance less attractive, or, in other words, make it less efficient compared to the base prospect in the SSD sense.

From another perspective, area "B" represents the amount of income a risk averter has to forego as a premium to reduce his probabilities of getting low (or negative) incomes (area "A"). Thus, because of the risk reducing nature of crop insurance, a risk averse farmer should evaluate areas "A" and "B" of Figure II.2 as well as the variability of returns. It is clear from the figure that crop insurance does reduce the range of possible outcomes. In addition, insurance serves to reduce the adverse effects of unusually bad draws on yield. In other words, the probabilities of low returns are reduced by the purchase of crop insurance. In evaluating these aspects, a risk averter may purchase insurance if his gain in utility by area "A" and variance effect reduction of insurance is greater than the disutility of area "B".

The CPDs of CF_I and CF_b cross just once, allowing the following assertion: it can be said that crop insurance prospect, CF_I, will dominate the base prospect, CF_b, in SSD, if the mean of CF_I is greater than the mean of CF_b, and if CF_I is less prone to low outcomes than CF_b distribution (Hammond, 1974). Again, from Figure II.2 we know that CF_I we know that CF_I is less prone to low outcomes. And, if in addition to this we know that mean of CF_I > mean of CF_b, then CF_I dominates CF_b in SSD; otherwise, numerical procedures need to be used to determine SSD.

Farm programs[1] prospect

Essentially, farm program participation requires the division of some of the crop land in consideration in exchange for monetary or

[1]Peat, Marwick, Mitchell & Co. published the "Agriculture and Food Act of 1981" where the major commodities programs are described.

in-kind payments.

If equation II.7 of base prospects is considered as a nonparticipation prospect, the equation for a participation prospect should be:

$$\mathbf{CF_p} = [\mathbf{P_y} \cdot Y - P_v) \cdot V \cdot (1-S) + PDIV + IDIV - D_p - C_d] \cdot [1-T_x] + DIF \qquad (II.9)$$

where:

PDIV = $d \cdot \tilde{Y} \cdot S \cdot V$ = total paid diversion: d = program payment per bushel;

$\tilde{Y}$ = program yield used to calculate payment per diverted acre;

IDIV = $P_y \cdot Z \cdot \tilde{Y} \cdot S \cdot V$ = In-kind diversion: Z = percentage of program yield, $\tilde{Y}$, to be received in-kind per diverted acre; and

S = proportion of acreage required to be set aside as a condition of program enrollment.

Thus, DFP is one of the rewards granted by putting aside S percentage of the base acreage V. Another reward is the risk reducing effect on price distribution $\mathbf{P_y}$ by a loan price, FP, issued in the farm programs. In other words, P_y distribution is now truncated to a minimum price equal to FP. Yield distribution remains unaffected and the number of actual acres planted is now equal to $V \cdot (1-S)$. However, set-aside may alter yield distribution because the farmer retires riskier or less productive land.

To better visualize the effects of program participation, let us draw in Figure II.3 a hypothetical distribution of cash flows under a farm programs prospect, CF_p, and the base prospect, CF_b (assuming no insurance and no farm program participation).

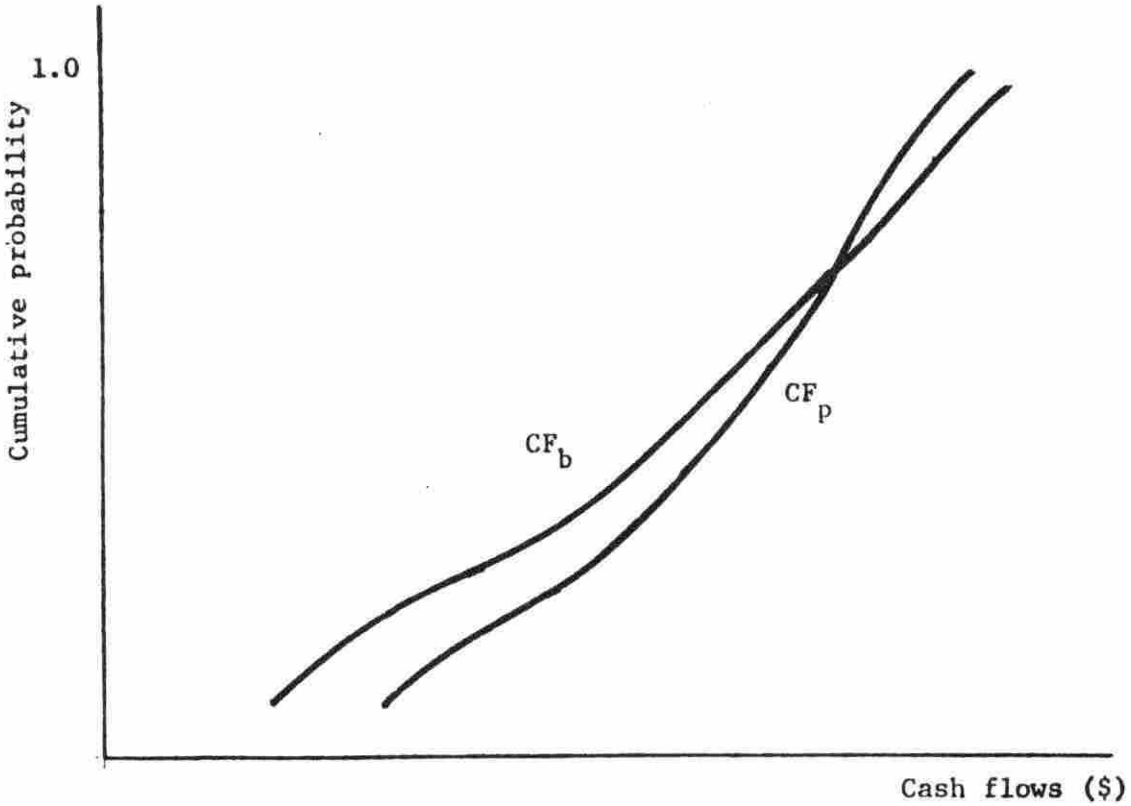

Figure II.3. Hypothetical CPDs of farm programs participation, CF_p, and base prospects, CF_b

Although total acres planted have been reduced by $V \cdot (1-S)$, the guarantee of a loan price plus the possible savings of set-aside acres in production costs when low yields occur (when $P_y \cdot Y < P_v$) cause the CPD of CF_p to be on the right of CF_b at least for low (or even negative) outcomes up to a point when the foregone income of unplanted acres ($P_y \cdot Y \cdot V \cdot (1-S)$) surpasses their costs ($P_v \cdot V \cdot (1-S)$, i.e., where CF_b and CF_p cross (Figure II.3).

Following a similar procedure as with crop insurance and base prospect, it can be said that the farm programs prospect dominates base prospect in the SSD sense by evaluating the areas between the distributions CF_b and CF_p in Figure II.3. In brief, the probabilities associated with negative outcomes are reduced not only by a loan price but also by the risk protection offered by program participation in reducing the variability of cash flows. Finally, when the reward is mainly in-kind (i.e., payment with grain), such a farm program acts as a crop insurance instrument since it provides a sure yield level per acre unplanted.

Marketing prospect

Hedging is widely used among marketing strategies. By trading contracts in the futures markets, a farmer protects himself against the risk of sudden price changes (Chase, 1980). In this view, a hedger makes use of the futures contracts as a temporary substitute of a cash market operation that will come later in the season. Three concepts are important in hedging: futures prices, cash prices, and basis.

Futures prices are established daily for several commodities and for specific months of the year. They reflect the buyers' and sellers' intentions now on prices they would like to trade for their products on some future date. Cash prices are daily prices received, usually by farmers, and referred to as local cash prices. Finally, basis reflects differences between cash and futures markets, i.e., transportation. By definition, futures prices ≡ Local cash prices + basis.

Usually when a shortage in production exists, futures prices are high and basis is low. This simple fact ensures first that futures prices and cash prices fluctuate together in the same direction in response to market conditions; and second, in connecting the fluctuation aspect, it actually permits hedging to work. However, price identity does not always hold true. Basis itself is a source of potential risk when it breaks the identity because of unexpected changing conditions in the markets, i.e. increases in fuel prices. In other words, hedging does not guarantee that profit will occur or losses will be avoided. Also, basis is not only in function of futures and cash prices, but in the general local market conditions.

An expression of cash flows with hedging strategies would be

$$\mathbf{CF_M} = \{[(\mathbf{P_y} + \mathbf{HR})\cdot Y - P_v]\cdot V - D_p - C_d\}\cdot\{1-T_x\} + DIF \qquad (II.10)$$

where the new variable

$HR = (P^f_{t+1} - P^f_t)\cdot K$ = Hedging stochastic revenue where P^f_t = futures price at the time of placing the hedge, P^f_{t+1} = futures price at the time of lifting the hedge, and K = proportion of production hedged.[1]

Except for $\mathbf{P_y}$, the rest of the variables remain as in equation II.7.

$\mathbf{P_y}$ is now a vector of cash prices directly related to futures prices. For instance, the difference between P^f and $\mathbf{P_y}$ narrows as the

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[1]If $P^f_{t+i} > P^f_t$, then a profit is accrued. If $P^f_{t+i} < P^f_t$, a loss is experienced. Normally, hedged bushels are sold in the cash market at the time the hedge is lifted.

maturity month approaches. Since independence of prices and yields is assumed, farmers' yield distribution remains unaltered and it does not influence market prices.

The impact of hedging is better seen in analyzing cash price, P_y, and futures price, P^f, distributions. Figure II.4 portrays CPDs for P_y and HP.

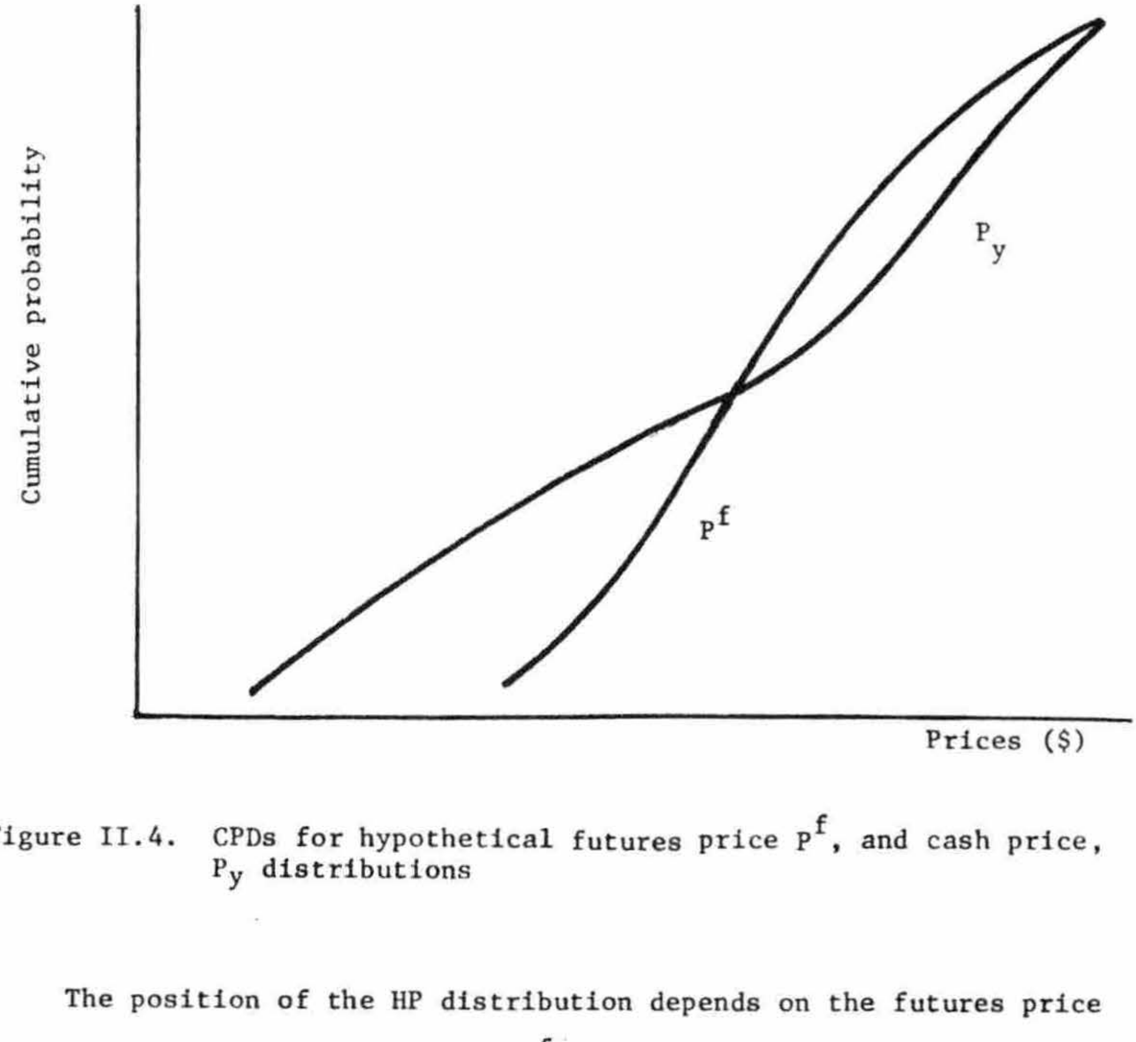

Figure II.4. CPDs for hypothetical futures price P^f, and cash price, P_y distributions

The position of the HP distribution depends on the futures price at the time the hedge is placed (P^f)--given that the distribution of basis is constant. Thus, if P^f and P_y cross just once, a hedging prospect dominates a base prospect (of cash marketing) in SSD, if the mean of P^f is greater than the mean of P_y. Finally, the hedge option is likely to reduce price variability if basis distribution is narrower than cash price distribution.

Leverage level

In general terms, leverage is equal to the ration of the firm's total debt to its equity. A high leverage level means more capital has been borrowed, permitting increased farm operations and farm revenues that otherwise would not be possible. However, along with borrowed capital, a financial risk is created in the form of fixed financial commitments, i.e., repayment of principal and interest. As a consequence, more leverage means higher financial risk.

Thus, on one hand, as leverage increases, it is likely that farm returns will also increase and, perhaps, risk in some other areas of farming activities will be reduced, with an improved irrigation system, for example. On the other hand, leverage is itself a source of risk because of its commitments to lenders. In brief, the utility a farmer gets from borrowing capital is a function of its risk and expected returns.

An expression for cash flows under a leverage prospect resembles that of equation II.7. It is

$$[(\mathbf{P}_y \cdot \mathbf{Y} - P_v) \cdot V - D_p - C_d] \cdot [1 - T_x] + D_p - PP \qquad \text{(II.11)}$$

Leverage affects C_d and PP through the farm debt (FD). FD = $(a \cdot \ell / H\ell) \cdot V$; a = asset value per acre V, and ℓ = leverage level. If V and a are held constant, a higher ℓ means a higher debt, FD, is carried on the farm.

An immediate effect of leverage in cash flows, CF_L, is that they are reduced as leverage increases. Another aspect of leverage is that it has some relation to farm size (or total crop acres), V. A farmer may borrow capital to increase farm acreage or may use it to purchase new machinery or some other investments in the farm. In regard to taxes, they are likely to be less with a high leverage position. Thus, leverage alters farm cash flows through P_v, V, T_x and DIF of equation II.11. It should be noted that P_y and Y distributions have not been altered by leverage.

For a given equity base, a farmer may expand total operation by using borrowed capital (nonequity capital). By transforming cash flows from a leverage prospect and a nonleverage (base) prospect into rates of return to equity capital,[1] we see that leverage is advantageous if returns are good (i.e., >0); otherwise, leverage will have a negative expansive effect on farmer's income. These aspects are portrayed in Figure II.5.

Based on return to equity, producers' preferences for leverage are likely to differ, given the risk involved in it. Thus, it suggests we consider the role of leverage in our model as a measure of farmer risk bearing ability which may influence the performance of other risk management strategies in the model.

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[1]Here, return to equity capital is what remains after paying the interest on borrowed capital.

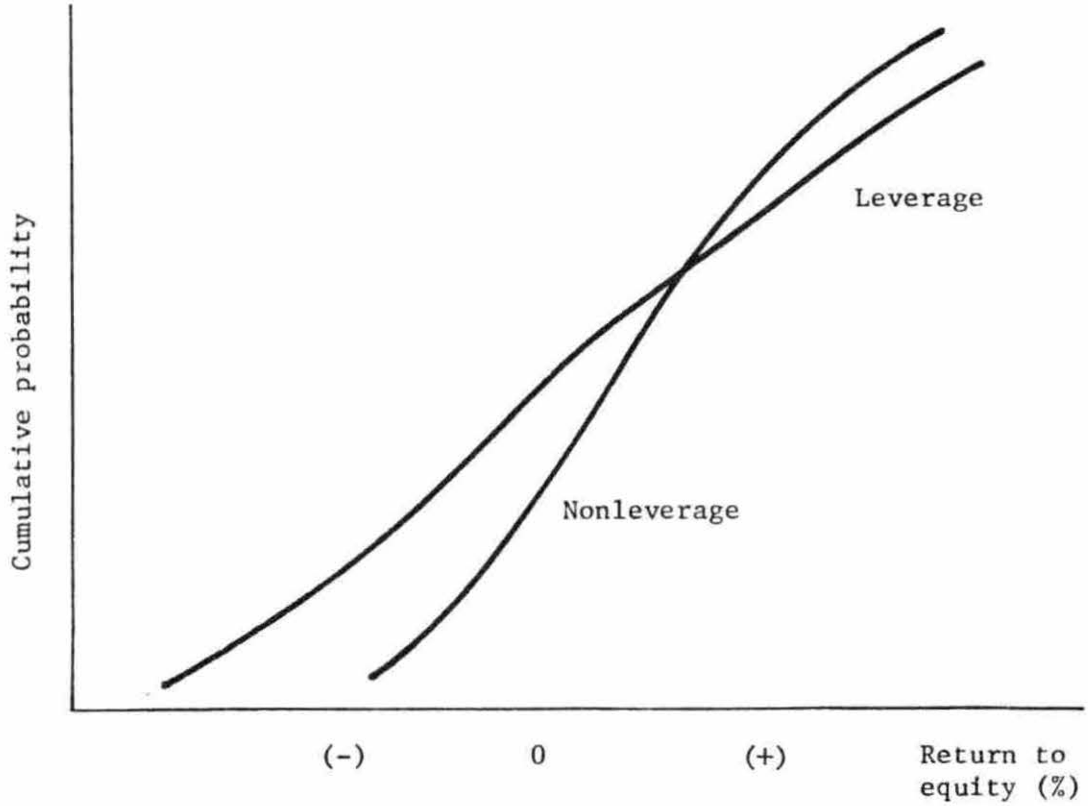

Figure II.5. CPDs of return to equity for a nonleveraged prospect and a leverage prospect

Implications

In general, the reviewed literature on risk and crop insurance and the model developed provide the basic elements to empirically evaluate the performance of crop insurance and its alternative risk control instruments. The next chapter presents the empirical model for this purpose.

CHAPTER III. EMPIRICAL MODEL

Introduction

Once we have established a theoretical framework of risk management strategies, we are now in a position to set up a computer model which will empirically evaluate the risk-reducing strategies of the theoretical model.

In addition, the computer model to be developed can be seen as a practical tool to evaluate and select an optimum farm plan under risk when a farmer's attitude toward it is unknown or difficult to elicit. Thus, the model not only serves to ascertain the merit of management strategies but also to judge farm plans when risk exposure is complex and difficult to assess. Briefly, this chapter will: (1) specify an empirical computer model, define variables in the model, and show how they are interrelated; (2) discuss data sources for the variables in the model, assumptions, and estimation problems; and (3) describe the computer model operation, algorithm, and solution and experimental techniques. A description of each of these aspects follows.

The Computer Model

The goal

We have stated in the theoretical model that the evaluation criterion of risk management strategies is cash flow after consumption (CFAC). Thus, the goal of the model is to capture the effect of any single or combined interaction of strategies on cash flows and some collateral impacts on taxes, farm net worth, and debt position (i.e., cash flows as a percentage of net worth).

Specifications of risk management strategies

In order to get a CFAC, we need to establish the specific ways in which insurance, leverage, marketing, and farm programs will be numerically considered in the computer model.

Starting with leverage, it is included in a way that any leverage level (debt to equity ratio) can be stated. It is also used to calculate the amount of farm debt for a given land value per acre. This land value is the sum of equity and non-equity capital including rented land and/or machinery, if any.

In the case of crop insurance, the different coverage and price protection levels of Federal Crop Insurance (FCI) are essentially the insurance alternatives considered in the model. The model asks for information, such as area average yield and proven farm yield (according to FCI standards). It also inquires for specific price, coverage, and premium levels in order to obtain guaranteed bushels, and possible indemnities.

In the marketing case, pre-harvest, as well as post-harvest hedges are available in the model along with direct fall cash sale (Oct.-Nov.) and direct summer cash sale (June-July after harvest). Pre-harvest hedges can be placed in any month after planting and before harvesting. Here, because actual yield per acre is still unknown, an expected yield is used instead. The hedged bushels are automatically sold during the fall as an indirect fall cash sale. Additionally, an expected local hedge price at pre-harvest time is matched with a local hedge price at harvest time to obtain any pre-hedge gain or loss.

A post-harvest hedge is similar to the pre-harvest hedge. One distinction is that the post-harvest hedge uses actual yields instead of expected ones. Another distinction is that the futures contracts are only placed at harvest time (Oct.-Nov.) and with a fixed delivery time of nine months later (June-July). The reason for this is given in the farm programs specifications. All post-harvest hedged bushels must be sold at the contract maturity time. Details of hedging prices are given in the next subsection.

Whatever is not hedged has to be sold either as a direct fall or summer cash sale. A reason for a fall sale is to cover some cash expenses due at harvest. In a summer sale, it is possible that storing the crop might pay for itself with better crop prices in summer.

For farm program participation, the following features of government farm programs are considered in the model:

(1) An acreage reduction which is considered as an unpaid diversion that might be required for eligibility in other farm program(s) (i.e., PIK Program).

(2) Eligibility for a short-term price support loan and/or target price.

(3) A paid land diversion option from which some cash is received at harvest for setting aside a portion of the crop land.

(4) A Payment-In-Kind (PIK) Program which allows for any set-aside

level that it may require. It also specifies a percentage of the ASCS crop yield to be paid (in-kind) per acre in the program.

It is important to note in point (2) that the loan is fixed to nine months according to the 1983 program. It is given at harvest and repaid or forfeited in the summer (nine months later). The loan is repaid if the summer cash price is higher than the loan rate plus interest on the loan; otherwise, no repayment is made, and the stored grain is turned over to the government.

This price support loan program is the main reason for setting both the post-harvest hedge and the summer cash sale to nine months after harvest. In this way, stored grain in the loan program can also be used against a post-harvest hedge contract and vice versa.

Finally, the target price is used against an average cash price calculated by a formula in the computer model. The difference between both is used to obtain deficiency payments.

These specifications of management strategies make up the main frame of the model. The remainder of this section will explain the elements, characteristics, and limitations of the model.

