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AN ECONOMIC ANALYSIS OF ALTERNATIVE CROP YIELD COVERAGE PLANS FOR MULTIPLE PERIL CROP INSURANCE

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1988

ABSTRACT

AN ECONOMIC ANALYSIS OF ALTERNATIVE CROP YIELD COVERAGE PLANS FOR MULTIPLE PERIL CROP INSURANCE

By

Gerald D. Toland, Jr.

Congress passed the Federal Crop Insurance Act (FCI Act) of 1980 to establish Multiple Peril Crop Insurance (MPCI) as the primary crop disaster program for agricultural producers. The Federal Crop Insurance Corporation (FCIC) was enabled under the FCI Act to expand MPCI's availability under the AREA Coverage Plan (AREA Plan). The AREA Plan was linked to adverse selection and low participation problems in MPCI.

The FCIC replaced MPCI's AREA Plan in 1985 with the Actual Production History Coverage Plan (APH Plan) to counter MPCI's adverse selection and participation problems.

The two alternative coverage plans and their impacts on a producer's MPCI purchase decision, were investigated in this dissertation. An MPCI purchase decision model and crop yield estimation procedures and were applied to better understand the factors that affected a producer's MPCI participation under the AREA and APH Plans.

The expected utility hypothesis was applied in the model to simulate a producer's MPCI purchase decision. Crop yield probability distributions (CYPD's) were used to represent uncontrollable variations in a producer's crop yields.

Evidence was presented to indicate that a producer's management skills were just as important as average soil productivity when establishing an insurable yield. The research results were used to predict that the AREA Plan's design as a soils-based technique for insurable crop yield determination would worsen MPCI's adverse selection problem.

The APH Plan was predicted to have marginally improved MPCI's attractiveness to an increased number of producers, as compared to the AREA Plan. New MPCI purchases were predicted under the APH Plan for South Dakota corn producers who were risk averse, had low net wealth and produced mean yields superior to the county average. Producers with medium to high mean corn yields were theoretically predicted to be better-off with an MPCI purchase under the APH Plan as compared to the AREA Plan, while predicted impacts on low mean corn yield producers were indeterminate. Welfare improvements under APH were expected to be small relative to the plan's administrative costs.

Corrected Ordinary Least Squares (COLS) was determined to be an inexpensive technique for estimating CYPD moments from crop yield capacity functions.

This dissertation would not have been
possible without the unswerving support
of my family, friends and colleagues.
It is dedicated to all of them.

ACKNOWLEDGEMENTS

The completion of this work depended on the guidance and support of many people. I thank everyone who aided me in my time of need. At the risk of leaving someone out, I mention those individuals who played a special role in my struggle.

My mentor and friend, Dr. Brian Schmiesing, was essential to the development of the thesis and my research skills. I consider his coaching, prodding and insightful mind as immeasurable factors in making this paper become a reality. Thanks, Brian.

Dr. Roy Black, my thesis advisor, had the courage to place his faith in my work when he might have thought it wise to do otherwise. I am grateful to Dr. Black for the support he gave me at critical points in the research. He made important contributions in sharpening the focus of this research on the critical issues in crop insurance.

I am also grateful to the MSU Agricultural Economics and SDSU Economics Departments for providing me with the technical and administrative support that made this dissertation possible.

My parents, my wife's parents and many friends, through prayers, words and actions, gave me strength to persevere in this endeavor. I owe a large debt of gratitude to all these special people.

Finally, and most importantly, I appreciate the sacrifices made by Mary and Mary Kay, my wife and daughter. Without their patience, this work could not have reached a successful conclusion.

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Chapter One

Introduction

Multiple Peril Crop Insurance (MPCI) was established by the U.S. Congress in 1938. MPCI was originally known as All-Risk Crop Insurance (ARCI). The ARCI program was eventually renamed as MPCI because the crop yield perils insured under the program were limited in number. The MPCI acronym was used throughout the rest of this study to identify the program in its past and present form.

The Federal Crop Insurance Corporation (FCIC) was authorized by Congress in 1938 to administer MPCI. The FCIC was founded as an agency of the U.S. Department of Agriculture (USDA). Throughout its past fifty years of operation, the FCIC paid MPCI indemnities to insured producers for crop yield losses caused by drought, blight, flood, frost, insect infestation and approximately one-hundred other uncontrollable perils (FCIC 1983).

The term "producers" referred to farmers who managed crop enterprises that qualified for MPCI coverage. Producers participated in MPCI voluntarily. When a producer decided to enter the MPCI program, he paid a premium for the insurance coverage.

Congress limited the available acreage and crops that could be insured under MPCI throughout most of the program's history. Consequently, the number of acres insured by producers with MPCI was generally much less than the volume of crop acreage in production. For example, U.S. producers in 1980 placed 27 million cropland acres

into the MPCI program and harvested an estimated 342 million acres of principle crops (AACI 1987; USDA, ERS 1988). The proportion of harvested acreage enrolled in the MPCI program during the 1938-1980 period was generally ten percent or less. Congressional agencies which reviewed MPCI determined that the limitations which had been placed on the program prevented MPCI from serving as an effective disaster relief mechanism for producers (GAO 1977; CBO 1978).

The year 1980 was a turning point in the development of the MPCI program. The Federal Crop Insurance Act (FCI Act) of 1980 was passed by the Congress to strengthen the MPCI program and encourage greater producer participation. Important policy changes in the MPCI program were initiated by the FCIC under the FCI Act.

Two alternative FCIC policies associated with the FCI Act were investigated in this study. The FCIC policies analyzed were competing plans for establishing producers' MPCI yield coverages. The term "yield coverage" referred to a producer's insured crop yield level. Economic and statistical techniques were applied in this study to quantify the effects of the alternative yield coverage plans on a producer's MPCI purchase decision.

An MPCI purchase by a producer was analyzed in this study as a decision made under risk. Risk was defined as the condition where a producer did not know what the exact consequences of a decision would be (Hirshleifer and Riley 1979). Producers were assumed to have personal views about the likelihood of a risky decision's particular outcomes (Savage 1954).

Fluctuations in crop yields and other sources of risk in a producer's farm operation were classified into business and financial categories in previous research (Gabriel and Baker 1980). Business risks were considered to be variations in net income caused by stochastic agricultural production and/or marketing conditions. Financial risk was the additional fluctuation in a producer's net income attributable to debt financing (Gabriel and Baker 1980). MPCI's potential as a tool for managing financial risk was examined in previous research (Pflueger and Barry 1986). The main focus of this study was the impact of MPCI on a producer's business risk of crop yield loss.

1.1. Justification for the Study

Congress hoped to improve farm income stability when the FCIC and its MPCI program were initially established (Halcrow 1984). However, the FCIC incurred large net indemnity losses with MPCI during the years 1938-1947. Congress subsequently scaled back its intentions of having MPCI serve as a major farm program. MPCI was maintained as an experimental project during the years 1948-1980 (Kramer 1983).

MPCI's current importance as a research topic was rooted in the FCI Act of 1980. The FCI Act was legislated by Congress to expand and

improve MPCI. Three primary changes initiated under the FCI Act were outlined and subsequently discussed below (U.S. Congress 1980):

1. MPCI was to become the primary government-subsidized method for producers to protect their incomes from crop failures. The MPCI program was no longer considered experimental. The FCI Act also contained provisions for phasing out the Disaster Payment Program (DPP). Producers' MPCI premiums were to be directly subsidized.
2. Private insurers were permitted to market MPCI. The FCIC was directed to perform actuarial and re-insurance functions for the private MPCI marketers.
3. The FCIC was empowered to make changes in its methods for determining MPCI premiums and insurable yield coverages. Actions taken by the FCIC were to encourage increased MPCI participation while maintaining the actuarial soundness and financial stability of the program.

MPCI'S Expansion. The number of crops and counties eligible for the MPCI program increased after the FCI Act's passage. The DPP was eliminated. Under the 1985 Farm Bill, participation in the Disaster Loan Program of the Farmer's Home Administration was restricted to those producers who had purchased MPCI in the preceding crop year (FCIC 1988). A direct subsidy to participating producers decreased their premiums by a maximum of thirty percent for yield coverages up to sixty-five percent of the insurable mean yield.

Marketing MPCI. Private insurers were encouraged to sell MPCI for two primary reasons. First, hail/fire crop insurance (H/FCI) was marketed separately from MPCI by private firms prior to the FCI Act. Insurers who sold H/FCI often considered MPCI's hail/fire coverage to be subsidized competition (Kramer 1983). Part of the FCI Act was written to allow a producer to drop the hail/fire coverage from an MPCI policy, obtain a reduced MPCI premium, and substitute an equal amount of H/FCI in place of the MPCI coverage.

A second reason why private insurers were "hired" to market MPCI was their potential ability to expand sales. The private firms were considered to have the profit incentive to seek out new customers. Crop insurance agents were also thought to have gained familiarity with producers through the sales of other insurance lines (FCIC 1987).

MPCI Program Changes. The FCIC was given the authority to expand producer use of MPCI by altering coverage and premium rate structures. The FCIC had developed the AREA Coverage Plan prior to the FCI Act to determine MPCI yield coverages within geographic areas of a county. This study was specifically concerned with the transition from the FCIC's AREA Plan to a new coverage plan, the Actual Production History (APH) Plan. The APH Plan was the FCIC's attempt to increase producer participation in MPCI by overcoming the adverse selection problem in MPCI's AREA Plan.