The elements of the model

Basically, the model is composed of five major elements which are shown in Diagram III.1. The first step is to obtain the necessary information to calculate revenues and costs of operating the farm. Next, income taxes and consumption expenditures are introduced to

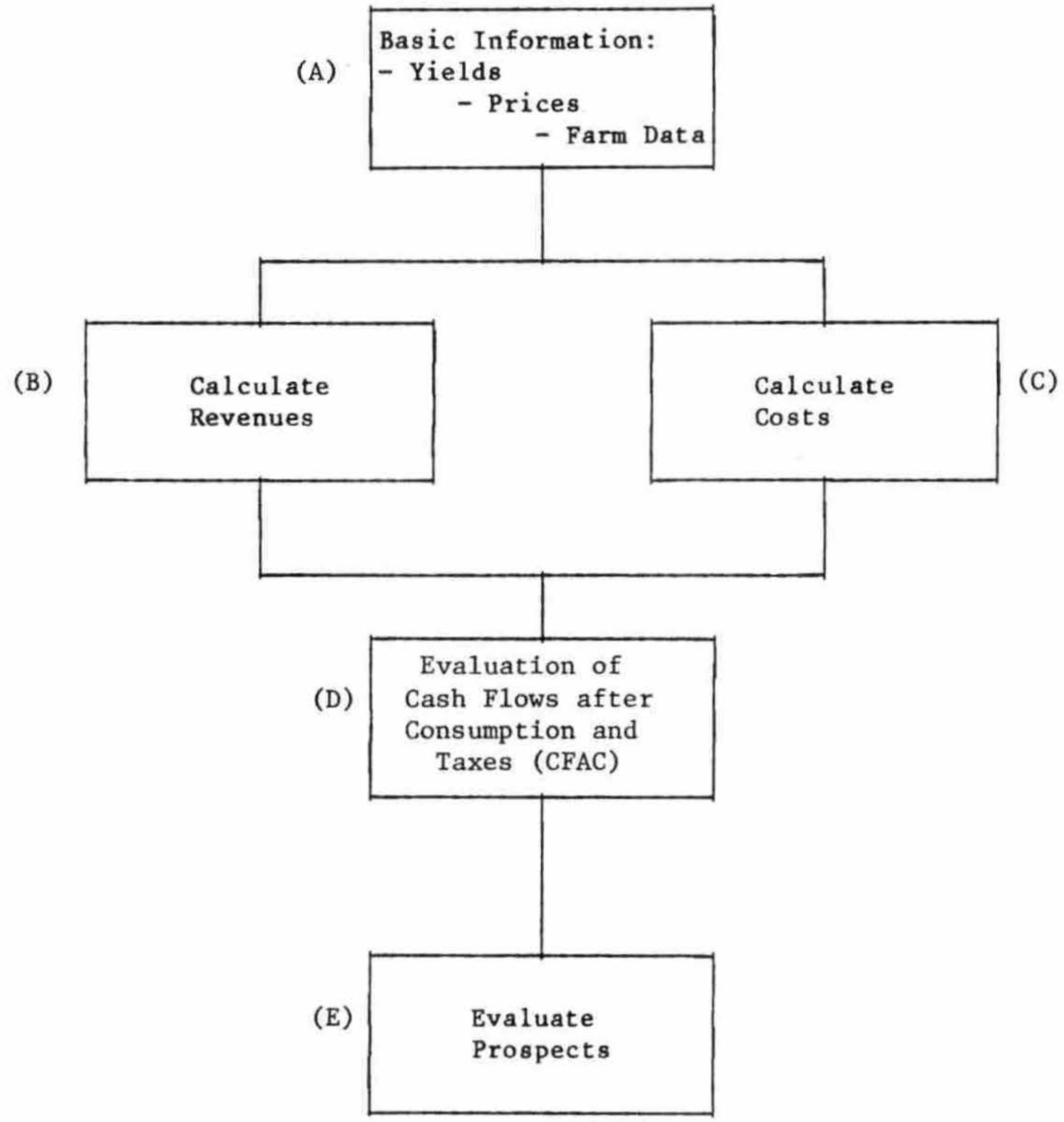

Diagram III.1. The computer model flow

finally get CFAC (step D). These first four steps form what will be called a "prospect". The last part of the model (step E) compares the risk-reducing efficiencies of prospects among them. An explanation of each of the five steps follows.

Under basic information (step A), a list of 38 input variables is needed to operate steps B and C of the model.[1] Variables such as land operated, interest cost of borrowed capital, variable cost of production, and yield per acre are included in the list.

This set of variables is better understood in steps B and C where revenues and costs are calculated respectively. The codes of Appendix B are used in all following expressions. Additionally, all sources of revenues and costs are brought to a present value at harvest time. Thus, CFAC represent harvest time values.

Revenues The final equation of revenues is[1]

$$\begin{aligned} \text{REV} = {} & (\text{CPF})\cdot(\text{PHBu} + \text{CSFBu}) + (\text{CPS})(\text{SCSSBu}) + \text{HEREV} + \\ & (\text{LR})(\text{LOCANBu}) + \text{DEPAY} + \text{LADP} + \text{FCI} \quad . \end{aligned} \qquad (\text{III.1})$$

The first expression of the RHS in equation III.1 is the income from fall cash sales, which is simply the sum of pre-harvest hedged and direct fall sale bushels times the cash price in the fall (CPF). This CPF is equal to a fall futures price (FPF) minus a fall basis (FB).

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[1]See Appendix B for the variables list and their codes.

The second term in the RHS of equation III.1 is the revenue from the summer cash sale. It is again the sum of post-harvest hedged and direct summer sale bushels times the cash price in the summer (CPS). This is a summer futures price (FPS) minus a summer basis (SB). The final amount is brought to a harvest-time value.

Any gain or loss by pre- and/or post-harvest hedging is captured in the third term of the revenue equation (HEREV), the difference between pre-harvest (post-harvest) futures price and fall (summer) futures.

For government farm programs, in a case in which a loan is asked for and is forfeited, it is similar to selling the bushels under loan at a price equal to the loan rate. This is reflected in (LR·LOANBu) in equation III.1. Deficiency payment (DEPAY) is calculated from a target price (TP) and an average cash price (ACP)[1] per bushel received during the five months after harvest. Finally, entries from land paid diversion payments are reflected in LADP. The last expression of the revenue equation accounts for any indemnity received if FCI was purchased. This varies among coverage and price levels selected and if area average yield (AAY), or individual yield plan (IYP), is in effect.

Thus, the revenue equation accounts for insurance as well as marketing and farm programs participation strategies. All of them can act independently or combined. The next step is to obtain farm

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[1]The ACP was obtained by the next expression: $ACP = CPF + CPS/CPF - 1$ which is an approximation to the five-month average.

operation costs.

Costs Following a similar exposition procedure as in revenues, the equation of costs is

$$TOP = TFC + TMC + TPC \quad (III.2)$$

where:

TOP = total operating costs;

TFC = total financial costs;

TMC = total marketing costs; and

TPC = total production costs.

In order, TFC is interest on borrowed capital and repayment of principal. TMC is hedging cost (i.e., broker's commission) and storage cost of summer bushels. Finally, TPC is the sum of fixed and variable costs of production (FPC and VPC, respectively).

Estimated FPC is basically machinery depreciation, excluding labor and land cash rent equivalent. These last two items are seen as a return to capital and they form part of cash flows which can be looked at as retained earnings.

On the other hand, VPC is formed by:

$$VPC = (VC)\cdot(AP) + (AP)\cdot(YIELD)\cdot(HC) + (MC)\cdot(UPA) + PREM \quad (III.3)$$

where the first term of the RHS of equation III.3 is all yield-independent variables costs (i.e., seed, fertilizer, etc.). The yield-dependent costs are reflected in the second term in equation III.3. They are those harvest costs such as fuel that vary with actual yield per acre. The maintenance cost of unplanted acres (UPA) is added to account for set-aside acres under farm programs.

Any insurance premium is expressed in equation III.3 by the variable PREM. Again, the premium varies depending on selected coverage and price levels, but the premium is calculated using AAY and not IYP in case the latter is used for indemnities.

Up to now we have constructed the major elements of the model (revenues and costs). They are the inputs of the next element (step D), in which cash flows are calculated.

Cash flows   By subtracting costs from revenues, we obtain a taxable farm income (TFI) which is the feature used to calculate income taxes.

Mathematically,

$$TFI = REV - TOP \qquad (III.4)$$

Federal, state and self-employment taxes are applied to TFI. The result is a farm income after taxes or "net farm income" (NFI).

Cash flows are real inflows and outflows of money on the farm. Thus, since principal payments on borrowed capital represent a real outflow of money, they are subtracted from NFI. Similarly, depreciation is not a real outflow of money; it is added back to NFI. The result of these two changes gives us a net cash flow after taxes (NCF). In mathematical terms, we have,

$$NCF = NFI - PP + DEP \qquad (III.5)$$

The final step in this element is to subtract family expenditures (consumption) to get a net cash flow after consumption (CFAC).[1] This is

$$CFAC = NCF - CONSP \tag{III.6}$$

This final step completes a so-called "prospect." In each prospect, a specific combination of risk strategies is stated. The prospects can be viewed as semi-final products of the computer model.

The final product of the model is the prospects evaluation (step E, Diagram III.1). Here, CFACs of each prospect are compared against each other in two main approaches. The first is an informative approach to describe certain characteristics of each prospect where different strategies intervene. This approach will serve as a background to support a more formal approach of stochastic dominance. By assuming certain properties of a farmer's utility function, stochastic dominance evaluates efficiencies of risk management alternatives among prospects.

In essence, the computer model

(1) is developed to be applied on a farm level;

(2) is flexible enough to accept any respecification of farm data and/or risk-bearing alternatives within the main framework of management strategies assumed in the model;

(3) is able to calculate both net farm income and cash flows after

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[1]The idea of CFAC is to look at them as real retained earnings in the farm.

consumption to fit different purposes. Calculations are at crop harvest time values.

(4) Moreover, any subjective elicitation of yield and price distribution, which in turn bring subjective outcomes, can easily be introduced in the model. This means the model can fit the specific farmers' perceptions.

(5) Finally, and most importantly, the computer model will help us study the problem of low participation among farmers in the federal crop insurance program.

Data Sources

The next action in the development of the computer model is to identify data sources. For this purpose, three sets of data sources, described below, have been established: farm level data, yield data, and price data. These sets provide the information for the 38 input variables in the model.

Farm level data

Farm level data deal with crop production costs, farm management aspects, and income taxes and consumption information. A common point is that they are somewhat controlled and manipulated by the farm operator, who decides on acres to operate (either rented or owned), on land investment, and on how much capital to borrow at a given interest rate, among other factors.

The data for production (fixed, pre-harvest, and harvest) costs were obtained from the 1983 estimated costs of crop production in

Iowa, published by the Cooperative Extension Service at Iowa State University (FM 1712). This report reflects average costs of purchased inputs for several crops and yields per acre.

The farm management information contains details of insurance, marketing, and farm programs. Crop insurance features are obtained from the actuarial documents of the Federal Crop Insurance Corporation. They include county coverage and rate tables from which premium and indemnities are acquired. Different documents are published for each county in the state (at least in the case of Iowa). This means that insurance data differ from county to county. The actual document for O'Brien County will be used in the analysis in Chapter IV.

Since marketing decisions depend on futures prices and basis, they are included in the discussion of "prices sources." Finally, the 1983 Feed Grain Program is the source of the information on farm program participation. Again, the relevant information for the state of Iowa is selected for the analysis in Chapter IV. No discussion of these farm management sources is included since no estimation of data has been done at this point.

Farmers pay income taxes on three levels: federal, state, and self-employment. Schedule Y (married taxpayers) of the 1983 Tax Rate Schedules was used to estimate federal tax.[1] A state tax table was obtained from the 1983 Iowa 1040 Long Form Individual Income Tax

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[1] Internal Revenue Service, 1983b.

Return. Finally, the self-employment tax rate was 9.35% of estimated taxable farm income.[1]

The last item to be considered as farm level data is consumption, which refers to family living expenditures such as food, clothing, etc. These expenses are included in the estimation of cash flows since first they are essential to survive, and second are used to estimate cash flows as returns to labor and capital (retain earnings) after consumption.

After attempting to estimate a consumption expression (as a function of farm income) using Iowa farm families surveys, it was decided to fix consumption as an amount that is regarded as a minimum needed for living. This amount is $15,000, which represents only cash expenses for living. Such a value was obtained from a 1982 survey value inflated to 1983 terms. The estimation attempts failed for two reasons: first, missing values in consumption and income variables significantly reduced the sample size; and secondly, even when a regression could be done, consumption was not significantly altered from $15,000 to justify the inclusion of such a consumption function in the computer model.

Yield data

Since crop insurance features are directly related to yield levels and their probabilities, it is important to estimate them carefully. A discussion of yield distributions is followed by an empirically

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[1] Internal Revenue Service, 1983a.

estimated yield distribution.

The essence of crop insurance is mainly concentrated chiefly on the lower tail of a "possible" yield distribution. It is widely accepted that a low yield[1] (eventually 0) does occur. But what is difficult to assess is how frequently it occurs. Thus, if one overestimates the probability of low yields, crop insurance (FCI in this case) will look like a very rewarding strategy. On the other hand, insurance might be viewed as unattractive when one underestimates the probability of low yields. Therefore, an important question should be raised at this point: what is the yield distribution that ensures us an accurate evaluation of the merits of crop insurance and its competitor strategies?

In addressing the question, such a distribution can be elicited either subjectively or historically. Nelson et al. (1978) identify the following four general approaches for field elicitation of subjective probabilities:

(1) The cumulative distribution approach;

(2) the conviction weights method;

(3) direct elicitation of probabilities; and

(4) triangular distribution method.

These approaches require a response from the decision maker in order to draw either a cumulative distribution function (CDF) or a probability density function (PDF). Answering the question posed above through a subjective approach requires two things: Knowledge of the decision maker's utility function from which attitudes can be derived to shape

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[1]A yield covered by most of the insurance policies.

the subjective yield distribution and a narrowed scope of the thesis into a case study. Because of the time and cost needed to collect the responses, it was decided to exploit the historical approach.

Historical yield records were collected from three farms in Iowa, the Crawford, Hancock, and Sutherland farms.[1] The central idea of considering three sets of data instead of just one is to look for a consensus on yield distributions. In addition, they are the best time series yield data in Iowa available for study. Estimation of a yield distribution for each farm follows.[2]

Crawford farm data   The Crawford farm is located in west-central Iowa in the county of the same name. It is primarily in the Ida-Monona soil association area of Iowa. Corn has been the major crop produced since the farm started operation in 1956. During this 27-year period, corn acreage increased from 55 acres to 282 acres. The land use system of row cropping was designed to improve soil productivity, minimize erosion, and improve crop yields. This has required a continued adoption of new technologies. Normal annual total precipitation in Denison, Iowa, which is located a few miles from the Crawford farm, is approximately 30 inches per year.

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[1]The first two farms are commercial farms administered by the Iowa State University Agricultural Foundation, which is a non-profit corporation for educational and scientific purposes. The third farm is an experimental farm.

[2]The estimation procedures to be shown for the three farm data sets were suggested by Dr. Vince Sposito and Dr. Wayne Fuller from the Department of Statistics, Iowa State University.

Figure III.1(a) shows the plot of actual corn yields per acre during the 1957-1982 period. Since the farm adopted new changing technologies, detrend of the data is suggested in order to measure technological effects. No significant trend is observed from the graph. Thus, the residuals of the detrended series follow exactly the same pattern of the original yield series.

The lack of an upward trend is blamed on the fact that corn acreage was increased by incorporating marginal land (land of lower quality) into production, thus diminishing average yields of the total corn field. However, implementation of new technologies has compensated for the lower productive land.

In order to gain some insight on how the PDF of the yield distribution for Crawford farm looks, a histogram is presented at the bottom of Figure III.1. It strongly suggests that Crawford data are normally distributed.

The first step was to reach a transformation of the data to a function which would have all the statistical appear required by statisticians. Transformations such as square root, square values and absolute values (to mention a few) of residuals were worked out, but none of them passes the 't' of student test. So it was decided to do a normality test since the Crawford histogram (Figure III.1(b)) evokes a normal distribution. Also, the mean, median and mode (77.07, 78, and 78, respectively) of the Crawford data are practically the same, which implies symmetry of the distribution.

The normal test can be easily done by a graph. If the cumulative

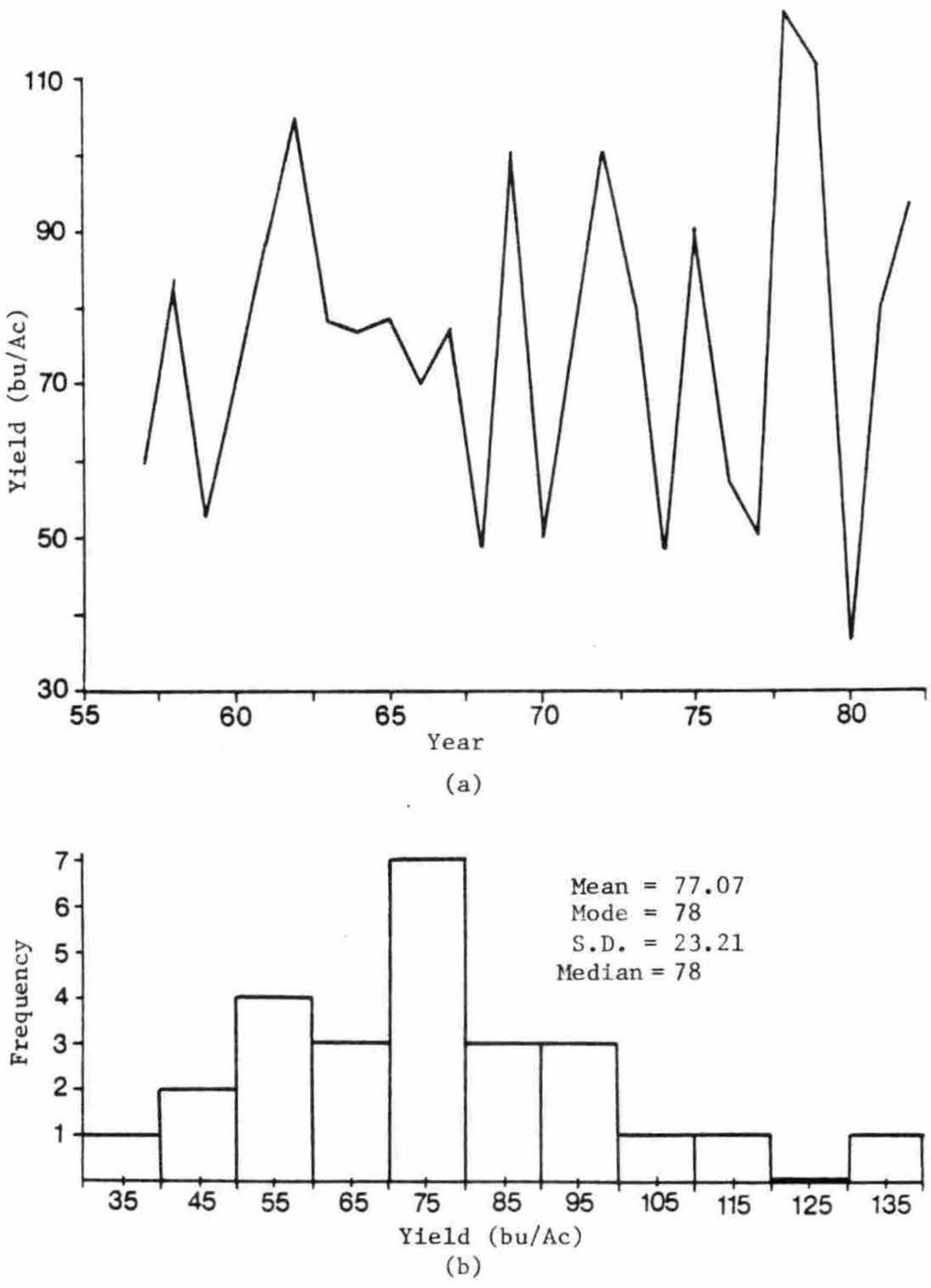

Figure III.1. Corn yield for Crawford farm (1957-1982)
(a) Actual yields; (b) Histogram

frequencies follow a straight line when plotted on normal probability paper, a normal probability process is operative (Anderson et al., 1977). The graph of Crawford cumulative frequencies is shown in Figure III.2. To fit a normal distribution, all we need to do is place a straight line through the data of Figure III.2. This is shown by the unbroken line. The parameters of the normal distribution can then be read directly from the graph; the mean corresponds to the 0.5 fractile and is indicated by the unbroken line as 75 bu/Ac. The standard deviation (S.D.) can be found at the 0.841 fractile of the cumulative frequency since 84.1% of the area under a normal PDF lies below the mean plus one standard deviation. From Figure III.2, the 0.841 fractile is read off the fitted straight line as 96 bu/Ac, so one S.D. is 96-75=21 bu/Ac. The mean and S.D. of the fitted normal distribution are not notably different from the observed data (in fact, mean and S.D. values differ by 2 bu/Ac only). Thus, normal distribution is regarded as the distribution that better approximates the Crawford data.

Hancock farm data The Hancock farm is located in the Clarion-Webster-Nicollet soil association area of Iowa (northcentral Iowa). Conservation practices to improve the drainage on the farm, in addition to row crop production, were the land-use system developed on the Hancock farm.

Corn and soybeans have been the major crops grown on the farm. The average acreage of corn planted during the 1954-1982 period is 120 acres, varying from 62 acres to a high of 154 acres. Hancock corn yields are shown in Figure III.3. Over the past 27 years, corn yields have ranged

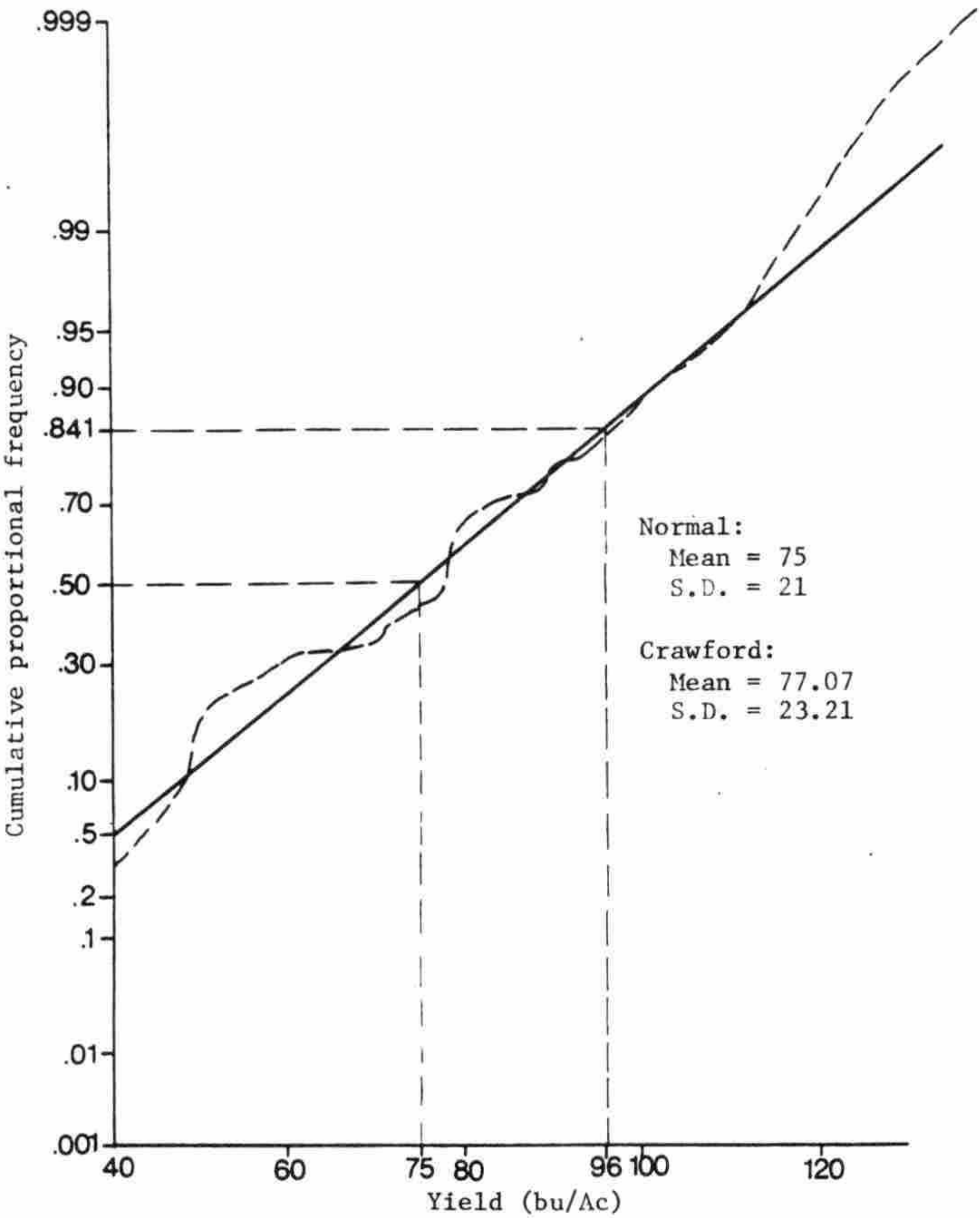

Figure III.2. Crawford. CDF for 1957-1982 yield values plotted on normal probability paper

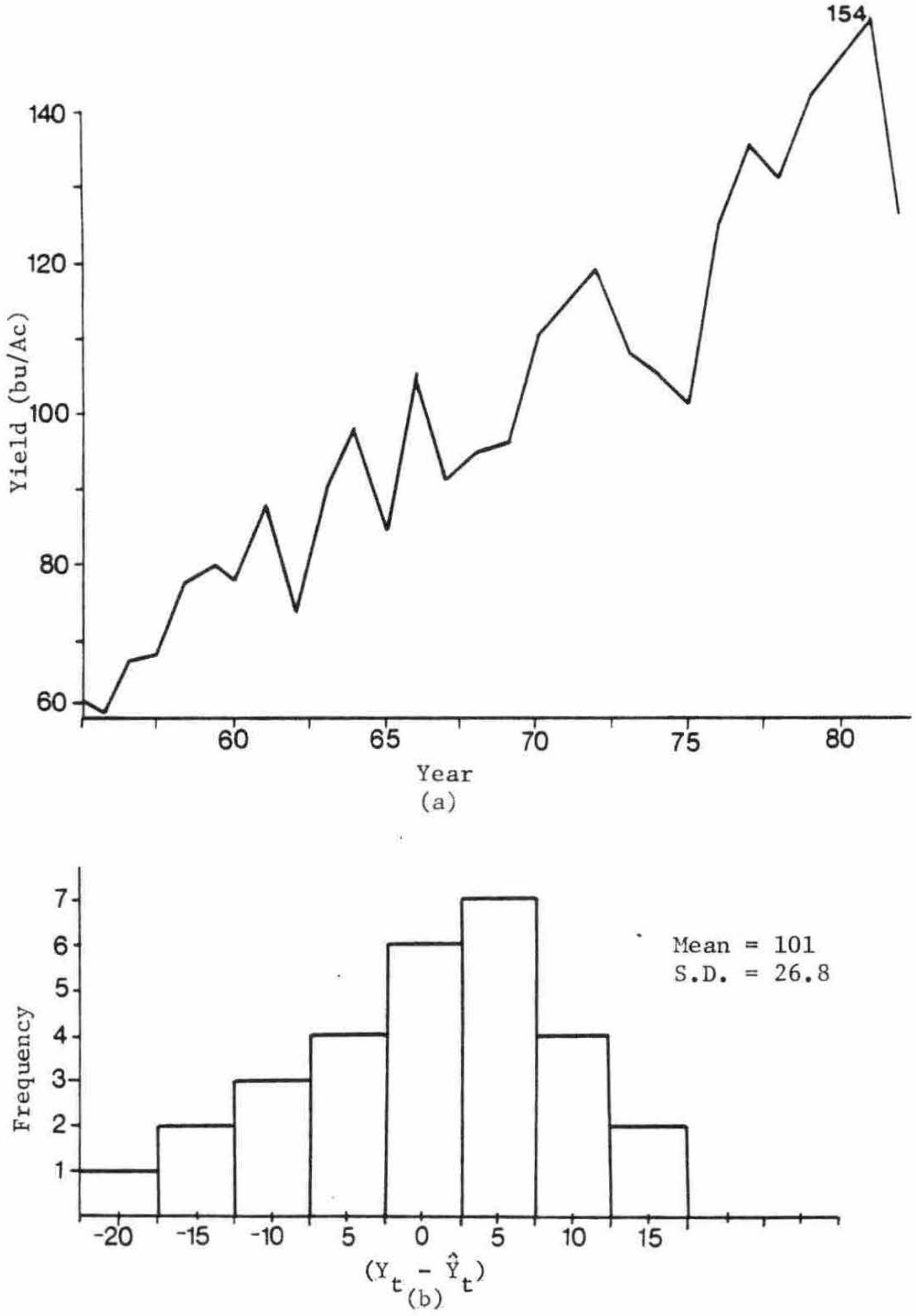

Figure III.3. Corn yield for Hancock farm (1954-1982)
(a) Actual yields; (b) Histogram (residuals)

from a low of 58 bu/Ac in 1955 to a high of 154 bu/Ac in 1981. While this represents a 266% variation, yields have tended to show a definite upward trend, as shown in Figure III.3(a).

A histogram of the same data is portrayed in Figure III.3(b). It does not show any clear indication that Hancock yields are normally distributed. In fact, a normality test[1] was performed affirming that a normal distribution (mean = 0 and variance = 1) does not fit Hancock historical data. Rather, the histogram suggests a negative skewed distribution.

Thus, the Hancock yields (Y_t) were regressed against time in order to take technological effects out. The regression equation is:

$$\hat{Y}_T = \underset{(3.388)}{57.987} + \underset{(0.197)}{2.983}\, T \qquad \text{(III.7)}$$

$$DW. = 1.619$$

where:

$\hat{Y}_T$ = fitted yield value at year T;

T = year (1954-1982); and

DW. = Durbin-Watson statistic.

From here, the residuals ($Y_t - \hat{Y}_T$) were calculated for each of the 29 observations. A plot of the residual (see Appendix C) reveals that the variance is not constant but increases with time, implying that a transformation on the observations Y_T is needed before any further analysis (Draper and Smith, 1966).

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[1]Performed using the "univariate" procedure of the SAS computer package.

In order to bring the variance to a constant, a transformation, suggested by Dr. Wayne Fuller from the Statistics Department at Iowa State University, was implemented. This is

$$\frac{Y_T}{6+0.2T} \text{ regressed on } \frac{1}{6+0.2T}, \text{ and } \frac{T}{6+0.2T}$$

The new term in the above expression is $(\frac{1}{6+0.2T})$, which will bring the variance to a constant along the residuals time-path. Thus, we have gotten rid of the increasing variance without substantially altering the regression coefficients of equation III.7. Now, the transformed expression is:

$$\hat{Y}^*_T = \underset{(2.541)}{57.557} \left(\frac{1}{6+0.2T}\right) + \underset{(0.177)}{2.897} T^* \qquad \text{(III.8)}$$

where:

$$\hat{Y}^*_T = \frac{\hat{Y}_T}{6+0.2T}$$

$$T^* = \frac{T}{6+0.2T}$$

which is normally distributed with $N \sim (\mu, \sigma^2)$.

Once we have a transformation where the errors are normally distributed and constant variance, the next step is to find the distribution function that fits our transformation. What follows is an approach suggested by Dr. Fuller.

This approach consists of altering a normal CDF ($N \sim (0,1)$) by generating a normal deviate ($N \sim (0,0.795$[1]$)$)and a deviate calculated

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[1] 0 and 0.795 are the mean and variance of the residuals of expression III.8 above.

from a series of interval functions developed by Fuller. These two "noises" are added to the 1982 detrended value of 142 bu/Ac.[1] Graphically, Figure III.4 portrays the transformed function with a mean of 142 and variance of σ_T^2, along with a normal function with the same mean but with a variance equal to σ_N^2 instead of σ_T^2 (where $\sigma_N^2 > \sigma_T^2$).

A characteristic of the transformed function is that it is continuous. A setback in this fitted function is that when a sample is drawn, the lowest possible yield value obtained is approximately 108.4 bu/Ac with a probability close to zero (0.0009). It means that the chances of getting a lower yield are zero. This might be the case for Hancock farm, as it is partially supported by the yields registered in the farm in the last seven years.

Sutherland farm data The Sutherland farm is situated in O'Brien County, which is located in the northwest corner of Iowa. The farm is on Galva-Primghar, Sac, and Marcus soils. Rainfall in the area averages about 26 inches per year, which is the lowest amount in the state. Consequently, water conservation practices are extremely important on the farm.

Fertility, tillage, planting population, moisture conservation, and crop variety testing are the major areas of activity on the farm. Under these activities, a long-term experiment was started for corn in 1960. Corn yields from 1961 through 1981 have been collected from this experiment where the same crop practices have been applied since 1960. Thus, constant technology is a major characteristic of the farm corn yield

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[1] See Appendix C for details.

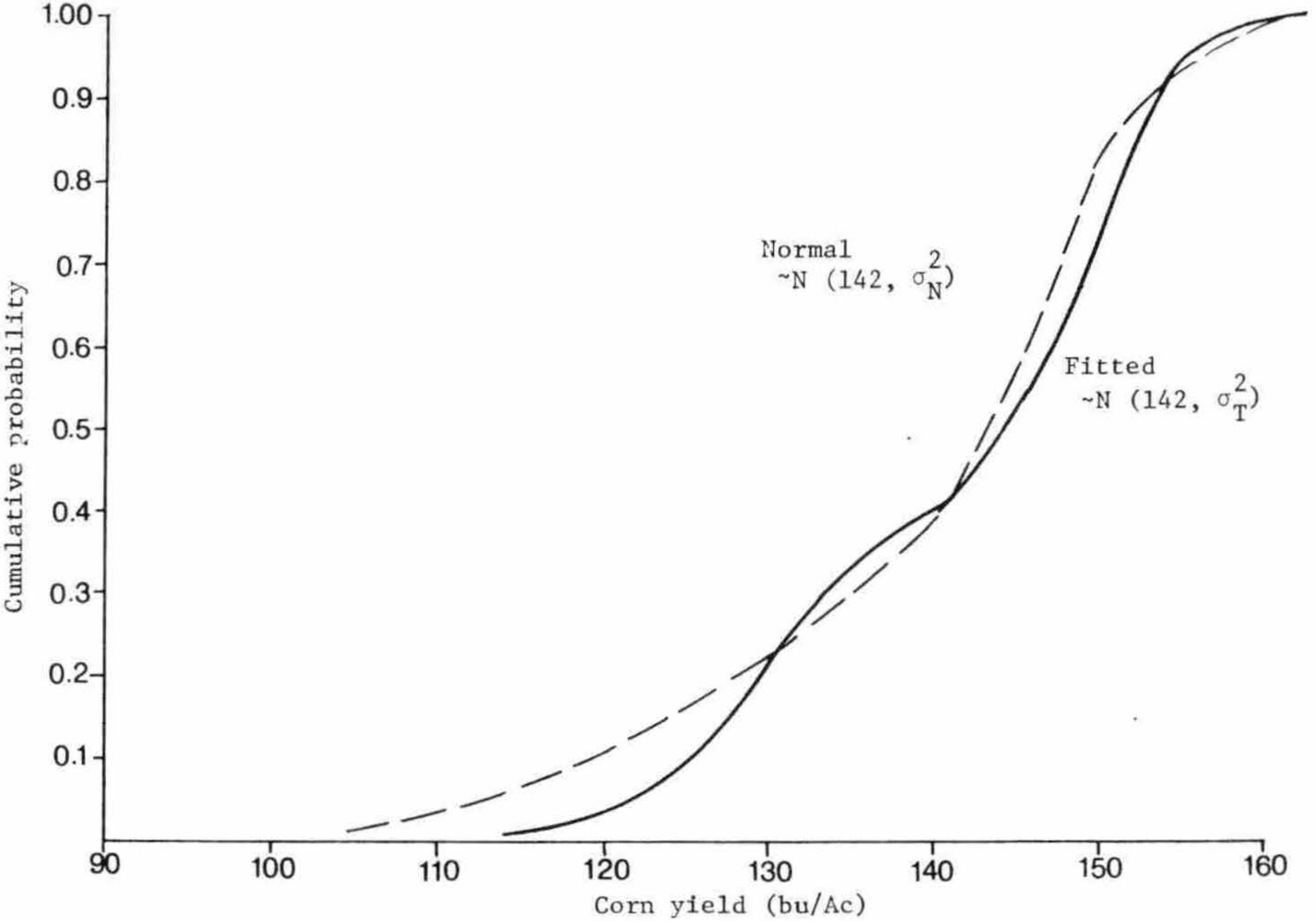

Figure III.4. Fitted CDF for Hancock farm corn data and a normal CDF for the same data

data.

Actual yields of Sutherland farm are plotted in Figure III.5(a). Except for the unusual observation of 3 bu/Ac in 1968, Sutherland data reflect a flat trend during the 1961-1981 period. A histogram of the same data is shown in Figure III.5(b). Again, no evidence is seen that presumes a normal distribution of Sutherland data. It rather suggests a negative skewed distribution (extended left tail). Thus, the task is again to search for the appropriate yield distribution for Sutherland farm.

A procedure similar to that followed with Crawford and Hancock data is used for Sutherland data. With the advice of Dr. Fuller, the selected distribution function is a proportional weight of two normals with different mean and variance. The normal functions and their weights are:

	Weight
$N_1\ (7,\ (19)^2)$	.9
$N_2\ (-63,\ (23)^2)$	.1

A mathematical expression looks like,

$$F_X(x) = P\{X \le x\} = P\{X = X_1\} \cdot P\{X_1 \le x\} + P\{X = X_2\} \cdot P\{X_2 \le X\} \qquad \text{(III.9)}$$

$$F_X(x) = 0.9\ \Phi(7,\ (19)^2) + 0.1\ \Phi(-63,\ (23)^2) \qquad \text{(III.9')}$$

where:

$F_X(x)$ = a continuous cumulative distribution function;

$\Phi(7,(19)^2)$ = a normal cumulative function with mean 7 and S.D. 19; and

$\Phi(-63,(23)^2)$ = a normal cumulative function with mean -63 and S.D. 23.

The weights 0.9 and 0.1 are directly related to the means of both normal functions. If we multiply each mean of the normal functions to

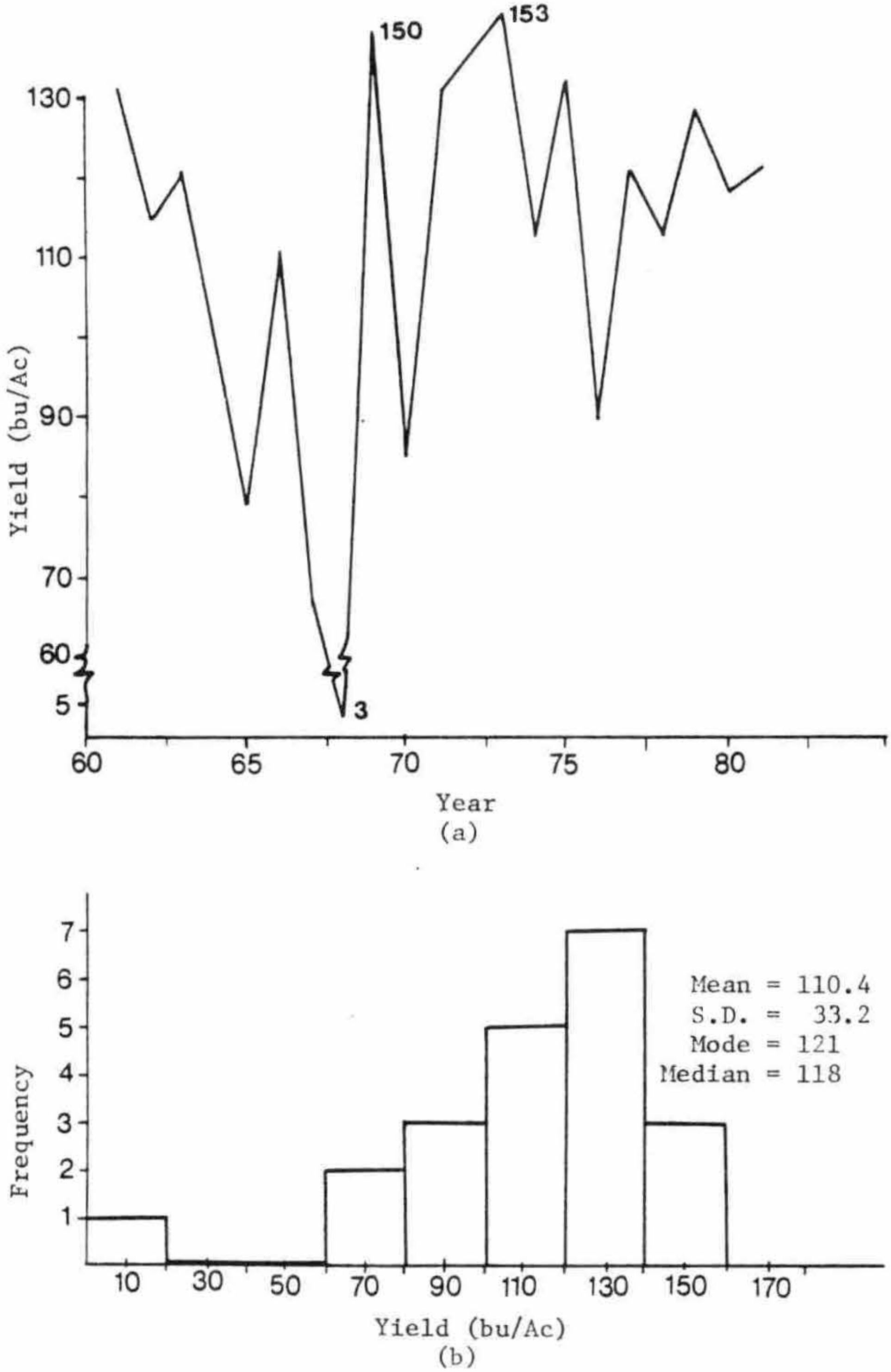

Figure III.5. Corn yield for Sutherland farm (1961-1981)
(a) Actual yields; (b) Histogram

its respective weight and add them, we are centering the distribution to zero.[1]

Figure III.6 shows the estimated CDF of the function expressed in equation III.9' (unbroken line). In the same graphic, a generated sample of the estimated CDF[2] is also plotted in a broken line. It can be seen that the sample CDF resembles the estimated CDF.

It was noted that the mean values of the two normal functions (7 and -63, respectively) have the purpose of centering the third function (equation III.9') to zero. But what do the values of their respective variance ($(19)^2$ and $(23)^2$) mean? The answer is simple: "to give a good visual fit of the sample CDF to the estimated CDF." Actually, the variance of the sample is less than the variance of the estimate. This is true since the sample has only 100 points of the continuous estimated CDF.

In order to clarify the CDF of Sutherland data, a probability density function (PDF) is drawn in Figure III.7. The PDF has a left spreaded tail with a leaning hump to the right tail. This PDF is the derivative of the sample CDF which has a mean of 105.7 and S.D. of 31.6 bu/Ac.

Selecting a farm yield distribution Three farm yield distributions have been estimated for three different farms. Since no strong consensus was found, it was necessary to choose one among them. Such

[1](0.9)(7) + (0.1)(-63) = 0; later we add up the mean of Sutherland data to center the distribution on it.

[2]The procedure that generated the sample is displayed in Appendix C.