1.1.1. Adverse Selection and the AREA Plan

Yield coverage determination under the AREA Plan was partly based on the USDA's Statistical Reporting Service (SRS) county-level crop yield data. The FCIC also utilized soil maps and other indicators to identify geographical areas within a county for MPCI purposes. The technical area information and the SRS county-level crop yield data were used to specify the insured crop yield levels within designated areas of a county.

If a producer's mean farm yield was greater than MPCI's area yield, he could only insure his crop up to the area yield limit. If a producer purchased MPCI under the AREA Plan, and if his historical mean yield were below the area yield, then he could obtain coverage which possibly exceeded his own expected yield. Not surprisingly, MPCI's AREA Plan was often purchased by producers with low mean yields (GAO 1977).

A producer had an increased chance of indemnity collection when the area yield coverage was a high proportion of his own mean yield. Adverse selection was defined to occur in any insurance program when the main pool of insured clientele collected indemnities more frequently than the potentially insurable population (Greene and Trieschmann 1981).

Adverse selection reduced the potential market for MPCI. MPCI was predominantly attractive to producers with yields below the area mean level. A goal of the Congress was to have MPCI become a major factor in farm income protection during crop yield disasters. If MPCI were to serve as a significant force for stabilizing net farm income, then

a larger proportion of producers would need to perceive MPCI as an economically rational purchase.

An independent group of insurance consultants and the Congress's General Accounting Office recommended that MPCI coverages be based on individual producer yield records instead of an area's mean yield (FCIC Task Force 1970; GAO 1977). The FCIC temporarily created the Individual Yield Coverage (IYC) Plan in 1984 to give producers the option of insuring their own yields or using the AREA yield (FCIC 1984). The APH Plan replaced the IYC and AREA Plans in 1985 (FCIC 1985). MPCI yield coverages were primarily based on producer yield records and/or ASCS yields under the APH Plan. In general, producers could not select the AREA yield coverages once the APH Plan was in place.

1.1.2. The Actual Production History (APH) Plan

The APH Plan was developed to increase producer participation in MPCI (FCIC 1985). Producer participation was to be expanded in two ways. First, MPCI's economic attractiveness was to be improved for producers who had mean crop yields greater than or equal to the area mean yield. Second, producers with low but improving mean yields were to be provided with an incentive to enter or remain in the program.

Two mechanisms were used to encourage MPCI purchases by producers who could appropriately demonstrate that their own mean crop yields were rising over time. Those mechanisms were: (1) to increase the insurable yield, and (2) to decrease the premium rate associated with the insurable yield.

A ten-year record of crop yields on a "farm unit" was utilized to compute the insurable "APH yield" under MPCI's APH Plan. An MPCI farm unit was determined on the basis of land parcel ownership, production records, a parcel's legal description and special production practices (e.g., irrigation). The APH yield was an olympic mean of a producer's own crop yields over a ten year period. The term "olympic" meant that the high and the low yields in the ten year series were eliminated before the APH mean was calculated. A producer could insure 50%, 65% or 75% of the APH yield (FCIC 1985).

If a producer did not have ten years of yield data, then the FCIC would substitute "transitional" yields. The transitional yields were a percent of the producer's ASCS yield.[1] If the producer purchased MPCI over a number of years, transitional ASCS yields would be gradually replaced by the producer's actual yields until all ten years of data were filled.

Ratemaking, the method for setting premium rates, was also modified to a limited extent under APH. Premium rates were generally recalibrated to a "sliding scale": the premium per acre decreased as the producer's APH yield rose. However, the FCIC made only gradual changes in the APH Plan's per bushel premium rates because of actuarial concerns (Driscoll 1986).

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[1] The Agricultural Stabilization and Conservation Service (ASCS) was created as an agency to administer the USDA's farm programs. The ASCS yield was the basis for determining a producer's farm program payments.

1.1.3. Need for the Study

Ratemaking and other post-1980 changes in MPCI were analyzed by agricultural economists (Zering, McCorkle, and Moore 1987; Skees and Reed 1986; Pflueger and Barry 1986; Black, et. al. 1985; King 1984; Dudek and Allen 1984). Legislators, FCIC administrators and crop insurance marketers were among the groups interested in research on APH premium and coverage plans and the associated changes in overall MPCI use by producers.

The method used to determine a producer's MPCI yield coverage was considerably changed when the FCIC replaced the AREA Plan with the APH Plan. The economic effects of that transition in yield coverage were not studied in previously published MPCI research.

Congress expected the FCIC to demonstrate that new policies such as the APH Plan were likely to increase producer participation in MPCI. The FCIC also faced congressional pressures to maintain a long run balance between premium collections and indemnity payments as participation in the MPCI program grew. The APH Plan's long term actuarial soundness was not investigated in this study because of limited time and resources. The impacts of alternative coverage plans on MPCI use by producers were studied.