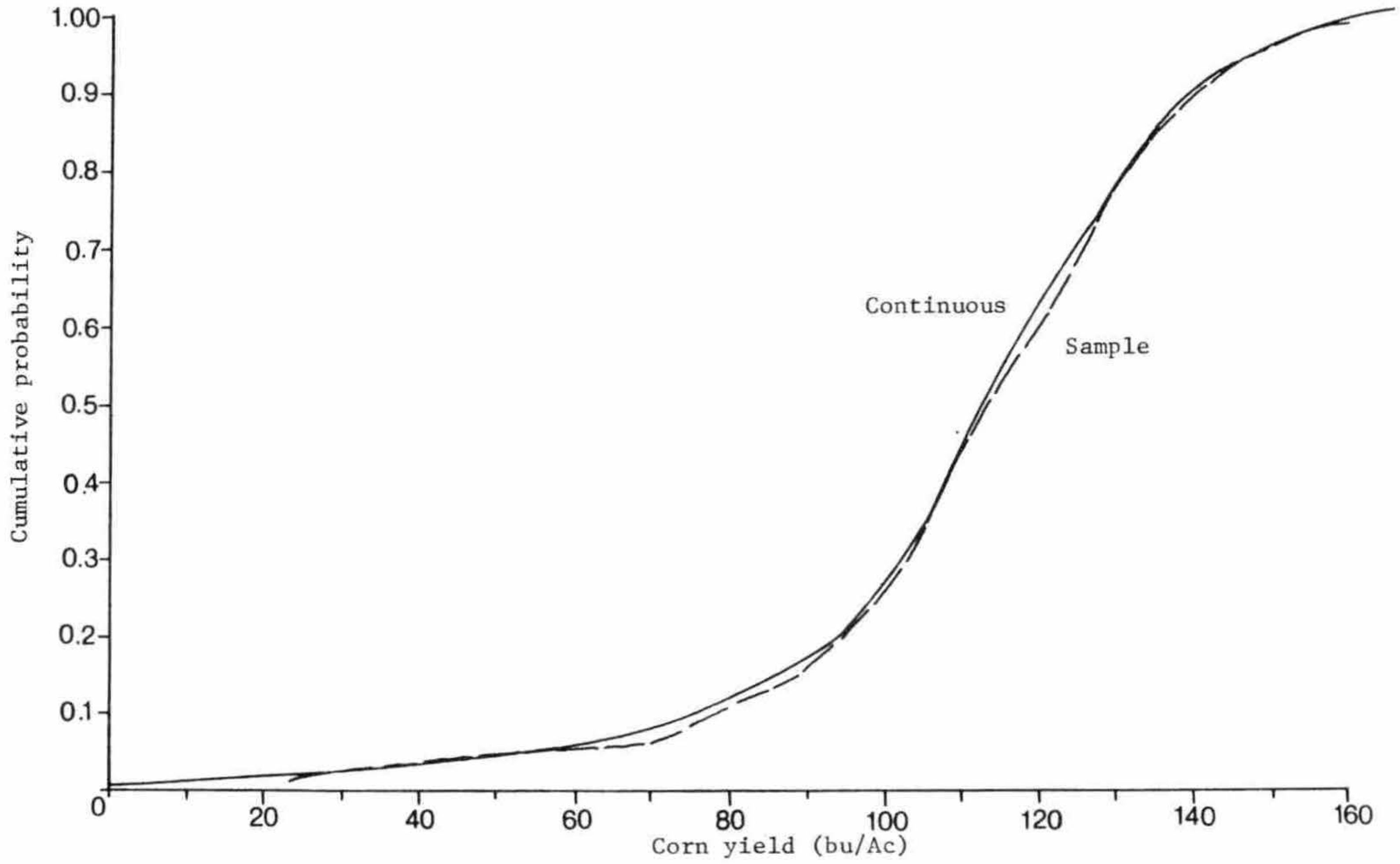

Figure III.6. Continuous and sample CDF for Sutherland farm corn data

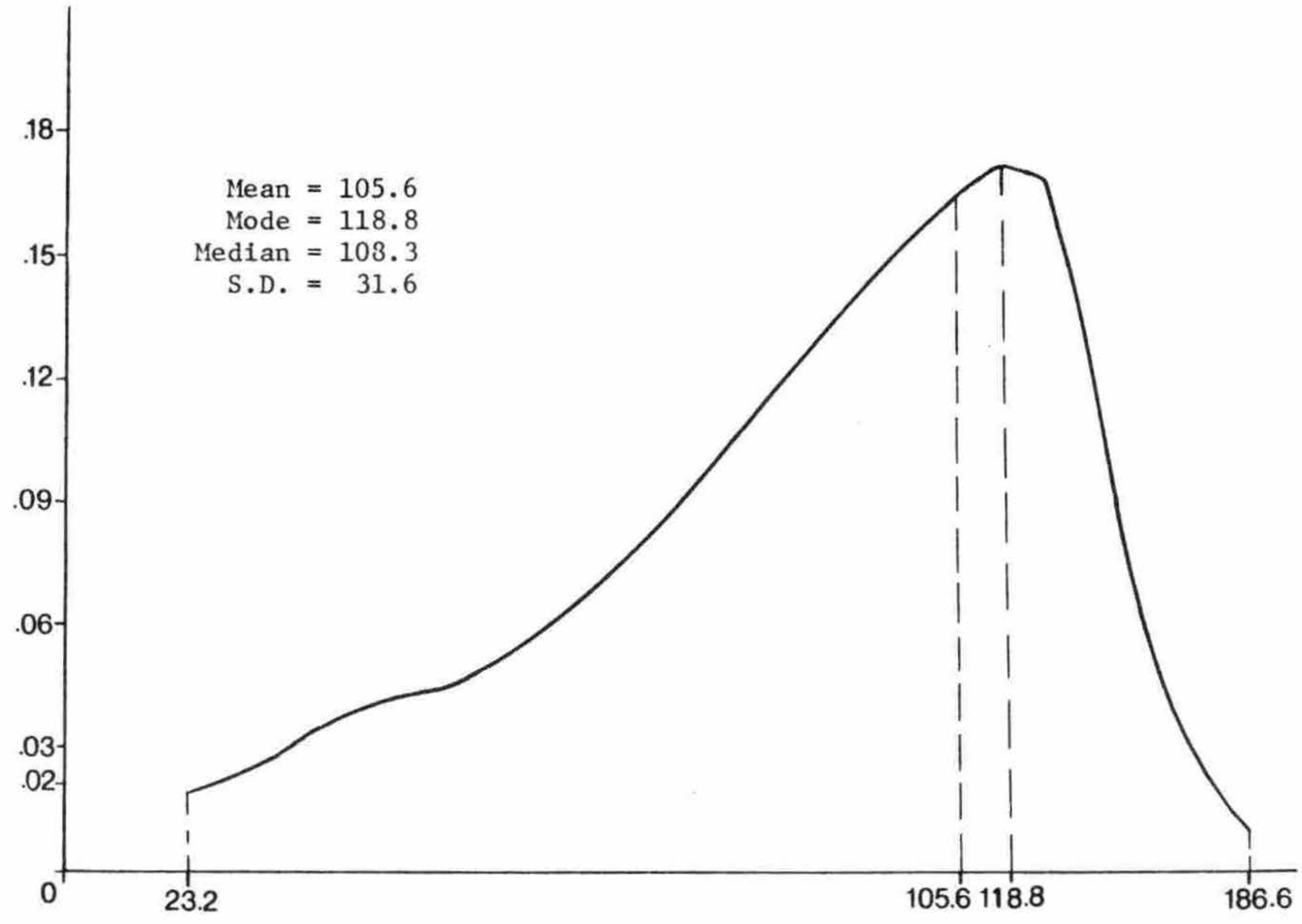

Figure III.7. Sample PDF for Sutherland farm corn data yield distribution shall be used for the study purposes.

Crawford yield distribution follows a normal distribution with an estimated mean of 75 and a standard deviation of 31 bu/Ac. No direct problem was found with the distribution; rather, it is easy to work with. However, a major setback is caused by the lower quality land that had been added to the existing corn acres. The main problem is that yields from the marginal land have been averaged with previous corn acres. This bias might have allowed the Crawford yield distribution to become a normal distribution in which the real distribution could be different from the normal if the marginal land were not considered. Thus, this bias in Crawford farm yields made us reject it for analysis purposes.

The case with Hancock yield distribution is somewhat different from the Crawford distribution. The concern is that Hancock distribution gives a probability of zero to yields below 108.4 bu/Ac. This is mainly because the distribution is centered at 142 bu/Ac with a small S.D. of 11.20 bu/Ac. However, common sense tells us that even a yield of zero bu/Ac is possible, though with a very small probability. Consequently, Hancock distribution is also rejected for estimation purposes.

Finally, and not because the former two distributions were rejected, the Sutherland yield distribution will be used in the estimations to be made by the computer model. It has both the statistical appeals and the economic sense demanded for analysis.

Price data

The last of the data sources to be discussed is prices, which are directly related to marketing strategies. Since pre-harvest hedging (after planting and before harvest) and post-harvest hedging are both considered in the model, two futures prices options and two basis options need to be evaluated: (1) fall futures delivery with its respective fall basis and (2) summer futures delivery with its respective summer basis.

Futures prices follow a seasonal pattern. Under normal conditions, the futures price pattern at harvest time is weak with a modest price rise in December as sales decline from harvest peaks. During the January-April period, prices are weak again as sales volume picks up due to increased producer marketing to meet cash flow needs. During the summer, the old crop is usually used up and inventories decrease, causing prices to strengthen (Stasko and Futrell, 1983).

Basis patterns can also be seen as seasonal. They are usually wide[1] at harvest time (October-November). Furthermore, as storage facilities empty and transportation carriers are less busy after a harvest peak, basis gradually narrows into the following summer.

Basis is primarily used to calculate local cash prices (fall and summer) in the model. Theoretically, by subtracting a basis under a specific futures prices delivery month from that futures price, we obtain a local cash price for that specific month. Mathematically,

$$LCP_m \equiv FP_m + Basis_m \qquad (III.10)$$

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[1]Since basis is normally negative, a wide (narrow) basis means that the absolute value is high (low) unless otherwise indicated.

where:

LCP_m = local cash price at month 'm';

FP_m = future price at month 'm'; and

$Basis_m$ = basis under delivery month 'm'.

This theoretical identity is based upon a set of "normal conditions" of weather, transportation, storage capacity in the area, and local demand and supply among others.

The marketing options considered in this model are (1) July hedge for December delivery (pre-harvest hedge); and (2) October-November hedge for July delivery (post-harvest hedge). Thus, the local cash price in fall is obtained from option (1) and the summer cash price is calculated from option (2) according to the theoretical identity in equation III.10.

As with the yield data, a price distribution for futures prices and basis is needed to acquire a sample from it. However, instead of empirically eliciting the price distribution, they (futures prices and basis) are assumed to follow a triangular distribution similar to the one depicted in Figure III.8.

A triangular distribution is quick and easy to administer. By specifying 3 parameters of the distribution, its mean and variance can be calculated exactly. The parameters are a lowest likely (a), a most likely (m), and a highest likely (b) value. Thus,

$$\text{Mean} = (a + m + b)/3$$

$$\text{Variance} = [(b - a)^2 + (m - a)(m - b)]/18 .$$

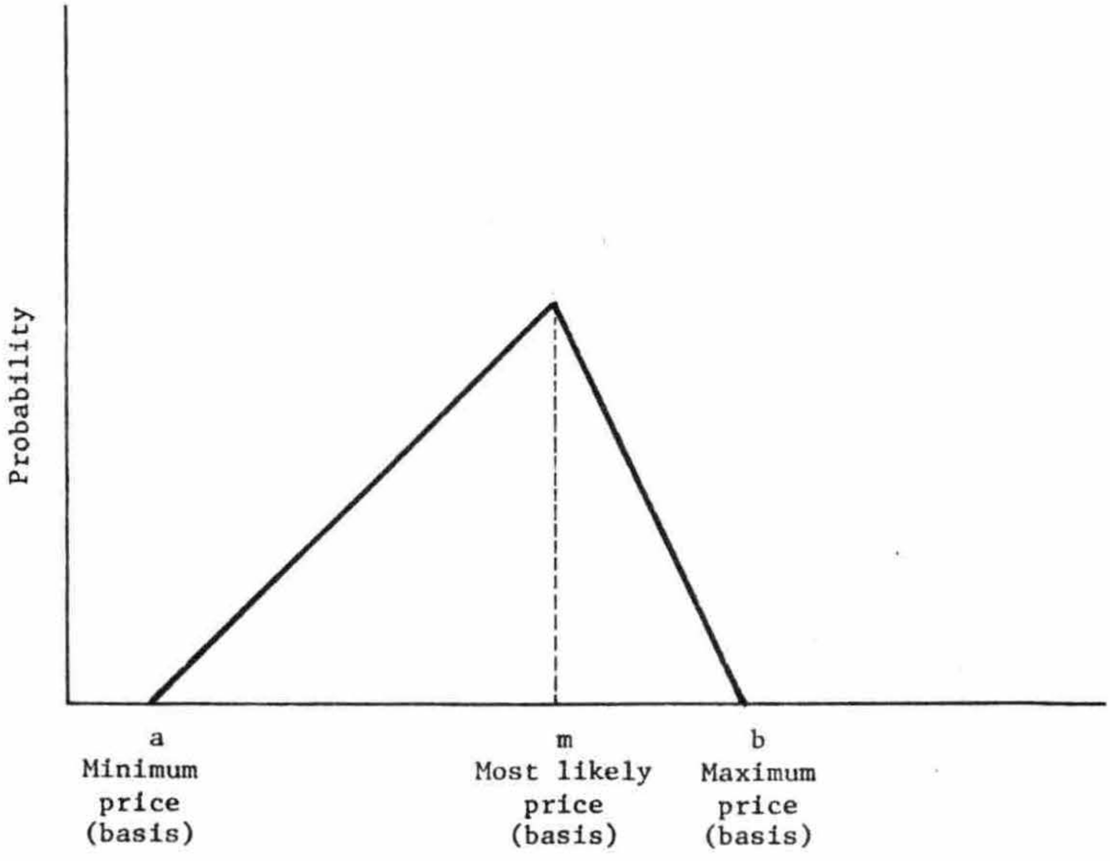

Figure III.8. Triangular probability distribution

Although simple to elicit and to work with, triangular distributions impose a rigid functional form that might cause accuracy to be sacrificed. Despite this drawback, it was used to draw futures prices and basis samples.

The first step in drawing the samples is to obtain the parameters of the triangular distributions for each of the four price variables listed in Table III.1.

Table III.1. Potential futures prices and basis for northwest Iowa in 1984-1985 marketing year: Corn[a]

Variable	Lowest likely a	Most likely m	Highest likely b	Mean μ	Variance σ^2	S.D. σ
	\$/bu.	\$/bu.	\$/bu.			
+1984 fall futures[b]	2.65	2.90	3.25	2.94	.014	.12
+1985 summer futures[c]	2.85	3.00	3.40	3.07	.014	.12
+1984 fall basis	-0.52	-0.42	-0.38	-0.44	.0001	.03
+1985 summer basis	-0.30	-0.25	-0.20	-0.245	.0004	.02

[a]Source: Robert N. Wisner, Extension Economist, Iowa State University, Ames, Iowa.

[b]December futures placed in July 1984.

[c]July 1985 futures placed in October-November 1984.

Given the recent tendency of corn futures prices and basis, the values of the variables in Table III.1 seem to bound expected prices for the 1984-1985 marketing year. The subsequent steps include the estimation of fall and summer cash prices displayed in Table III.2.

Table III.2. Corn potential fall (1984) and summer (1985) local cash prices for northwest Iowa[a]

Variable	Lowest likely	Most likely	Highest likely	Mean μ	Variance σ^2	S.D. σ
	$/bu.	$/bu.	$/bu.			
+1984 fall cash price	2.13	2.48	2.87	2.50	.014	.12
+1985 summer cash price	2.55	2.75	3.20	2.83	.014	.12

[a]Source: Table III.1.

As a final note on prices, the probability distributions of prices and yields are considered independent. Empirical support or refutation for this assumption is difficult to obtain since farm level data are not available.

In summary, the data sources for corn production costs, crop insurance, and the farm feed grain program were established. The procedure for estimating yield distributions for three farm-level data sets was discussed, selecting the Sutherland farm distribution as the supplier of yield data needed in the computer model. Finally, the triangular distribution was examined as the one that will generate prices and basis data for the marketing options in the model.

Computer Coding, Operation, Solution Techniques and Experimental Techniques

To this point, a model has been constructed capable of giving a result (i.e., cash flow after consumption) by means of executing a series of operations (steps (A), (B), (C), and (D) of Diagram III.1).

These operations (including step (E) of Diagram III.1) were re-written in a computer language called "Business Basic" of the Apple III micro-computer. It is an easy language to learn and work with. In addition, the cost of manipulating the model in a micro-computer is essentially null, and, most of all, the needs of the model are sufficiently satisfied by this type of computer.

The computerized model is operated by vectors of inputs that have to be filed on a floppy disk. Each of the five vectors is given a different name: yield vector, fall future prices vector, summer futures prices vector, fall basis and summer basis vectors, and farm level data vector. All of them together compound the 38 input variables of the model (i.e., the farm level data vector contains all the information about production costs, insurance, leverage and farm programs).

After going through all the calculation steps, the model's output reports the following variables: yield, fall cash price, fall futures price, indemnity, gross farm income, taxes, net farm income (NFI), net farm income after consumption (NFIAC), and cash flows after consumption (CFAC).

The model was solved by using simulation techniques. Let us first define what simulation is and what steps are followed in a simulation experiment.

Naylor (1971, p. 2) defines simulation as "a numerical technique for conducting experiments with certain types of mathematical models which describe the behavior of a complex system on a digital computer . . . ."

An important question should be posed here: why use simulation and not any other standard analytical technique (i.e., mathematical programming)? With economic systems, frequently it is simply impossible, impractical, or uneconomical to conduct controlled experiments. Thus, computer simulation becomes a relevant tool for analyzing economic systems.

Following the definition of computer simulation, experiments with this tool usually involve a procedure that consists of these six steps (Naylor, 1971):

(1) Formulation of the problem;

(2) Formulation of a mathematical model;

(3) Formulation of a computer program;

(4) Validation;

(5) Experimental design;

(6) Data analysis.

The first three points have been covered in Chapters I, II, and the first part of this chapter.

Point 4 (validation) is generally referred to as the "goodness of fit" of the simulation model. The accuracy of the computer model depends heavily upon yield and price distributions. These distributions were validated by the Kolmogorov-Smirnov test of goodness of fit (Ostle et al., 1975, pp. 489-90) at the .05 level of significance.

Experimental design (point 5) concentrates mainly on the identification of endogenous (output) variables and exogenous (input) variables.

In simulation experiments, there are never any uncontrolled or unobserved factors. The role that uncontrolled and unobserved factors play in the real world is played in a computer simulation model by the random character of exogenous variables. The input or exogenous variables in the computer model are all the variables listed in Appendix B: chiefly, farm level data, yields, futures prices, and basis. Among the input variables, some are fixed (no random selection process is applied), while some others are generated randomly. A variable is said to be random when it comes from a sample of the population distribution's "random" variable generator. Yield, futures prices, and basis are the random variables in the computer model. The output or endogenous variables in the model are taxes, gross and net farm incomes, indemnities, and cash flows after consumption.

Another aspect of experimental design is the selection of experimental techniques that are suitable for the computer simulation experiment. Monte Carlo methods are the techniques employed in the generation of yield and prices data. Yield sample is found from the estimated negative skewed distribution of the Sutherland farm. Futures prices and basis are drawn from a triangular distribution.[1]

The experimental technique used for comparison of prospects is the stochastic dominance procedures[1] described by Anderson et al. (1977, Chapter 9).

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[1]The main concern of Monte Carlo routines is to obtain a respectably small standard error in the final resort (generated random values). This is done by a sophisticated procedure of random number manipulations (Hammersley and Handscomb (1964).

Stochastic dominance allows the ranking of probability distributions for different classes of risk attitudes. This technique focuses directly on the estimated probability distributions of outcomes (CFAC in our case). It is described as first-, second-, and third-degree stochastic dominance (Hadar and Russell, 1969; Meyer, 1977). First-degree stochastic dominance (FSD) holds between two distributions if cumulative distribution of one is equal to or greater than the other. Second-degree stochastic dominance (SSD), a weaker condition than FSD, holds whenever the integral of one cumulative distribution is equal to or greater than the integral of the other. Third-degree stochastic dominance (TSD) holds in the second integral if one cumulative distribution is equal to or greater than the second integral of the other. TSD is weaker than SSD.

For the purpose of the empirical model, only FSD and SSD are considered. Cumulative distributions are generated for each prospect to be evaluated in step (E) of Diagram III.1. Such cumulative distributions of CFAC are drawn from samples of 100 observations for yield and prices functions. As a consequence, the samples of yield and prices remain the same for each prospect. In other words, the samples become endogenous to the model, even though they are randomly generated. The objective of this is to have compatible prospects.

After the experimental design, the next step is to obtain empirical

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[1] An extensive bibliography on stochastic dominance can be found in Bawa (1981).

results of the endogenous variables in the model in order to analyze the model's precision and implications of the results, as discussed in Chapter IV.

CHAPTER IV. ESTIMATION AND DISCUSSION OF RESULTS

Chapter III established the procedures for estimating farm incomes under different management strategies. This chapter goes into the estimation of some of the many possible ways crop insurance, federal farm programs, and marketing can be combined in a risk management framework. The risk management options used to generate each prospect are explained in detail. In addition, average comparisons of cash flows after consumption are made among prospects. This serves as the background of a more formal analysis of stochastic dominance procedures, which will be presented and discussed later in the chapter.

General Considerations

In order to generate prospects, the following assumptions are made:

(1) The analysis is concentrated on a 400-acre farm where no crop rotation is practiced; specifically, the farmer plants corn following corn.

(2) Yield, futures prices, cash prices, and basis vectors are all held constant for each generated prospect.

(3) Pre-harvest cost per acre and harvest cost per bushel are also held constant throughout the analysis.

(4) In the case of insurance, it is assumed that all planted acres are insured.

Table IV.1 has a summary of the variables and their specific values used to generate prospects. For instance, three leverage positions, four

Table IV.1. Parameters of selected risk management strategies

	Leverage			Insurance				Marketing		Farm programs	
Plan	I	II	III	I	II	III	IV	I	II	I	II
Leverage level	.50	0	1								
Coverage level				75%	75%	50%	50%				
Price level				2.70	2.70	2.00	2.00				
Individual yield				No	Yes	No	Yes				
Direct fall sale								30%	30%		
Post-hedge								0%	70%		
Direct summer sale								70%	0%		
Paid Div. + Loan										10%	10%
PIK										0%	30%

insurance alternatives, two marketing options, and two farm programs are the group of variables used to run the model.

Table IV.2 shows how each group of variables was combined to arrive at the 22 final prospects. For example, using Table IV.1 in

Table IV.2. Risk management strategies considered in prospect analysis

Prospect	Leverage	Insurance	Marketing	Farm program
	Plan			
1	I		I	
2	II		I	
3	III		I	
4	I	I	I	
5	I	II	I	
6	I	III	I	
7	I	IV	I	
8	I		II	
9	I		I	I
10	I		I	II
11	I	I	II	
12	I	II	II	
13	I		II	I
14	I		II	II
15	I	I	I	I
16	I	II	I	I
17	I	I	I	II
18	I	II	I	II
19	I	I	II	I
20	I	II	II	I
21	I	I	II	II
22	I	II	II	II

combination with Table IV.2, it can be read that prospect 1 has leverage equal to .5 and 30% fall and 70% summer direct cash sale (no hedge) as a marketing option. Insurance and farm programs are not considered in prospect 1.

The analysis is concentrated on the following aspects: average cash flow (ACF), its standard deviation, effects on taxes, the probability of negative cash flows, and how the distribution of cash flows is altered. These aspects are summarized in Table IV.4, which is used for reference throughout the analysis.

Prospect Estimation: General Analysis

Leverage (LE)

Prospects 1, 2 and 3 represent three kinds of farms. The first is a non-leveraged farm (LE = 0, prospect #]) on which debt amounts to zero. A second type of farm, in which the debt/equity ratio is .5, represents a middle-leveraged farm (prospect #1). Prospect #3 represents a high-leveraged farm with a level equal to 1, which is equivalent to 50 percent of farm equity.

From Table IV.4, it can be seen that as the non-farm equity/farm equity ratio increases, average cash flow decreases and becomes negative at .5 and 1 levels (-1,397, and -13,319, respectively). On the other hand, deviation from the mean spreads out as leverage increases.

Looking to the lower- and upper-bound (observations 1 and 100) suggests the impact of a higher leverage on cash flow increases at a decreasing rate when a low yield occurs. For instances, the differences of the lower values of prospects 1 and 3 can be compared with prospect 2 where LE = 0. One way of explaining this decreasing impact is that as leverage level doubles, non-farm equity increases less than double, as is the case between prospects 1 and 3.

On the other hand, as yield per acre increases, the cost of borrowed capital per bushel decreases. This has the effect of narrowing the gap among leverage levels, for example, in terms of prospect 2's upper value, prospect 1's value is .71, and prospect 3's is .57 of that value. In contrast, these levels are magnified when comparing lower-bound values--if prospect 2 is equal to -1 (because of negative figures), prospect 1 is equal to -1.74, and prospect 3 is equal to -2.11. This suggests (1) farm risk increases as the leverage level increases, (2) given certain yield and price distributions, a higher leveraged farm is more susceptible (prone) to lower cash flows than a less leveraged farm, and (3) the capacity of bearing risk is decreasingly reduced as the farm relies more and more on borrowed capital.

Consider how the farm uses borrowed capital as a means of farm investments. Thus, leverage effects on equity returns can be viewed in the following example. Assume four rates of return on total capital and a 12% interest rate (Table IV.3); as the rate of return goes

Table IV.3. Leverage impacts on equity

Return on total capital	Debt to asset ratio		
	0	.5	1
	——% return to equity (12% interest rate)——		
15%	15%	17.0%	18%
10%	10	9.0%	8
5%	5	1.5	-2
-5%	-5	-13.5	-22

Table IV.4. Cash flows from risk management strategies

Strategies	Prospect	Average cash flow (ACF) ($)	Standard deviation ($)	Cash flow	
				Lower bound ($)	Upper bound ($)
Leverage	1	- 1397	23480	-70476	31703
	2	18657	18529	-40476	44432
	3	-13319	25569	-85476	25145
Insurance	4	3027	11027	-17982	30549
	5	3482	10510	-15552	30549
	6	-150	19324	-43150	31433
	7	6	18989	-41950	31433
Marketing	8	- 3058	23230	-70423	31849
Farm programs	9	909	20828	-60275	32871
	10	7371	10432	-22921	25765
Combined	11	1261	1099	-16466	30695
	12	1716	10517	-16314	30695
	13	-677	20807	-60227	32998
	14	6097	10582	22826	25877
	15	4930	9657	-13291	31850
	16	5319	9232	-11104	31850
	17	9258	5067	280	25090
	18	9418	4900	1164	25090
	19	3257	10169	-16646	31982
	20	3648	9798	-16646	31982
	21	7992	5481	-2251	25203
	22	8155	5340	-2251	25203

up the return to equity of higher leverage is above the non-leverage. On the contrary, as the rate of return goes down, the return of 1:1 asset to debt ratio will go down more sharply than the no debt position. This explains, in part, point 1 of the above paragraph.

For purposes of simplicity and concentration, for the analysis on insurance, marketing, and impact of farm programs (prospects 4 through

22), a further assumption has been made:

(5) A single farm leverage position is considered in the remaining prospects. The leverage level is assumed to be .5.[1]

Federal crop insurance (FCI)[2]

Prospects 4 through 7 picture four different insurance policies. Prospect 4 has a maximum protection against crop losses. It is 75 percent of the Area Average Yield (AAY) as guaranteed yield and a price level of \$2.70 per bushel. Prospect 5 uses the Individual Yield Plan (IYP) option of FCI instead of using the AAY to calculate guaranteed bushels. The modal value of the historical yield data of Sutherland farm was used for this purpose. This value is 121 bu/Ac, which is only 3 bushels above the AAY; however, this small gap should be enough to tell the direction of the impact on cash flows by introducing IYP. Premium rates are not altered under IYP. Finally, prospects 6 and 7 represent the lowest protection levels of FCI using AAY and IYP, respectively.

In general, average cash flows are improved under insurance prospects. The larger improvements are on prospects with high protection levels. Specifically, prospect 5, which considers IYP, is the one that resulted in the biggest boost in cash flow. Between prospects with low

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[1]Indeed, a leverage level of 1 or 0 could be used instead of .5 since its impact on other risk strategies is only in absolute terms, although a highly leveraged farm would be more willing to purchase insurance and/or participate in farm programs because of the extra risk put into the farm operation by borrowed capital.

[2]See Appendix A for an explanation of FCI components.

protection, prospect 7, which again makes use of IYP, proved to be better in average than AAY prospect 6 (see Table IV.4).

From another perspective, FCI does pay an indemnity about 1 out of 5 times on high protection levels and 1 out of 8 times on low protection (Table IV.5). Furthermore, average indemnities seem to be greater than premium costs. In fact, $2.11 is received as indemnity per each dollar paid as premium in prospect 5. This figure is $2.39 for prospect 7. Table IV.5 summarizes these and other figures. Here, it is good to note that total premium costs remain unchanged within the 75 and 50 percent coverage levels. One would expect that by increasing the number of bushels guaranteed and at the same time holding premium rates constant, the insurance policy would be sounder and more attractive than it would be otherwise.

Moreover, any indemnity received is subject to taxes, and any premium paid is deductible from it. On the average, taxes are slightly modified under insurance prospects. Switching from any AAY to IYP has a negligible impact on taxes.

For the purpose of illustration, Table IV.6 shows ten possible cash flows with and without FCI. Ten yield values were picked from the sample of 100 observations. By studying the distributions in each column, it is clear that cash flows are improved at low yields with insurance.

Finally, it seems logical to expect a lower chance of negative income with high protection levels than low protection levels. However, the 100 observations drawn for this study show the opposite. Under the 75 percent guaranteed yield level, negative cash flows occurred 43 times.

Table IV.5. Protection level, premiums and average indemnities of crop insurance prospects

	Prospect	(1) Guaranteed Bu/Ac	(2) Selected price level ($/Bu)	(3) Times that actual yield was below guaranteed yield	(4) Average indemnity ($)	(5) Total premium ($)	(6) (4)/(5) ratio
75% Coverage Level	4	88.50	2.70	19	7,190	3632	1.98
	5	90.75	2.70	22	7,672		2.11
50% Coverage Level	6	59.00	2.00	13	1,874	850	2.20
	7	60.50	2.00	13	2,030		2.39

Table IV.6. A sample of cash flows after consumption under distinctive insurance policies

	Yield/ planted acre	Summer cash price ($/bu)	No insurance	50% yield guarantee[a]		75% yield guarantee[b]	
				AAY 59 bu/Ac	IYP 60.5 bu/Ac	AAY 88.5 bu/Ac	IYP 90.75 bu/Ac
			Cash flows				
1.	31	2.84	-64101	-42603	-41403	- 6174	- 3971
2.	43.5	2.65	-54159	-42630	-41430	- 9399	- 7159
3.	52.8	2.76	-45527	-41453	-40253	-10831	- 8457
4.	75	2.85	-21828	-22739	-22739	-11169	- 8763
5.	87	2.67	-15725	-16636	-16636	-17982	-15552
6.	90.1	2.80	- 5598	- 6423	- 6423	- 9141	- 8442
7.	100	2.99	2209	1574	1574	- 600	- 600
8.	114.7	3.12	14393	13915	13915	12345	12345
9.	124	2.74	10252	9726	9726	7936	7936
10.	145.9	2.84	21185	20821	20821	19608	19608

[a]2.00 price level assumed.
[b]2.70 price level assumed.

This occurred 38 times under the 50 percent protection level. A closer look at these prospects ought to explain the controversy. Either the premium paid at the 50 percent level is too low or the premium at the 75 percent level is too high compared to the coverage received. Thus, CFAC around zero are sensitive to them.

Under IYP, of the 22 times that FCI paid an indemnity with the 75 percent level, 13 of them were also covered by the 50 percent level. Moreover, 4 (of the 22) observations had fewer than 4 bushels below the guaranteed yield of 90.75 bu/Ac.[1] This suggests that the 75 percent protection level was not enough to turn cash flows from red to black ink. Neither does it overcome the 50 percent level in regard to negative incomes. It was found, in connection with coverage levels, that while the protection level is raised 50 percent when going from the 50 percent level to the 75 percent level, the total premium paid went up 300%. Part of this faster increase in premium paid is justified by the increasing chances of a yield between 50 and 75 percent levels and by the higher indemnity to be paid for a loss covered by the 75 percent level. Nevertheless, it seems to be a sharp increase in premiums. In per acre terms, an additional premium of $6.21 is paid when moving from the 50 to the 75 percent level.

Marketing

Switching to marketing strategies, it is well-known that selling and buying futures contracts is a tool (usually called hedging) widely used

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[1]With indemnities lower than premium paid.

among farmers. Its main goal is to offset some risk of the price variability in the cash market.

A post-harvest hedge (or storage hedge) operation is pictured in prospect 8. In this prospect, 30 percent of the total corn production is sold in the fall in order to meet some cash flow expenses due at harvest time. The remaining 70 percent is hedged for July delivery (9 months after harvest). At maturity time, a July futures contract is bought back to offset the former contract. The gain or loss by hedging is reflected on CFAC.

Some important aspects of hedging need to be stated before detailing the marketing prospect. Table IV.7 contains the boundaries

Table IV.7. Potential futures prices and basis for corn in northwest Iowa ($/bu) (1984-85)

	(1) July 1985 futures in Oct.-Nov. 1984	(2) Basis under July 1985 delivery	(3) Local hedge price 3.00[a] - (2)	(4) Local cash price (1) - (2)
Lowest likely	2.85	.30	2.70	2.55
Most likely	3.00	.25	2.75	2.75
Highest likely	3.40	.20	2.80	3.20
		Average	2.75	2.83

[a]This value is the hedging price assumed for selling futures contracts at harvest time. It is also the most likely parameter of July 1985 futures prices.

of potential futures prices and basis for corn in northwest Iowa. Local hedge prices (LHP) were obtained by subtracting potential basis from an expected July futures price of $3.00/bu., which is the most likely value of potential futures prices distribution. Similarly, local cash price (LCP) was calculated by using the potential July futures prices distribution instead of its expected value.

On the average, LCP has a mean $.08 higher than LHP. Thus, it might appear that cash sales are better than storage-hedge. However, a close look at the range of prices in both alternatives indicates that LCP varies $.65 while LHP only varies $.10. This can be considered in terms of the risk on price variability and how much of it can be afforded. Unfortunately, there is no "free lunch"; with hedging, a higher income is sacrificed in return for some income stability.

As a result, ACF is lower with hedge than without it (prospects 8 and 1). The reason for this can be found in the distribution of July futures prices; for instance, a futures contract was bought back at a higher price than the selling July futures price of $3.00 more than 60 percent of the time. Thus, because cash flows went down with hedging, average taxes paid also went down. Finally, in looking for a break-even price between hedge and no-hedge, a price of $3.10 was found to be the expected futures price which would achieve it, providing futures and basis distributions remain the same.

Federal farm programs (FFP)

Two types of FFP plans were considered here: a paid diversion program plus a set-aside program with eligibility for price support loans. The second plan is equal to the first one plus an extra acreage reduction placed under the Payment-In-Kind Program (PIK).

Prospect 9 has a 10 percent land paid diversion at a rate of $1.50 per bushel. The yield from O'Brien County is used to calculate direct payment per acre. The land diversion allows for a short term loan (price support loan) of $2.65 per bushel harvested. In prospect 10, PIK participation requires an extra 10 percent of unpaid land diversion and an additional 30 percent diversion from which the farmer will receive at harvest 80 percent of ASCS county yield in kind per each PIK acre. However, PIK grain is not loan eligible.

Participation in FFP reduces income variability by truncating low incomes to a certain minimum and high incomes to a maximum. For instance, compare the lower and higher bounds of prospect 1 (no participation) with those of 9 and 10. In terms of mean values, prospect 9 has a higher mean than prospect 1 ($909 against $-1397) and lower S.D. (20828 against 23480, respectively). It suggests that, in this case, participation is preferable to non-participation in a mean standard deviation discussion. This statement is reinforced by PIK participation (prospect 10), which accounts for an average improvement of $10,000 in cash flows and an additional reduction of $10,000 in the S.D. (see Table IV.4).

Moreover, negative cash flows occur in 27 instances out of the 100 observations of prospect 9. Under prospect 10, they occur only 14 times. This is reflected in the differences between ACF and S.D. of both prospects.

In general, FFP seems to perform fairly well with low yields and/or low corn prices. On the other hand, they seem to put a top on high income when high yield and/or high prices exist. Here, the opportunity cost of non-planting a portion of the crop land goes from negative (with low yields) to a positive value (with high yields).

Finally, FFP participation has a slight effect on taxes compared to the improved cash flows. With paid diversion and loan programs, taxes paid increased (on average) $.17 per each extra dollar of gain. With PIK, the extra tax paid was only $.08 per dollar.

Combined strategies

So far, we have analyzed alternatives where either FCI or marketing or FFP options have been used. This section examines new prospects where interaction of options is allowed. These are prospects 11 to 22 of Table IV.2.

The reason for this set of prospects is to dig more into the impact of marketing and FFP strategies on the desirability of crop insurance. Table IV.4 is again used for reference. In brief, it will be seen that the effect on cash flows by mixed options is similar to the sum of the separate impact of those mixed alternatives. However, distributions of cash flows are somewhat altered.

While FCI is used to reduce risk in production, marketing tools such as post-harvest hedge reduce the risk in crop prices. Prospects 11 and 12 combine these alternatives. Major impacts are on taxes paid and deviations from the mean which become diminished.

Prospects 13 and 14 merge marketing and FFP options. Under the former prospect, ACF is lower than ACF under either alternative alone.

Here, post-hedge has a negative impact on FFP, because of the losses experienced in the futures market. Less taxes are then paid and the chances of negative outcomes increase from 27 to 35 percent (prospects 9 and 13, respectively). Prospect 14 (compared to prospect 10) gives a similar picture to that in prospect 13, the only difference being negative incomes, which rise from 14 times in prospect 10 to 18 under prospect 14.

FCI and FFP are combined in prospects 15, 16, 17 and 18. In 15 and 16, only 360 acres were insured because 10 percent of the 400 acreage base was set aside in farm programs. With PIK participation, acres insured were further reduced to 200. Thus, the importance of crop insurance as a tool to bear production risk is diminished by FFP enrollment, especially with PIK participation.

FFP insures, on the average, a minimum return per acre by reducing possible losses when putting acres out of production and taking advantage of the price support loan to increase sale revenues.

Under these prospects, ACF and its standard deviation are improved. Minimum cash flows are raised and maximum levels are limited by the cost of insurance and the opportunity cost of set-aside acres when high yields occur. It is worth noting that negative incomes are out of the map in prospects 17 and 18. Here, both FCI and FFP performed very efficiently with low yields. Finally, taxes paid are boosted because of improved incomes (Table IV.4).

Prospects 19, 20, 21 and 22 are the last to be studied. Here, post-hedge, FCI and FFP are all combined. In brief, the results of these prospects are similar to prospects 15, 16, 17 and 18, respectively. The major change is due to the hedge option which was analyzed earlier.

To summarize the prospects reviewed,

(1) Given a farm size, alternative leverage positions alter the range of cash flows.

(2) FCI is effective on the lower portion of cash flow distributions by truncating the chances of big losses usually related to low yields.

(3) Post-harvest hedge did not take a predominant position over FCI mainly because of poor performance of hedging decisions in the model.

(4) Farm programs show them to be a close competitor of insurance, mainly when the PIK program was considered.

Some insight has been gained with this general analysis of prospects, fulfilling its purpose of clarifying the understanding and discussion of prospects' merits prior to a more rigorous procedure of analysis as presented in the next section.

Prospect Evaluation: Stochastic Dominance Approach

The motivation for using stochastic dominance comes from its accessibility for discrete choice efficiency analysis. The principles of first- and second-degree stochastic dominance--FSD, and SSD, respectively--are considered in the simulation model as follows.

FSD: The probability function f(x) of prospect "A" is said to dominate the probability function g(x) of prospect "B" by FSD if, and only if $F_1(R) \leq G_1(R)$ for all values of $R\varepsilon[a,b]$ with strict inequality for at least one value of $R\varepsilon[a,b]$; $F_1(R)$ and $G_1(R)$ are the cumulative density functions (CDF) of prospects "A" and "B" in question, respectively. Any intersection of CDFs will mean the prospects involved are both efficient in FSD.

The reasonable assumption behind FSD comes from the basic idea that if x is the unscaled measure of consequence such as profit (or cash flows in our model), decision makers always prefer more to less of x.

SSD: The probability function f(x) is said to dominate the probability function g(x) by SSD if, and only if, $F_2(R) \leq G_2(R)$ for all values of $R\varepsilon[a,b]$ with strict inequality for at least one value of $R\varepsilon[a,b]$. $F_2(R)$ and $G_2(R)$ are the SSD cumulative for the $F_1(R)$ and $G_1(R)$ cumulatives of FSD. Again, to assess efficiency in SSD, we need to ensure that the SSD cumulatives of $F_2(R)$ and $G_2(R)$ of prospect "A" and "B" do not cross at any point of the SSD distributions.

The graphs presented in this section do not show SSD cumulatives of the prospects involved. A mathematical computer subroutine was built into the computer model to solve SSD. This subroutine is for the discrete case of SSD presented in Anderson et al. (1977).

The assumption in SSD is that, in addition to the FSD's assumption, the decision maker is averse to risk. No specific measure of risk aversion is assessed in SSD. In terms of the utility function, the presumption is that the function is not only monotonically increasing

(FSD assumption), but also strictly concave. Thus, risk neutral or risk prone individuals are automatically out of the analysis.

Note that CDF (cumulative density function), distribution, or prospect are all used interchangeably when referring to the cumulative density distribution of cash flows of a prospect. The analysis is done in pairwise comparison of the relevant prospect dealing with crop insurance, and the two leverage prospects that are first discussed. All figures have cash flows after consumption (CFAC) on the horizontal axis and cumulative probability on the vertical axis.

A pairwise comparison of a nonleverage farm and a leveraged farm is depicted in Figure IV.1 (prospects 2 and 1 of Table IV.4), clearly showing that the nonleveraged's CDF (broken line) is completely below the leveraged's CDF (unbroken line). This result is as was expected, since as the debt to equity ratio increases, the leveraged's CDF moves farther left relative to the nonleveraged's CDF. The shift is not parallel because less taxes are paid at higher leverage. But the essence of leverage is related to the probability and relative impact on owned capital by the two leveraged CDFs of Figure IV.1.

For instance, using the information of prospects 1 and 2, a \$-30,000 CFAC means a 7.5% loss on equity capital for the .5 leveraged farm (prospect 1) and only a 5% loss for the zero leveraged farm (prospect 2). However, the probability of \$-30,000 or less is about 18% for the .5 leverage position and only 4% for the nonleveraged position. On the other hand, a CFAC of \$30,000 is equivalent to a 7.5% gain on equity capital for the .5 leveraged farm and a 5% gain

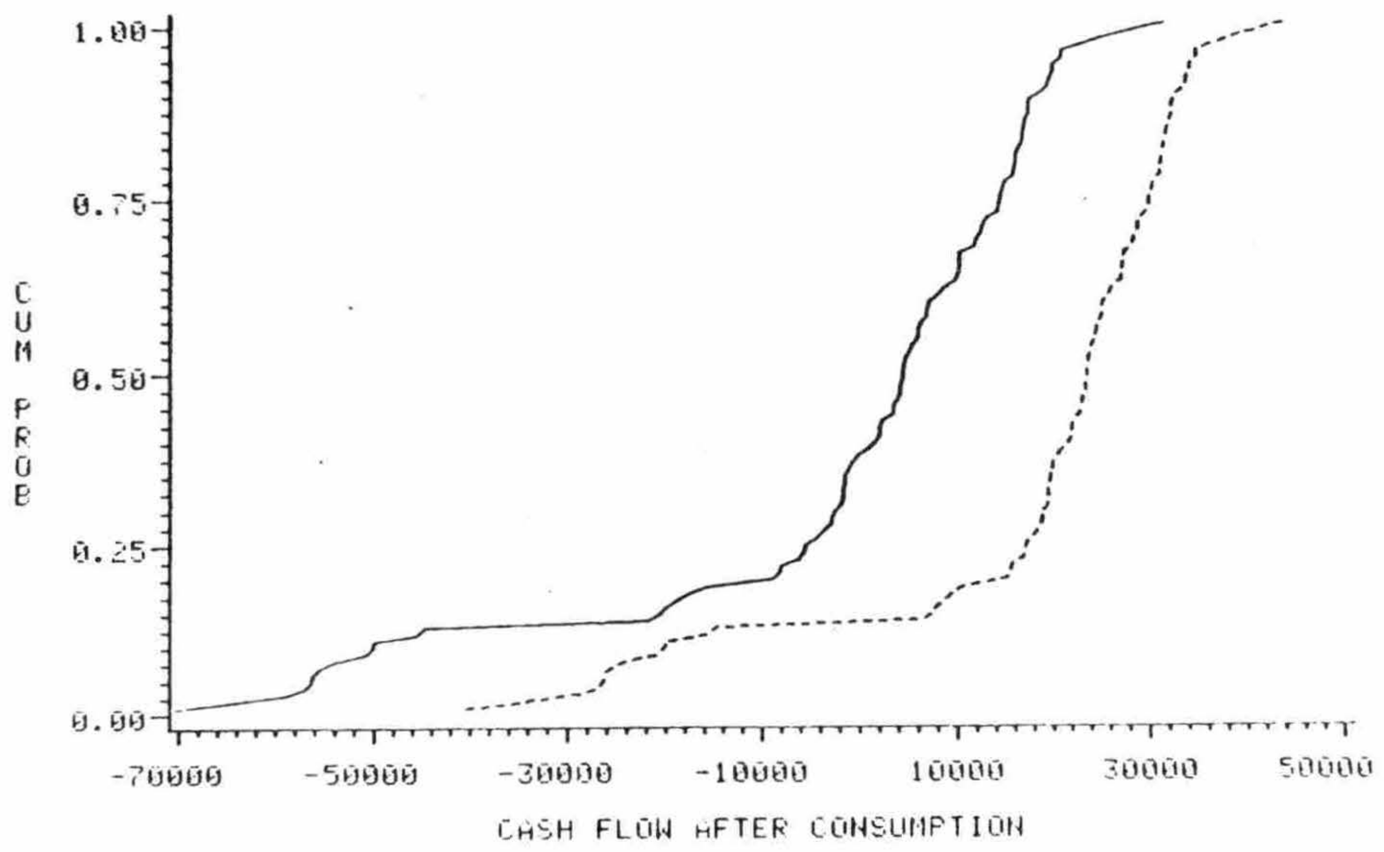

Figure IV.1. Plot of cash flows for a .5 leverage (——) and nonleverage (---) farm for the nonleveraged farm. Thus, a farmer's ability to bear the increase in income variability caused by leverage may influence preferences for other risk-sharing options.

One way of preventing the associated risk with leverage (other than not borrowing capital) is to reduce as much as possible the chances of rates of returns below the capital cost rate. The purchase of crop insurance will ensure a minimum return to the leveraged farm and some security to lenders. Figure IV.2 shows the CDFs of CFAC for the IYP prospect 5 of crop insurance (broken line) and the .5 leveraged farm prospect (unbroken line).

In Figure IV.2, the insurance prospect truncates the lower tail of the CDF (usually related to low yields) significantly. The gap between insurance and no-insurance CDFs is sharply reduced as we move up along the distributions. The crossing point A means that the amount of indemnity received is equal to the amount of premium paid, and it is equivalent to the no-insurance outcome at that point. After point A the insurance prospect does not pay any indemnity, and it only brings an absolute cost equal to the premium, although it dominates the no-insurance prospect in SSD. It implies that a rational risk averter whose utility function is represented by the sample CDFs of Figure IV.2 should reduce the risk he/she bears by purchasing crop insurance.

The leverage distribution in Figure IV.2 is plotted again in Figure IV.3 against the marketing prospect (discontinuous line). This picture clearly shows that the marketing option selected in

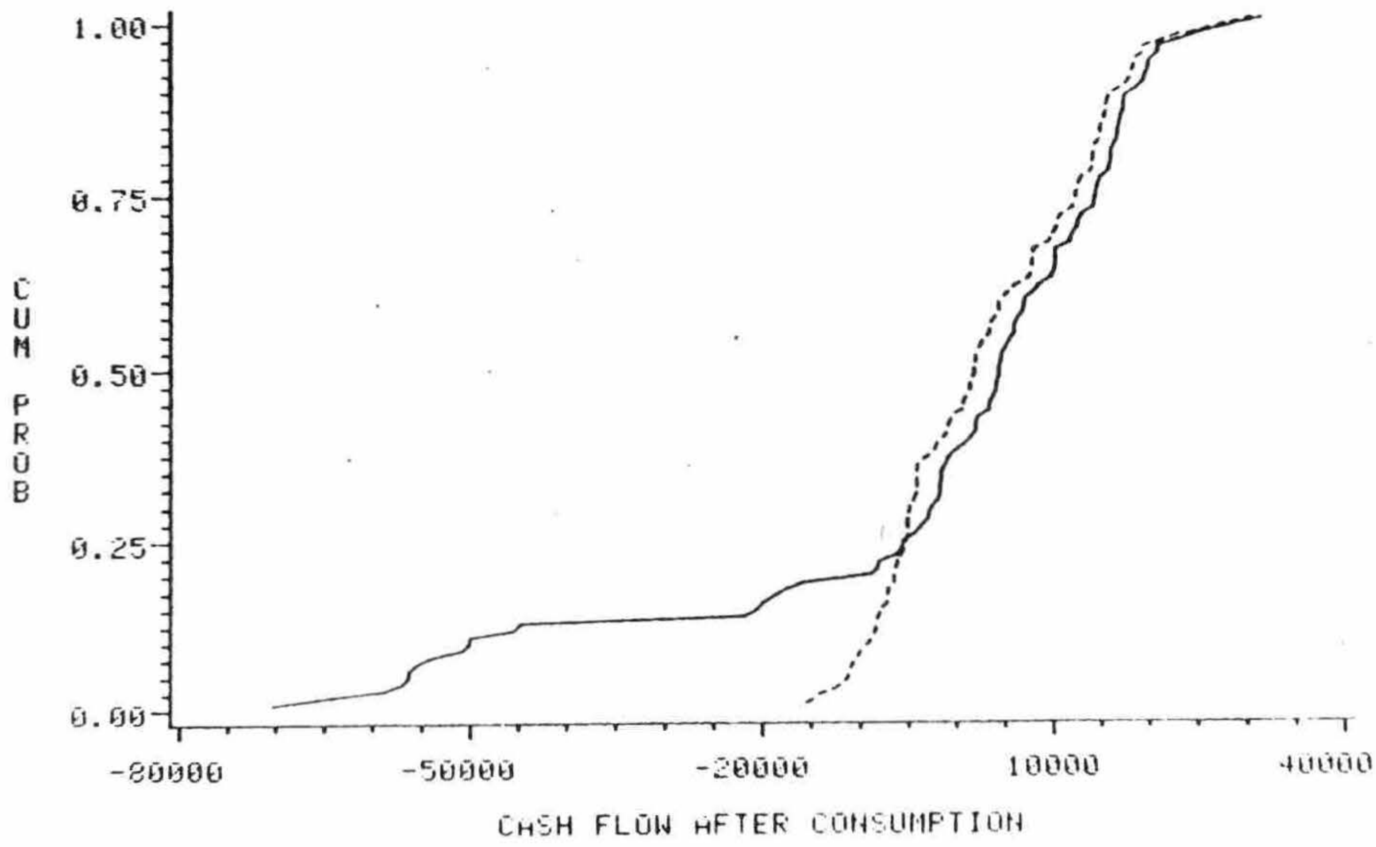

Figure IV.2. Plot of cash flows for leverage (——) and IYP insurance (---) prospects

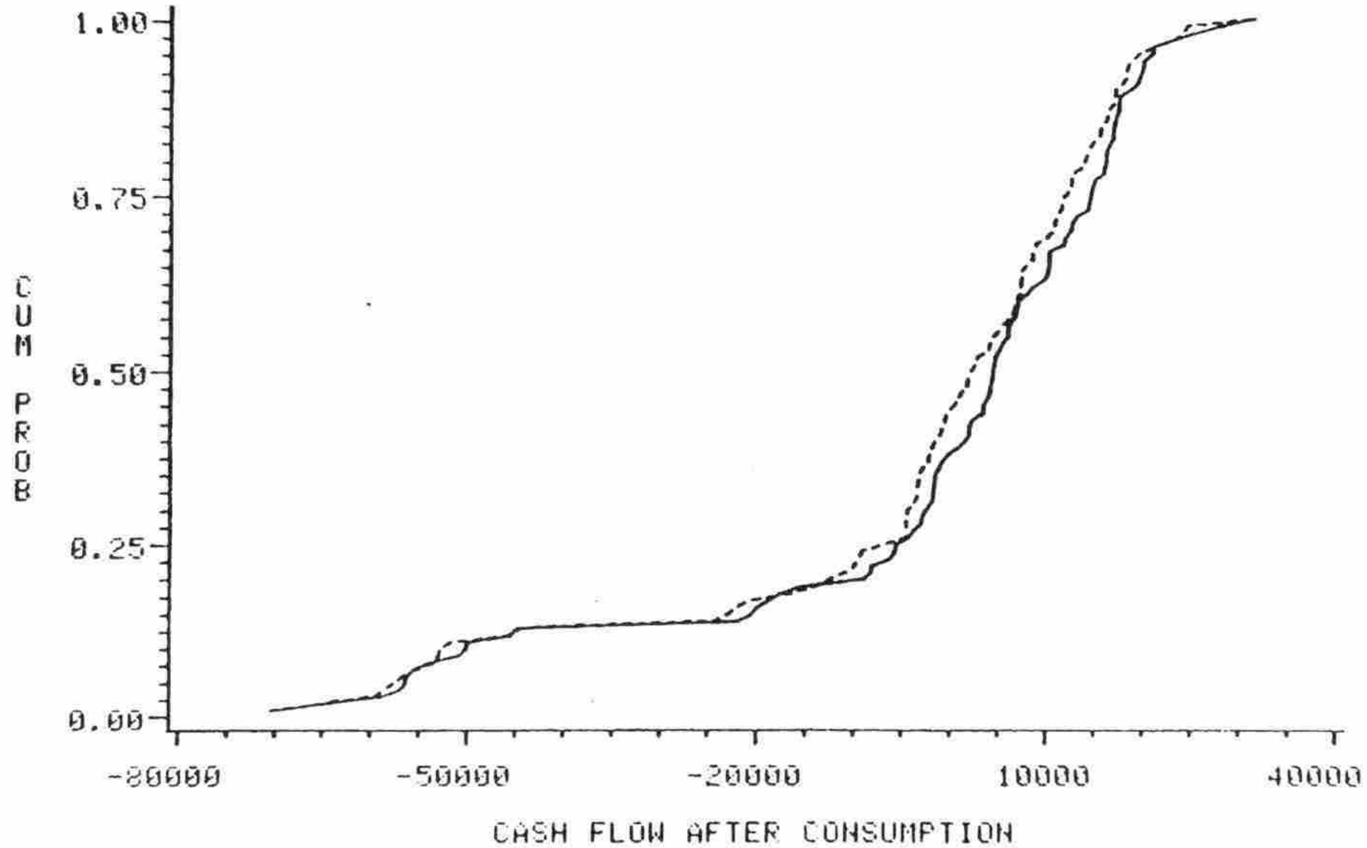

Figure IV.3. Plot of cash flows of leverage (——) and post-harvest hedge (---) prospects the model had a poor performance in boosting cash flows through reducing price variability. From this graph, it can be concluded that leverage distribution dominates the marketing distribution by FSD.

On the contrary, farm programs dominate the leverage distribution in SSD criteria. Farm programs do bring real increments of cash flows in almost all paths of the distribution, as depicted in Figure IV.4. Such increments are wider when PIK is included in the farm program distribution, as is seen in Figure IV.5. However, the possibility of very high incomes is sacrificed when the opportunity cost of diverted land turns out to be higher than actually planting those acres. This is shown by the upper part of the distribution of Figure IV.5. Overall, SSD is exerted by PIK distribution over the leveraged one.

From this point, all pairwise comparisons will observe the efficiency and desirability of FCI as a risk management tool. The analysis is made with the help of graphs which will facilitate the presentation. Again, words such as CDF, prospect, or distribution are used interchangeably to refer to cumulative distributions of CFAC. Furthermore, a leverage level of .5 is used in all prospects as a fixed financial position.

Insurance prospects are depicted in Figure IV.6. The continuous line is AAY prospect 4 of Table IV.4. The broken line corresponds to the IYP prospect 5. Since the guaranteed bushels have been raised with the IYP option, the AAY prospect lies above the IYP prospect on the lower portion of the CDFs. Then, they merge at point

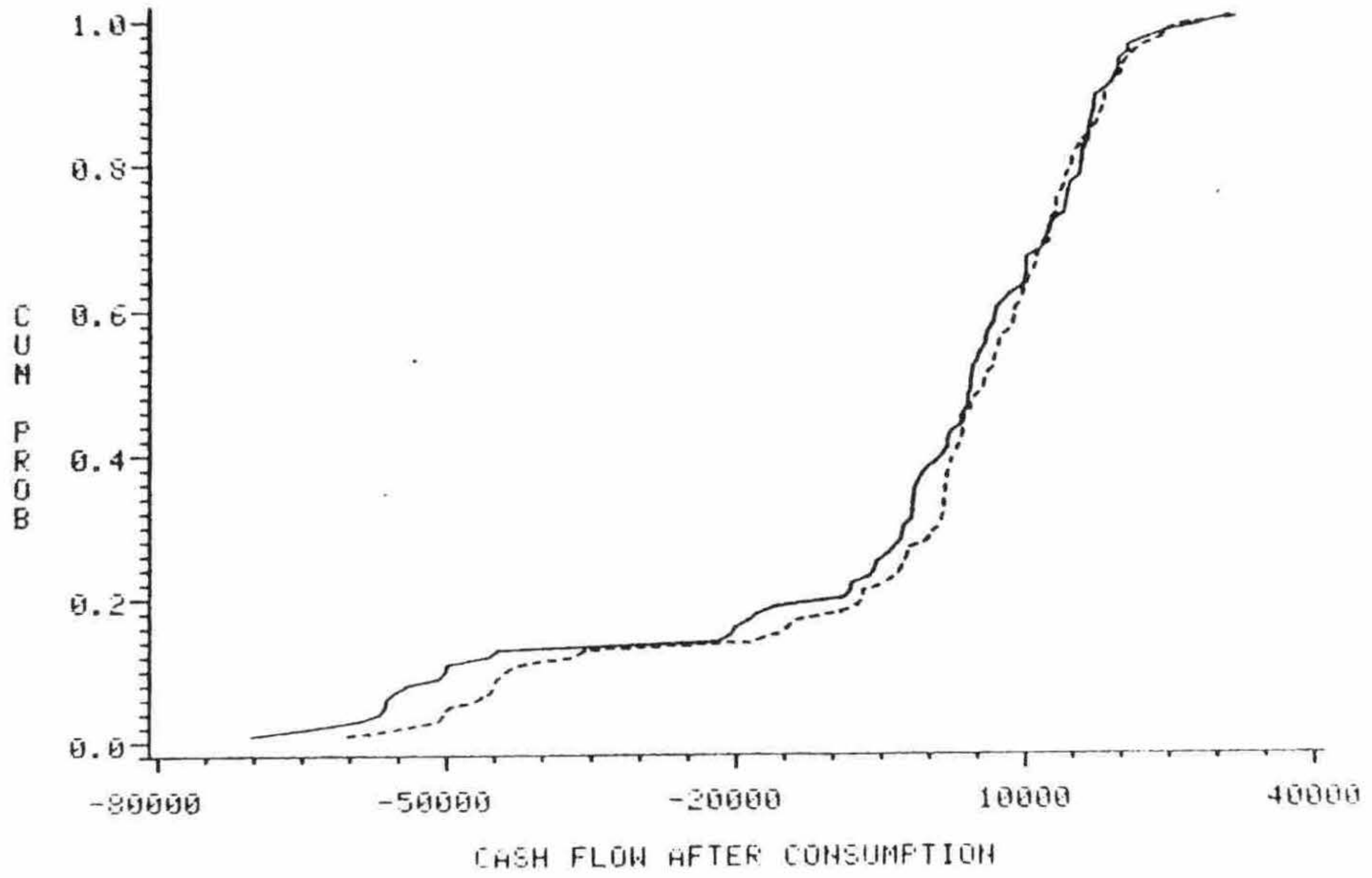

Figure IV.4. Plot of cash flows for leverage (——) and no-PIK farm programs (---) prospects

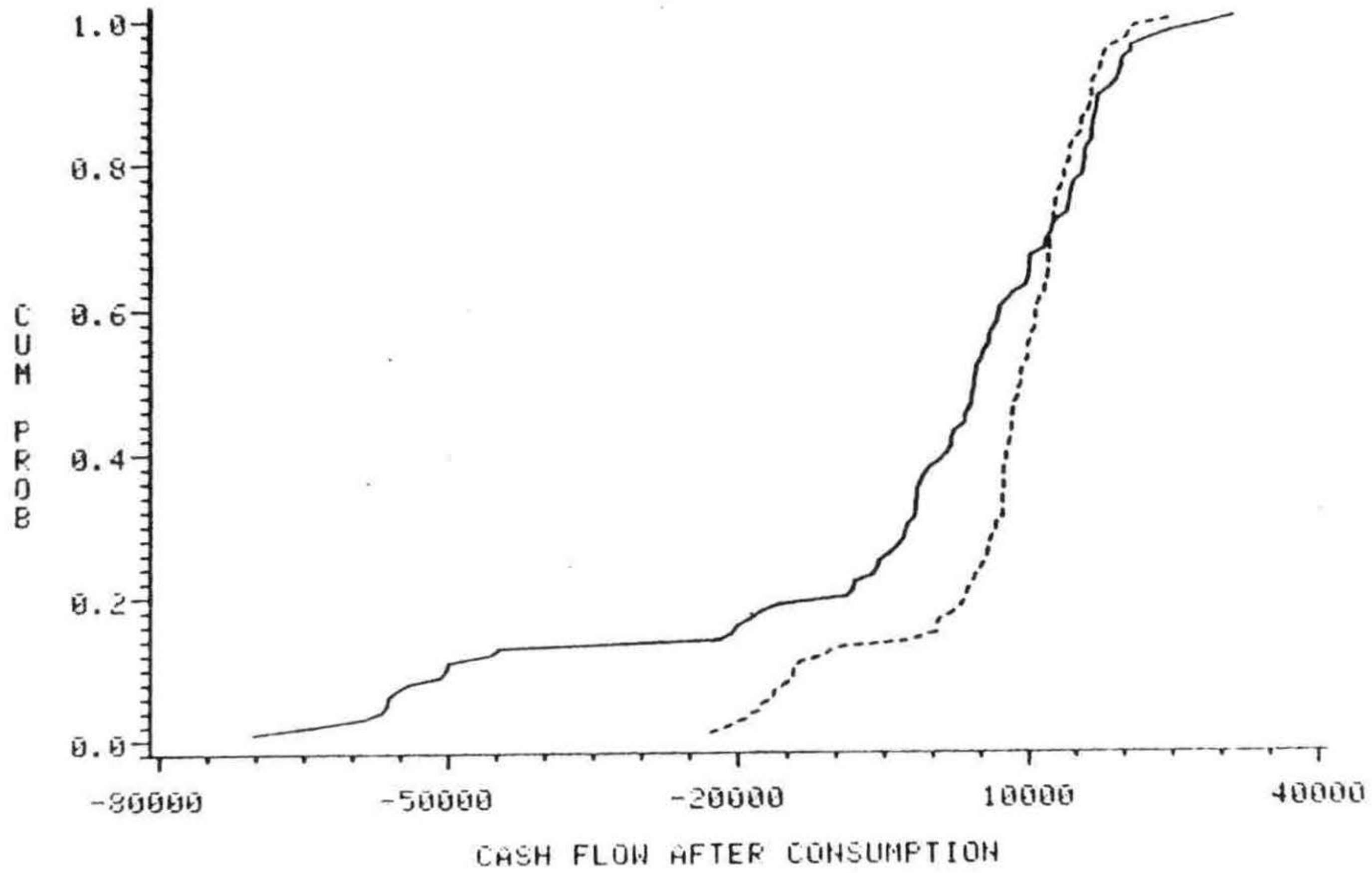

Figure IV.5. Plot of cash flows for leverage (——) and PIK-farm program (---) prospects

A and from there on they form a single solid line. FSD by the IYP's CDF over the AAY's CDF is evident.

If there is a FSD between two high insurance protection level prospects, the same might be expected to happen between a high and low protection level. Certainly it is not the case with prospect 5 (75 percent protection) and prospect 7 (50 percent protection), as is shown in Figure IV.7. Although prospect 5 (unbroken line) dominates the lower 1/4 of prospect 7's CDF (broken line), the signs are reversed in the upper 3/4 of the distributions. However, prospect 5's CDF does dominate prospect 7's CDF in SSD (area A is greater than area B).

Thus, Figures IV.6 and IV.7 indicate that IYP at 75 percent coverage level is stochastically the efficient insurance option among the insurance alternatives analyzed. Prospect 5 contains this efficient option.

Once an efficient insurance prospect is established, it can be compared against prospects with alternative risk strategies. The pairwise comparisons to be discussed are insurance--marketing, insurance--farm programs, and insurance--marketing and farm programs.

Figure IV.8 depicts the insurance and marketing distributions. The performance of insurance significantly offsets the marketing (post-hedge) option in regard to the lower portion of both distributions. Insurance distribution brings a higher mean (expected value) of CFAC with a lower variance than marketing distribution. However, in regard to the upper 3/4 of the distributions, no clear domination

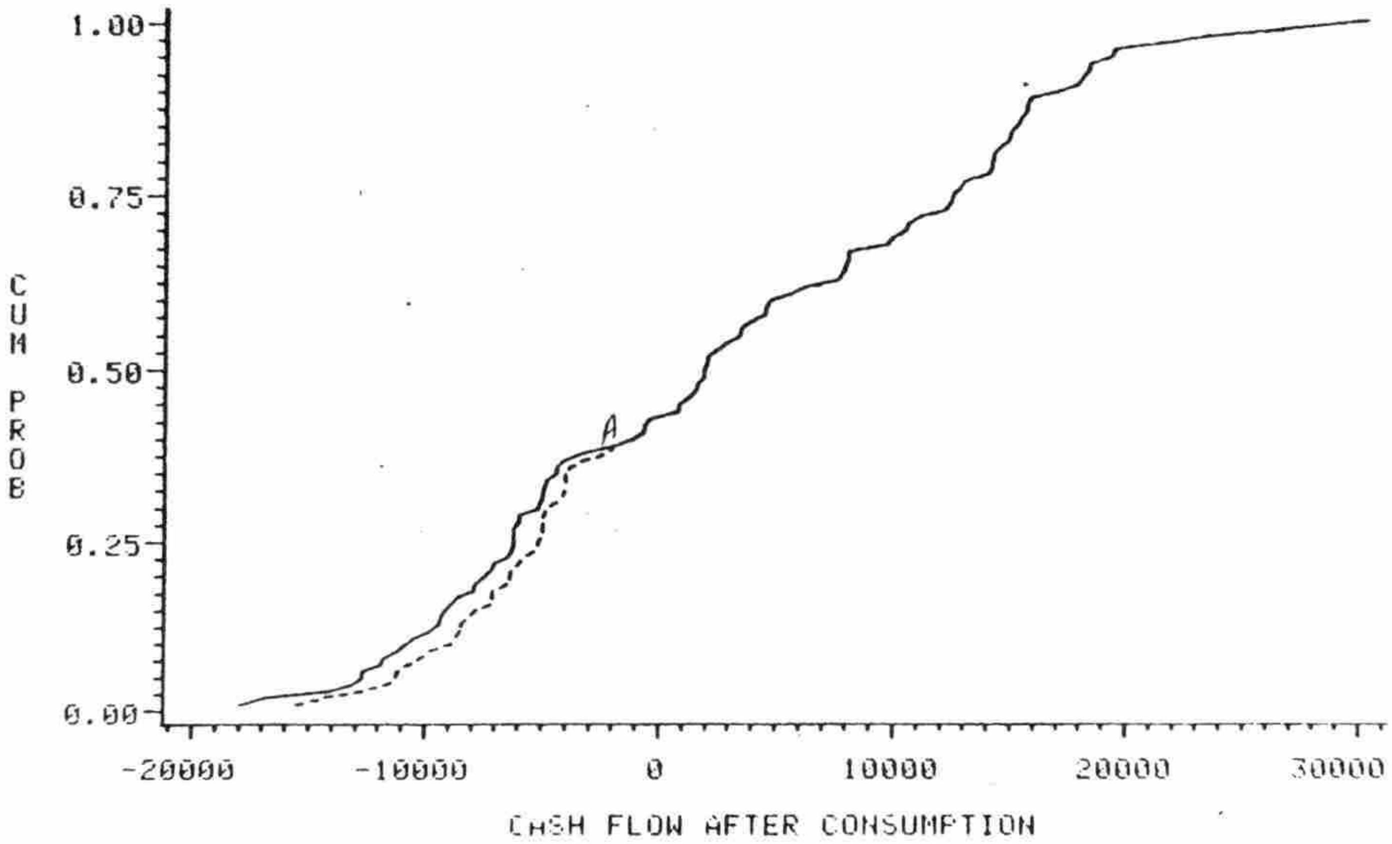

Figure IV.6. Plot of cash flows for AAY insurance (——) and IYP insurance (---) prospects

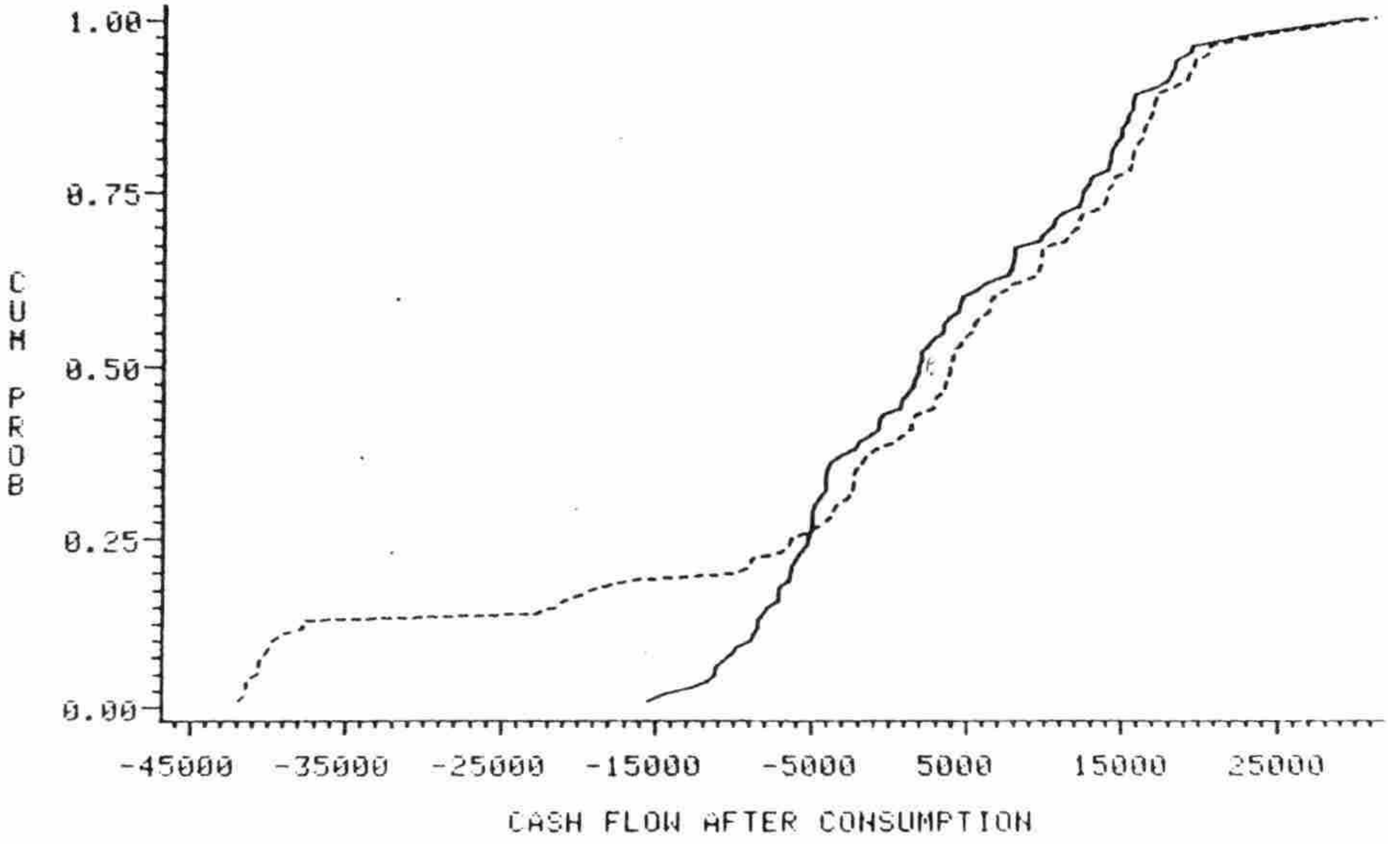

Figure IV.7. Plot of cash flows for 75% IYP insurance (——) and 50% IYP insurance (---) prospects is seen by either prospect. Overall, SSD is exerted by the insurance distribution over the marketing distribution.

Between crop insurance and farm programs, there are two different pictures. The first one is plotted in Figure IV.9. The broken line refers to prospect 9 (no PIK) of Table IV.4. As with the marketing distribution, insurance's CDF (unbroken line) dominates farm programs distribution in SSD. However, it is clear from the picture that the farm programs' CDF does reduce the gap between it and insurance's CDF when no farm program is considered (i.e., compare the lower tails of distributions in Figures IV.9 and IV.1). Some of the gain brought by insurance (area A of Figure IV.9) is at the expense of foregoing some gain with farm programs (area B in the same figure). Thus, it might be the case that in a wide range of risk averse farmers (i.e., low to high), some might prefer insurance and some others might prefer farm programs.

A decision between farm programs or insurance is made more simply when the PIK program is included in the farm programs (prospect 10 of Table IV.4). Figure IV.10 depicts such a situation. Farm programs with PIK (broken line) simulate the insurance distribution (continuous line) in regard to low yields (where the effectiveness of insurance is attributed) which corresponds to low cash flows. It is clearly seen by the narrowed area A in the figure. On the other hand, benefits from PIK participation expand the differences between it and insurance as can be seen by the area B in Figure IV.10. This area shows that PIK's CDF accumulates higher gains than insurance in

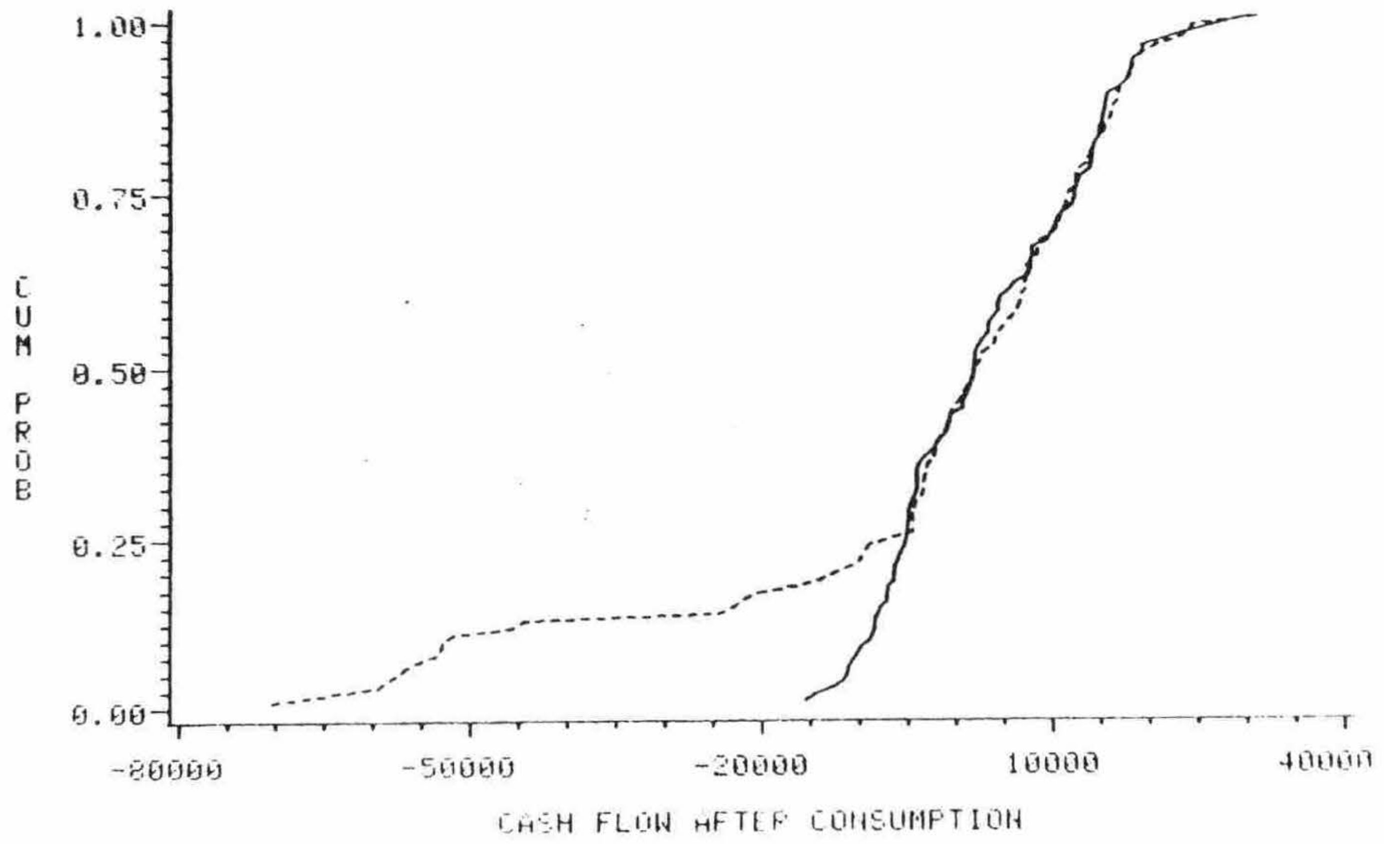

Figure IV.8. Plot of cash flows for IYP insurance (——) and post-harvest hedge (---) prospects

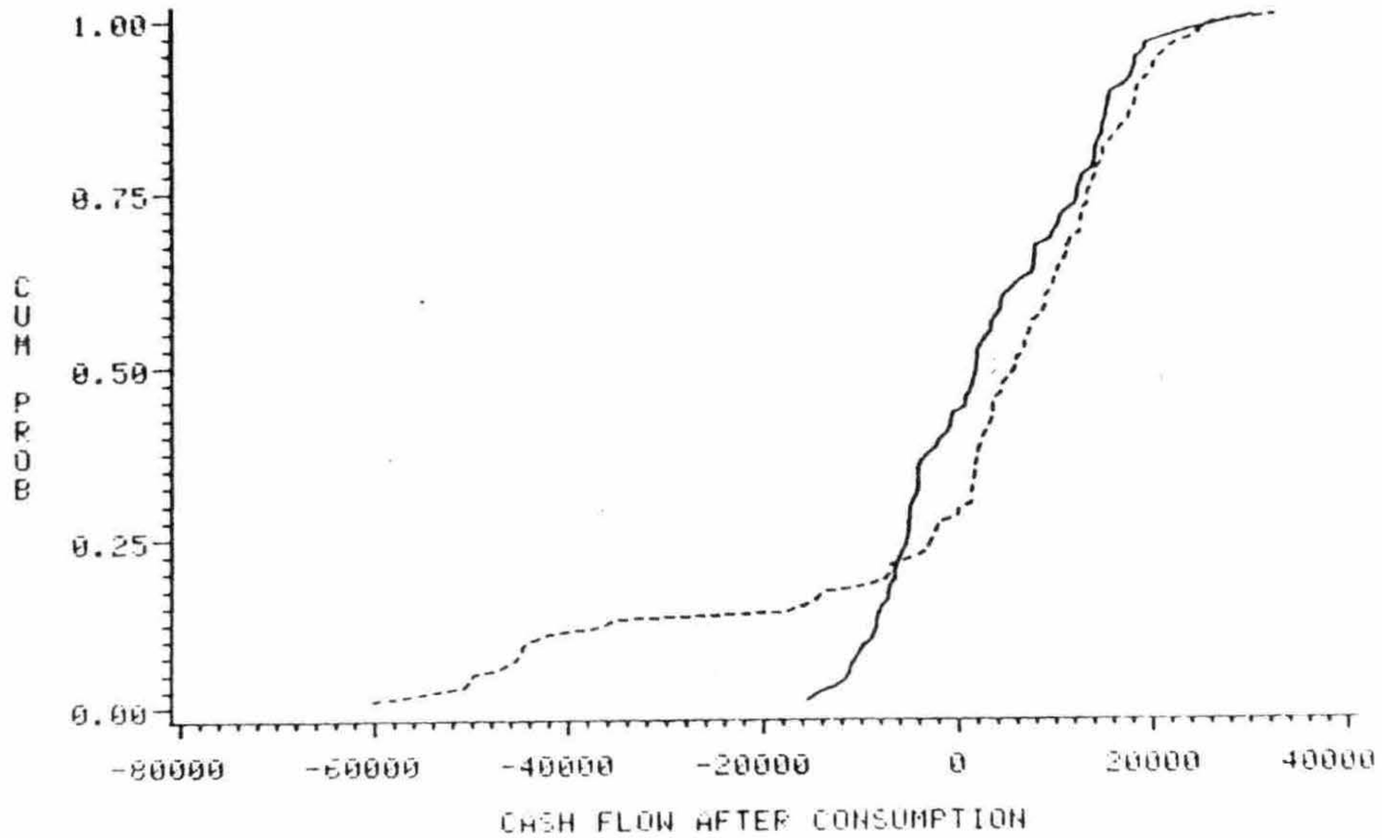

Figure IV.9. Plot of cash flows for IYP insurance (——) and no-PIK farm program (---) prospects

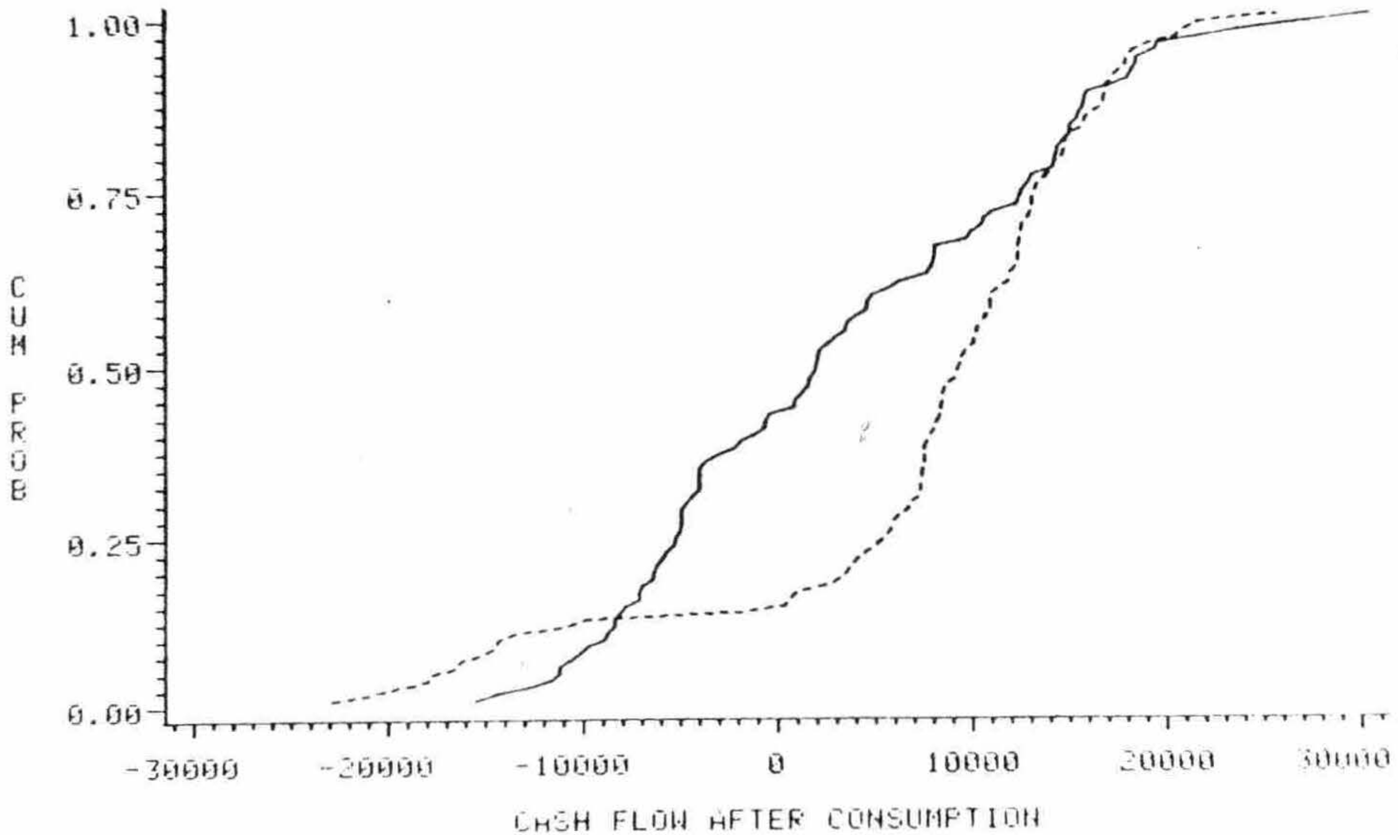

Figure IV.10. Plot of cash flows for IYP insurance (——) and PIK-farm programs (---) prospects more than 50 percent of the distributions. However, surprisingly enough, SSD is not shown by either prospect. This means that both prospects are efficient in a second degree sense. The source of the ambiguity is in the upper 10 fractile (.90-1.00) of the distributions. PIK distribution stops accumulating cash flows before insurance's CDF does. A third or higher degree of stochastic efficiency needs to be stated. This is beyond the scope of this study. All that can be said here is that PIK and insurance prospects are both in the efficient set of second degree dominance.

Finally, the added impacts of marketing and farm programs on the desirability of insurance are pictured in Figure IV.11. A farm program (without PIK) and a post-harvest hedge form both the discontinuous line in the figure (prospect 13 in Table IV.4). The insurance prospect (continuous line) dominates in SSD. This is simply the reflection of what was seen in Figure IV.9, where only farm programs were considered. Again, marketing shifts the farm programs' CDF to the left, making insurance's CDF more attractive than before.

Table IV.8 summarizes the stochastic analysis done among prospects. Leverage distribution is clearly dominated by nonleverage distribution and risk management distributions except for marketing (prospect 8), which is dominated by the former. Among insurance alternatives, IYP option of federal crop insurance seems to perform better than the AAY option. Insurance dominates marketing and farm programs without PIK. It is as efficient as farm programs with PIK, as seen in Table IV.8 (prospect 5 against prospect 10).

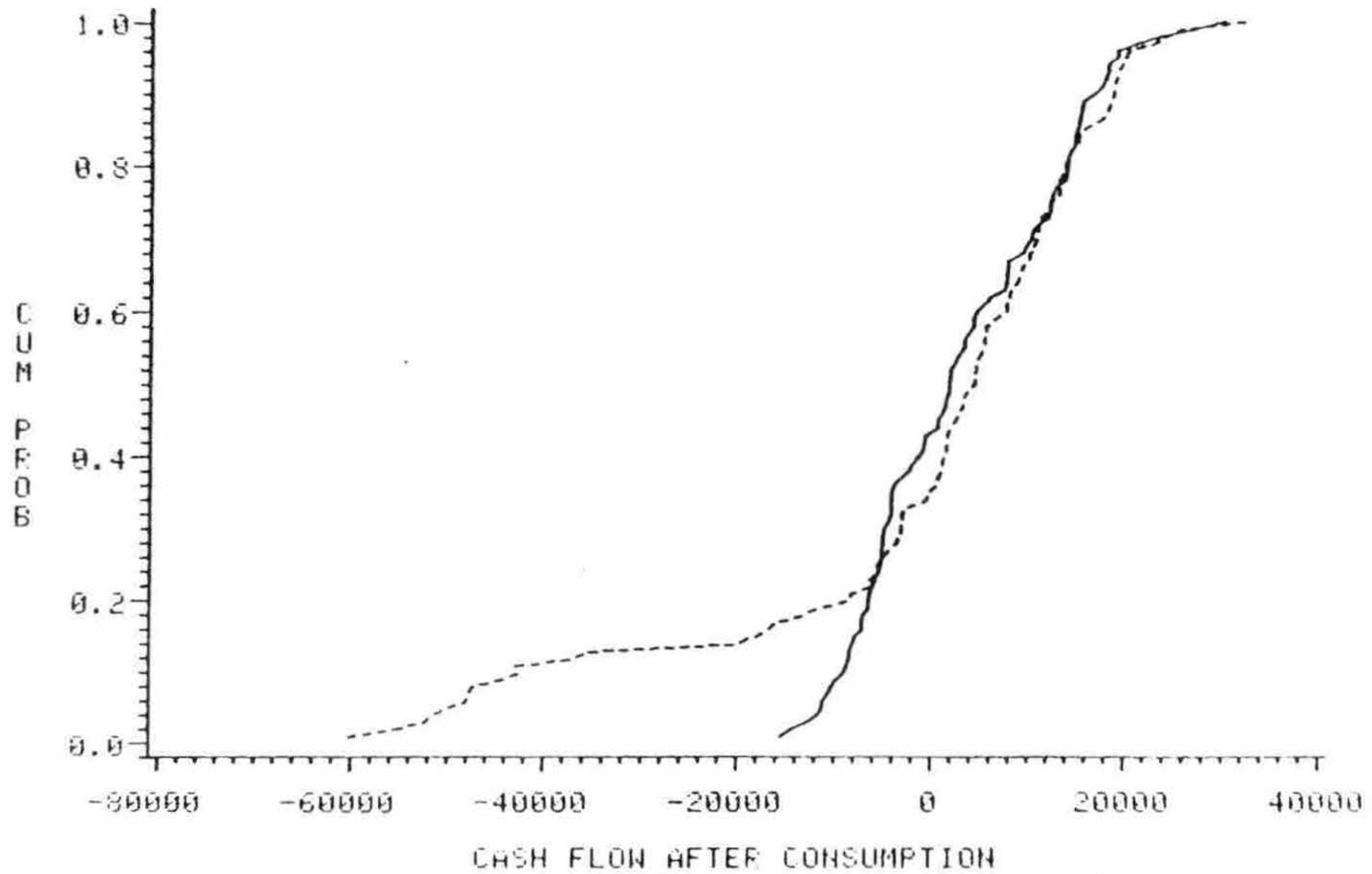

Figure IV.11. Plot of cash flows for IYP insurance (——) and joined farm programs and marketing (---) prospects

Table IV.8. Stochastic dominance results of 9 risk management prospects[a]

Prospect	2	4	5	7	8	9	10	13
1	1	-	2	-	-1	2	2	-
4	-	-	1	-	-	-	-	-
5	-	-1	-	2	2	2	0	2

[a]See Table IV.2 for a description of these prospects:
"-" means no comparison has been done b/w. row and column prospect.
"-1" - row prospect dominates column prospect in FSD.
"0" - no domination by either prospect in SSD.
"1" - row prospect is dominated by column prospect in FSD.
"2" - row prospect is dominated by column prospect in SSD.
"-2" - row prospect dominates column prospect in SSD.

CHAPTER V. CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

Participation by farmers in the Federal All-Risk Crop Insurance program (FCI) has been rather low. Farmers' perception of risk or their ability to bear it may make FCI unnecessary. Moreover, it is possible that premiums and/or coverage levels do not accurately reflect the probabilities of crop failures. In addition, other risk control instruments may compete with FCI.

To cope with the problem, the performance of FCI was contrasted to the performance of farm commodity program participation and marketing alternatives in a single-period Monte Carlo simulation model. Also, farm leverage was manipulated in the simulation model to measure the ability of producers to bear risk and to discover interference with FCI and the other strategies. The evaluation criteria used in the model were cash flows after taxes and consumption from the production of corn.

A key element in the simulation model was the estimated yield distribution from which yields were drawn to calculate cash flows under the different alternatives. Rather than assuming normality in the yield distribution, time series yield data from experimental farms in Iowa were used. The result was a left-skewed (long left tail) yield distribution that gives lower probabilities to low yields than a normal yield distribution. Thus, cash flow distribution under each strategy is sensitive to the assumed yield distribution. Further, another less relevant element in the model was the distribution of market prices. For its facility in manipulation, a triangular price distribution was assumed, though it may have a serious impact on the marketing performance.

After estimating cash flows distributions under each strategy and combinations of them, first- and second-degree concepts of stochastic dominance were used to compare the risk-reducing effects of the strategies. Focusing on FCI performance relative to and in combination with farm programs and marketing tools, the results show that FCI is an efficient strategy at high coverage and price levels (75 percent and \$2.70/bu, respectively). Its efficiency increases even more when higher bushels can be guaranteed, i.e., an individual yield plan of FCI program.

Compared to farm programs, FCI performed better in boosting cash flows related to yields below the guaranteed level. Thereafter, the performance of farm programs was more efficient than FCI's. Moreover, when payment-in-kind is included in farm programs, the results show that FCI and farm programs have equal relative performance in farm cash flows.

Similarly, FCI performed better than the hedge option of marketing at low (and eventually negative) cash flows. However, their performance is practically the same on the positive domain of cash flows.

Finally, the performance of FCI remains the same when compared with the combination of FCI and/or farm programs and/or marketing options. In other words, the impact of combined strategies on cash flows is equivalent to the sum of the impact of individual strategies.

From the results of this study, FCI can be viewed as an attractive option for managing crop production risks. However, its risk-reducing and return (i.e., indemnities) performances are influenced by such factors as the yield distribution and its probabilities of low yields; the probability that average yield per insured acres falls below the yield guaranteed per acre; and the relation of indemnities received to premiums paid as a measure of insurance return.

A major setback of FCI is that it does not guarantee a profit either on lost production or on harvested bushels. This is where farm programs and marketing instruments may influence the performance of FCI in the risk management system. On one hand, farm programs provide a minimum price for all harvested bushels in case the market cash price is below the minimum. FCI provides a price usually below the cash price and only on bushels below the guaranteed yield. On the other hand, marketing options play a more direct role on price risk than farm programs by reducing price risk variability even more.

From another angle, FCI performance is also influenced by the farm leverage position which is a measure of risk-bearing ability. Besides the opportunity for expanding farm operations, a higher leverage position requires a higher rate of returns to capital. An insufficient return on capital caused by a crop failure may make FCI more attractive than it would be otherwise. Thus, it is likely that a farmer's ability to bear a production failure declines as leverage increases, causing FCI to have a better performance in the model.

Why don't farmers buy FCI? From this study, it can be said that FCI only protects against production risk and that production risk is only a portion (perhaps small, perhaps large) of the total farm operation risk. In addition, an intuition derived from the study suggests that price risk may play a more important role in the farm risk exposure and with higher probabilities of adverse impact on farm returns than FCI's role. However, this partial answer should be limited to the study's considerations.

It is hoped that this study will serve to increase the understanding of the role of crop insurance in managing risk. However, due to the study's characteristics, it is difficult to extrapolate the results to other farm settings or even to state- or nation-wide validation. Further research might involve estimation of yield distributions on different geographical areas of the country. It would be of interest to study the performance over time of FCI and other alternatives to it. Finally, more research on farmers' risk perceptions might increase our understanding of farmers' decisions under risk.

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APPENDIX A. FEDERAL ALL-RISK CROP INSURANCE BASICS AS AMENDED ON OCTOBER 1, 1980

Under FCI, crops are insured against essentially all unavoidable causes such as drought, lightning, hail, excess moisture, frost, excessive rain, hurricane, wind, insect infestation, tornado, flood, winter kill, snow, disease, fire, earthquake, wild life and such other unavoidable causes. Plant coverage is not provided against losses due to theft and neglect or failure to follow established good farming practices. Nor does it cover financial losses resulting from low prices received for farm products. Furthermore, insurance is not provided on any agricultural commodity in any county in which the FCIC determines that the income from such commodity constitutes an unimportant part of the total agricultural income of the county.

Levels

Producers can purchase insurance with widely different yield and price provisions. Yields may be guaranteed at 50, 65 or 75 percent of the appraised average yield for the crop and county in question. County yields are computed by the USDA's Statistical Reporting Service (SRS) and used by the FCIC. A producer can also choose from three price levels established each year by the U.S. Department of Agriculture to provide different levels of return if a loss occurs. One of the price elections offered shall approximate (but be no less than 90 percent of) the projected market price for the commodity involved.[1] In addition, producers may elect to have deleted from the FCIC's policy of insurance the coverage against losses caused by hail and fire, and this in turn is reflected in the premium. However, if fire and hail insurance are not purchased through FCIC, proof must be submitted that, at least, an equivalent amount of coverage is being carried with another insurance company.

Premiums

In each county, premiums are based on actuarial data to reflect differences in soil types, historical pattern of crop loss due to covered insurance factors, and crop yields. Land in each county is classified into several categories to establish expected normal yields. The normal yield as established by the FCIC reflects yield records for designated areas over the more recent ten years on which records have been assembled. It is not the farm "normal" yield used in government price support and acreage reduction programs.

For the purpose of encouraging the broadest possible participation in the insurance program, the federal government subsidizes up to 30 percent of each producer's premium up through the 65 percent coverage level. The dollar amount subsidy to the 65 percent level is used in the 75 percent coverage level.

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[1] This price election does not guarantee farmers a fixed price. They are only used to calculate indemnities if yields are below specified levels. Farmers who wish to also manage price risk have several options, e.g. price and income support programs, hedging, and forward contracting.

The FCIC may enter into agreements with any state or agency of a state under which such state or agency may pay to the FCIC additional premium subsidy to further reduce the portion of the premium paid by farmers in each state.[1]

Over the long run, premiums will be adjusted for all insured farmers in relation to their loss experience. Farmers with a loss ratio of less than one (ratio as indemnities paid to premiums) can achieve up to a 50 percent reduction in premiums over a 15-year period. Those with a loss ratio above one will face an increasing premium.

Premiums are fully tax deductible. They are used only to pay losses and reserves for catastrophic losses. They are not used for administrative expenses.

Historical pay out as losses for 1948-80 period was $1.09 of each premium dollar. The target pay out as losses is $.90 should be returned as losses throughout the years.

Another aspect of the FCI is the insurance unit. In order to define the insurance policy unit, the FCIC has established the following unit division guidelines:[2]

(1) The insured maintains written verifiable records of planted acreage and harvested production for the previous year.

(2) The acreage planted to the insured crop is located in <u>separate</u> legally identifiable sections or, in the absence of section

---

[1]Texas is the first state that has submitted a bill to provide such aid to the agricultural sector.

[2]Effective beginning with the 1983 crop year.

descriptions, the land is identified by separate ASCS farm serial numbers provided (a) the boundaries of the section or farm serial numbers are clearly identifiable and the insured acreage determinable, (b) the crop is planted in such a manner that the planting pattern does not continue into the adjacent section of farm serial number.

(3) The acreage planted to the insured crop is located in a single section or farm serial number and consists of acreage on which both an irrigated and non-irrigated practice is carried out provided (a) the crop planted on irrigated acreage does not continue into non-irrigated acreage in the same rows and/or planting pattern, and (b) planting, fertilizing and harvesting are carried out according to recommended dryland and irrigated practices for the area.

The purpose of the unit guidelines is to clearly identify the block of acreage on which indemnities are determined, if losses occur.

Indemnities

An important issue is how loss adjustment will be handled. Farmers should report loss to the agent from whom they purchase insurance as soon as a loss is apparent. They should not wait until loss is proven at harvest time. Losses are adjusted on a per unit basis.

Loss measurement as reflected in yield reduction should be relatively straightforward, though the question of whether a damaged crop should be harvested could occur.

Loss of quality is a new protection that has been included in the FCI coverages (i.e. excess moisture). A recent statement by the FCIC concerning quality loss is as follows:

> The insured may suffer a loss in quality as well as a loss in quantity. A loss in quality will generally be reflected in the price at which the product can be sold on the market. There are a number of methods used, depending upon the commodity, to reflect this type of loss. Essentially, these methods are to reduce the amount of damaged production to be counted against the production guarantee, thus increasing the indemnity payable.
>
> It should be noted that quality and quantity losses are not settled separately but are combined. High production may offset some or even all of the loss from poor quality of production. Quality protection was not given in the early years of federal crop insurance, but was added as workable methods were developed.

In any event, determination of indemnity involves dealing with an individual loss contractor designated by and directly representing the FCIC. Private sales agents or insurance companies are not involved in evaluating losses in determining indemnities.

Once the damage is determined, i.e. total number of bushels below the guarantee level, the indemnity is calculated at the pre-selected price level specified in the contract.

Crucial Dates

Several final dates are established each year for the following purposes:

- "Sales Closing" is the last date that insurance can be purchased for each crop.
- "Final Planting" is the date at which planting must be completed.

- "Acreage Report" is the date by which a final planted acreage report must be submitted to FCIC.
- "End of Insurance Period" is the final date at which harvest must be completed to qualify for indemnity if a loss is incurred.
- "Termination of Indebtedness" is the final date at which premiums must be paid.
- "Cancellation" is the final date for cancellation of the contract if a producer does not wish to continue the insurance the following year.

Individual Plans

Individual Yield Coverage Program

Farmers who demonstrate yields significantly above those established by FCIC inthe county where their farm belongs can arrange an Individual Yield Plan (IYP) with the FCIC.

Three years' individual production records are required to be compared with county yield averages to arrive at a producer yield index. The farmer's index is determined by dividing the yields from the farmer's records by the USDA's Statistical Reporting Service (SRS) yields for those years. This index will be applied to the county average (as computed by the SRS) for up to seven additional years to determine the producer's individual yields.

For purposes of illustration, assume that the farmer's most recent yields of corn are 120, 100 and 110 bushels per acre in the last three years. Also assume that the SRS county records yield per acre for the same years are 80, 75 and 70. Thus, the producer index is equal to the average farm records divided by the average of SRS records (Table A.1).

Table A.1. Examples of individual yield plan estimation

	Farmer's records yield per acre	SRS county records yield per acre
Most recent year	120	80
Second most recent year	100	75
Third most recent year	110	70
Average	110	75

Producer Index: 110 ÷ 75 = 1.47

Yield Calculation:

Farmer's records (3 years) 120
100
110

Seven years (no records) times 70 bushels per acre times 1.47 index = 720

SRS Yield used by FCIC for missing years of the ten-year base period = 70

(720 + 120 + 100 + 110) = 1050 ÷ 10 = 105 bushels per acre

As a result, this farmer can purchase insurance at 50, 65, or 75 percent of his actual weighted farm yield of 105 bushels per acre instead of the 75 bushels per acre of the SRS yield records. The yield guarantee has increased, but the maximum protection is still 75 percent.

On the other hand, the premium rate as well as the total amount of premium remain based upon area average yield (75 bu/Ac in this case) according to a special provision of the Federal Crop Insurance Act of 1980.

Individual Certified Yield Plan

This program was designed mainly for farmers who feed their crop production to livestock or poultry and do not keep adequate production records.

Under the ICYP, farmers must produce satisfactory acreage and yield data for at least the most recent crop year, plus any complete or incomplete data for that crop for the previous two years. Crop yield data must be certified by ASCS.

The remaining years of a ten-year base period will be calculated by adjusting the county average as computed by SRS. This will be done in the same manner as for IYP.

As soon as three conseecutive years of acreage and yield data are available, the producers using the ICYP must convert to the IYP for determining yields.

Under the ICYP, higher coverages require additional premiums per acre than under the IYP program. The ICYP program will apply to 1983 spring planted corn, grain sorghum, barley, and oats, and only in certain counties.

Late Planting Agreement Option

Farmers who are not able to meet FCIC's planting deadline will be able to purchase insurance protection. The coverage is extended on acreage planted up to a maximum of 20 days after the final planting day. The production guarantee on the acreage will be reduced ten percent every five days up to the 20th day following the final planting date. The premium rate will remain the same for the coverage provided.

An example

The following example is given with the purpose of presenting a practical calculation of a typical FCI. No attempt is made to cover all the details of insurance explained above.

Data of FCI in O'Brien County, Iowa, had been selected for 1983 and succeeding crop years on insurance of corn. This crop is one of six insurable crops in Iowa (others are barley, grain sorghum, oats, soybeans and wheat).

Table A.2 contains different insurance options for each land classification. Corn producers can insure to cover a price of $2.00, $2.40 or $2.70 per bushel at three yield levels and with or without hail and fire protection. In O'Brien County, six land classifications are established to indicate average yield levels on different quality land in the county. These classes reflect average corn yield expectations from land classification categories 1 through 6 of 110, 86, 100, 118, 76 and 104 bushels per acre, respectively.

Assume a farmer in O'Brien County wants to insure a unit of 80

Table A.2. Example county coverage and rate table, corn, O'Brien County, Iowa, 1983 crop-year[a]

Classification	Base premium rate	Excluding hail and fire protection	Protection guarantee per acre (bu.)	Premium: With hail and fire protection			Premium: Without hail and fire protection		
				Price election per bushel					
				2.00	2.40	2.70	2.00	2.40	2.70
	(%)	(%)		Base premium reduced by government subsidy in dollars per acre (30% subsidy).[b]					
				LEVEL 1 - 50% of Normal Yield					
1	2.8	0.8	55	2.15	2.60	2.90	1.55	1.85	2.05
2	3.5	1.1	43	2.10	2.50	2.85	1.45	1.70	1.95
3	3.1	0.9	50	2.15	2.60	2.95	1.55	1.85	2.05
4	2.6	0.8	59	2.15	2.60	2.90	1.45	1.80	2.00
5	4.2	1.3	36	2.10	2.50	2.85	1.45	1.75	1.95
				LEVEL 2 - 65% of Normal Yield					
1	3.8	1.1	72	3.80	4.60	5.20	2.75	3.25	3.65
2	4.9	1.5	55	3.80	4.50	5.05	2.60	3.15	3.55
3	4.2	1.3	65	3.80	4.60	5.15	2.60	3.15	3.55
4	3.6	1.1	76	3.80	4.60	5.20	2.65	3.20	3.60
5	5.8	1.5	47	3.80	4.60	5.15	2.80	3.40	3.80
6	3.8	1.1	68	3.60	4.35	4.90	2.55	3.10	3.45
				LEVEL 3 - 75% of Normal Yield					
1	5.0	1.5	83	5.80	6.95	7.85	4.05	4.85	5.50
2	6.4	1.5	64	5.75	6.90	7.75	4.35	5.25	5.90
3	5.5	1.5	75	5.75	6.95	7.80	4.20	5.05	5.65
4	4.7	1.4	88	5.75	6.95	7.80	4.05	4.85	5.50
5	7.6	1.5	54	5.75	6.90	7.75	4.60	5.55	6.25
6	5.0	1.5	78	5.45	6.55	7.40	3.80	4.60	5.15

[a]Source: FCIC Actuarial Documents, Iowa, O'Brien, 1983.

[b]The "Base Premium" is the total cost of insurance to government and producers. The "Base Premium Reduced by Government Subsidy" is the amount that a farmer will pay for FCI.

acres under classification 2 (Unit A) and a unit of 60 acres under classification 4 (Unit B), both of corn.

In this case, the farmer has 18 different insurance options for each land unit. There are three aspects the producer has to decide on: the percentage of normal yield to be guaranteed, the price guarantee per bushel he would like to be paid if a loss occurs and whether to take hail and fire insurance protection with the FCIC.

Now, assume the same farmer chooses to insure unit A at 75 percent of the area average (normal) yield and at a price of $2.70 per bushel and unit B at 65 percent of the normal yield and at a price of $2.40 per bushel. Also assume that insurances policies for the units A and B include hail and fire protection. Total insurance cost to the farmer is as follows:

	Unit A	Unit B
(1) Number of Acres	80	60
(2) Guaranteed production	(64x80) = 5120 bu.	(76x60) = 4560 bu.
(3) Subsidized insurance cost per acre	$7.75	$4.60
(4) Total Cost Per Unit (1x3)	$620.00	$276.00
(5) Total insurance cost to the farmer	$896.00	

Suppose that for some insured causes, the farmer harvested only 3,500 bushels in unit A and 3,700 bushels in unit B. Moreover, the 1,620 bushels lost in unit A include 1,000 bushels lost for low yield per acre and 620 bushels lost because of loss in quality as estimated by the "loss contractor" of FCIC.

In spite of these facts, the producer's indemnity will be:

		Unit A	Unit B
(6)	No. of bushels under guaranteed production level	1,620	860
(7)	Guaranteed price per bushel	$2.70	$2.40
(8)	Total indemnity per unit (6x7)	$4,374.00	$2,064.00
(9)	Total indemnity to the farmer	$6,438.00	

Total return would amount to $6,438.00 plus the market value of 7,200 bushels of corn that were harvested.

If a crop is damaged to the extent that it is left unharvested, the indemnity payments are based on the total production guaranteed per unit (5,120 and 4,560 bushels in this example). The indemnity payment is reduced by whichever is the lesser of bushels per acre as a percent of the production guaranteed to offset the lack of harvesting costs. The reason for this is that premiums are formulated to cover the cost of production. Since no harvesting costs were incurred in this case, they were actual costs of production.

APPENDIX B. CODES OF THE 38 INPUT VARIABLES OF THE COMPUTER MODEL

AAV = Average Asset Value ($/Ac)

AAY = Area Average Yield (bu/Ac)

APIK = Percentage of Base Acreage in PIK (%)

ARP = Percentage of Base Acreage in ARP (%)

ASCS = ASCS Yield Program (bu/Ac)

ASPIK = Percentage of ASCS Yield to be Paid (%)

CL = Coverage Yield Level (%)

CSF = Percentage of Actual Production (Yield (I) + PIK) to be Sold at Harvest Time (%)

DF = Discount Factor (Annual Rate)

DPR = Diversion Payment Rate ($/bu)

EY = Expected Yield (bu/Ac)

FB(I) = Fall Basis (¢/bu.)

FC = Fixed Production Cost ($/Ac)

FFP(I) = Fall Futures Prices ($/bu)

FTP = Federal Tax Paid Last Year ($)

HC = Harvest Cost ($/bu)

IR = Capital Interest Rate (x/100)

IYP = Individual Yield Plan (bu/Ac)

LDP = Percentage of Base Acreage in Land Diversion Program (%)

LE = Leverage Level ($0 \leq LE \leq X$)

LO = Land Operated (Ac)

LR = Loan Rate ($/bu)

L%R = Loan Interest Rate ($/100)

MC = Maintenance Cost Per Unplanted Acre ($/Ac)

OH = Percentage of Yield (I) + PIK in Post-Harvest Hedge

PH = Percentage of EY to Hedge b/Harvest (%)

PHFP = December Futures Prices at Harvest Time ($/bu)

PL = Price Coverage Level ($/bu)

POFP = July Futures Prices at Harvest Time ($/bu)

PR = Insurance Premium Rate (% of CL)

PRR = Principal Retirement Rate (%)

SB(I) = Summer Basis (¢/bu)

SC = Storage Cost Per Month (¢/bu)

SFP(I) = Summer Futures Prices ($/bu)

TAI = Total Acres Insured (Ac)

TP = Target Price ($/bu)

VC = Variable Production Costs ($/Ac)

YIELD(I) = Yield per planted acre

APPENDIX C. TRANSFORMATION FUNCTIONS OF YIELD DATA

The purpose of this appendix is to facilitate the understanding of Hancock farm and Sutherland farm yield data analysis.

Hancock Farm

The residuals of the detrended observations are plotted in Figure C.1. They spread out rather than show a constant variance. To bring cone-shape residuals to parallel-lines residuals (constant variance), the regression equation $Y_t = f(T)$ was divided by (6+0.2T). The value of 6 is equal to two times the coefficient of T in the regression. Thus, (6+0.2T) will keep the residuals within a band of -6 and 6 and, in this way, the variance had been brought to a constant.

The transformed expression is,

$$\hat{Y}^*_t = \frac{\hat{Y}_t}{6+0.2T} = 57.557 \left(\frac{1}{6+0.2T}\right) + 2.897 \left(\frac{T}{6+0.2T}\right) \qquad (C.1)$$

The residuals of the function in equation C.1 are assumed to be normally distributed with mean 0 and variance σ^2 (0.795 in this case). However, by plotting the "estimated" residuals

$$\left(\frac{Y_t}{6+0.2T} - \frac{\hat{Y}_t}{6+0.2T}\right)$$

against those from a normal ~N(0,.795), small discrepancies were found that needed correction. The corrections were obtained from the following functions:

Correction function	Cumulative probability (P)
-0.12	$0.10 \leq P \leq 0.30$

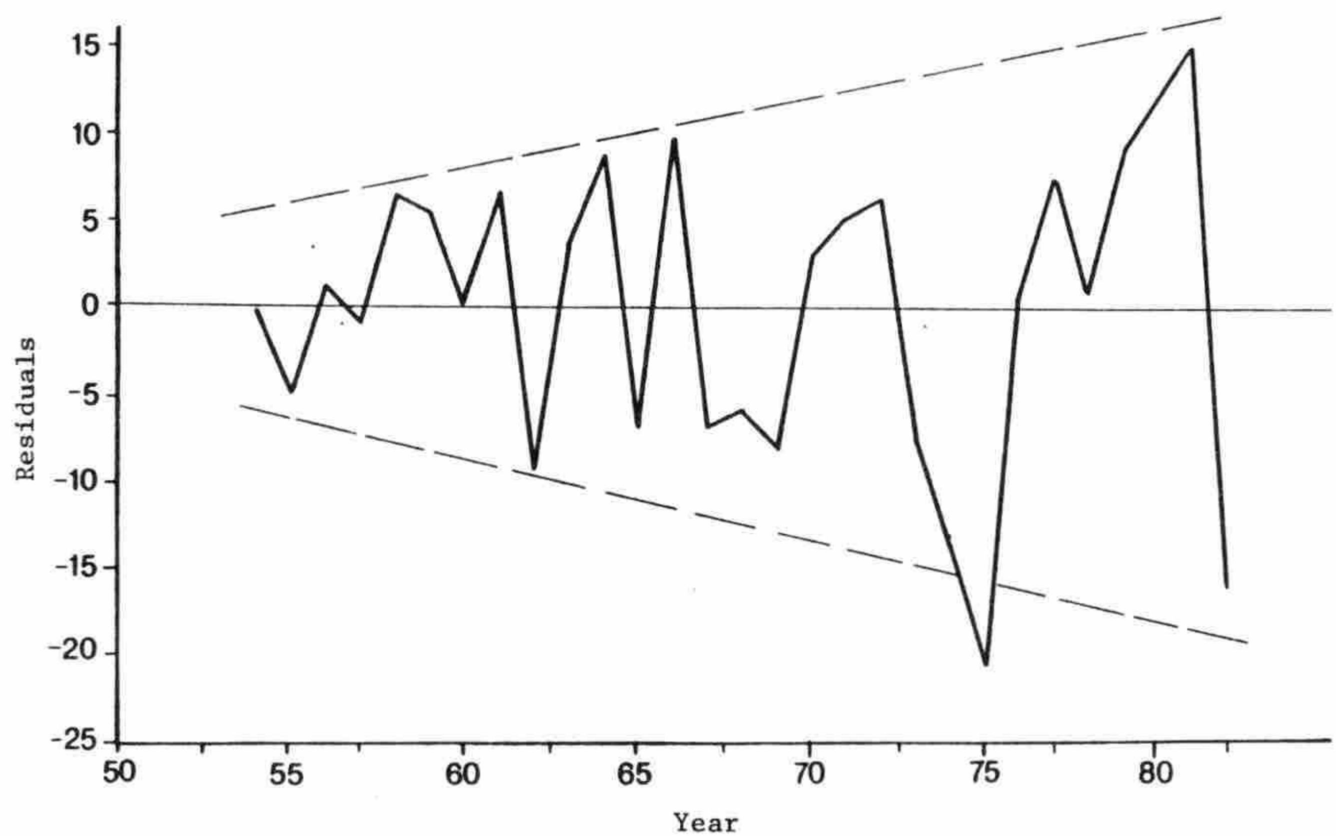

Figure C.1. Graph of residuals for Hancock farm $(Y_t - \hat{Y}_t)$ where $\hat{Y}_t = \alpha + \beta_0 T$ (1954-1982)

Correction function	Cumulative probability (P)
$-0.12 + 56\ (P-0.3)^2$	$0.30 \le P \le 0.35$
$+0.16 - 56\ (P-0.4)^2$	$0.35 \le P \le 0.4$
$+0.16$	$0.40 \le P \le 0.75$
$+0.16 - 13\ (P-0.75)^2$	$0.75 \le P$

where P is a randomly generated uniform deviate ($0 \le P \le 1$). For instance, when P is between 0.40 and 0.75, the correction is equal to +0.16. Thus, generating a sufficient number of uniform deviates, we get a transformed Hancock CDF derived from a normal CDF, which is corrected by (1) a uniform deviate, and (2) a correction function. Finally, since the normal CDF is centered at a mean equal to 0, the mean of 1982 Hancock yield ($\hat{Y}_t$ = 142 bu/Ac) is added to bring the transformed CDF at present yield values.

Sutherland Farm

In the text of Chapter III, we have said that the Sutherland cumulative yield distribution sample has been generated from two normal distributions: $N(7, (19)^2)$ and $N9\text{-}63, (23)^2)$. Thus, the generating process is as follows:

Step 1. Generate a uniform deviate between 0 and 1. This deviate is called Z.

Step 2. If $Z \le .9$, then generate a normal deviate (X) with mean 7 and variance $(19)^2$. (Go to step 4).

Step 3. If $Z > .9$, then generate a normal deviate (X) with mean -63 and variance $(23)^2$.

Step 4. Add the normal deviate (X) to the mean of the Sutherland yield series (110.42 bu/Ac in this case).[1] This is,

$$Y_s = X + 110.42$$

where: Y_s = yield sample.

Step 5. Calculate the cumulative probability at Y_s.

Step 6. Return to step (1) and stop after 100 iterations.

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[1]This is done with the purpose of bringing the center of the distribution from 0 to actual yields.