1.2. Problem Statement and Study Objectives

The FCIC's AREA and APH Plans and their effects on producers' MPCI purchases were investigated in this dissertation. The expected utility hypothesis (EUH) was applied to analyze producers' perceived crop yield risks, risk attitudes and net wealth positions as important

explanatory variables in the MPCI purchase decision. The results of the analysis had implications for the potential to improve MPCI participation with the APH Plan by reducing the adverse selection problem that existed under the AREA Plan.

The three specific objectives of the study were to:

1. empirically estimate producers' subjective views of their crop yield probabilities,
2. theoretically analyze how producers' subjective crop yield perceptions, risk attitudes and wealth level influence the MPCI purchase decision, and
3. identify policy and welfare implications of an MPCI purchase decision model when insurable yields were determined under the AREA and APH Coverage Plans.

1.3. Research Methods

The MPCI purchase was analyzed as a decision made under risk. Insurable crop yield losses were considered risky events because the underlying probability distribution of crop yields was not precisely known by the producer. The EUH was developed to analyze how individuals make risky decisions (Arrow 1971). An application of the EUH was used in this study to investigate the producer's MPCI purchase. One of the basic assumptions in the EUH was that decision makers formulate subjective probability distributions of risky events (Savage 1954).

The study's research methods were divided into four basic steps to analyze the MPCI purchase as an economic decision made under risk:

1. Subjective crop yield probability distributions (CYPD's) were obtained using an elicitation procedure developed in previous research (Nelson and Harris 1978; Pease 1987). The CYPD's were elicited from a random sample of South Dakota producers. The sample was taken from Brookings County, located on the East Central boundary of South Dakota.
2. Alternative techniques for approximating subjective CYPD's were sought. Crop yield capacity functions were econometrically estimated with county-level crop yield data obtained from the South Dakota Crop and Livestock Reporting Service (SDCLRS). CYPD's were derived from the capacity functions (Gallagher 1983, 1986, 1987). CYPD's were also derived directly from a frequency distribution of the observed historical county crop yield data.

   The subjective CYPD's obtained with elicitation methods were aggregated. The capacity-derived and the historical-frequency CYPD's were statistically compared with the aggregated-elicited CYPD's to determine whether subjective CYPD's could be estimated more economically.
3. A producer's MPCI purchase/no purchase decision was modeled under the AREA and APH Plans using an application of the EUH. Alternative assumptions were made about the

underlying crop yield probability distribution, producer risk attitude and wealth level in the model.

4. The results of the MPCI purchase decision model were analyzed to determine the economic implications of the AREA and APH Coverage Plans for producers.

The subjective CYPD estimations outlined above were incorporated into an EUH analysis of a producer's MPCI purchase decision. Each CYPD was used to derive a distribution of net wealth and income, given that an MPCI purchase decision was made and that prices were deterministic. It was assumed in the EUH that decision makers selected the distribution of net wealth and income which maximized expected utility (von Neumann and Morgenstern 1944).

The EUH model used to study the MPCI purchase consisted of subjective CYPD's evaluated by two alternative parametric utility functions. The utility functions shared the property of decreasing absolute risk aversion as a producer's net wealth increased, but differed in the rate of change of risk aversion with respect to net wealth.

The EUH analysis of the MPCI purchase decision was based on an approximation to a producer's global risk attitude (Robison and Barry 1987). A "global" expected utility value (EU_{global}) was derived for each ending net wealth distribution (ENWD) associated with an MPCI purchase decision.

A EU_{global} was first derived for a producer with no MPCI coverage. Then the MPCI purchase was analyzed. The MPCI premium was adjusted until the producer's EU_{global} with an MPCI purchase was equal to the producer's EU_{global} without MPCI. The premium rate which equated the

producer's EU_{global} with MPCI to his EU_{global} without MPCI was called the "indifference premium rate." If the indifference premium rate was higher than the FCIC's actual premium rate, then the producer was predicted to buy MPCI in the model; otherwise, MPCI was not purchased.

The EU_{global} analysis was used to evaluate the MPCI purchase decision under the AREA and APH Plans for alternative assumptions about a producer's perceived CYPD, risk attitude, and wealth level. Implications were drawn from the results of the decision model for producer participation in the MPCI program.

An important component of the MPCI purchase decision model was a producer's subjective CYPD. Crop yield capacity functions and historical frequency distributions were alternative methods used to approximate the subjective CYPD's derived from the elicitations.

Credibility and aggregation theories were applied to compare the results of alternative CYPD estimations. Credibility theory, a set of actuarial principles, was a basis for validating or "checking" the elicited CYPD results against information contained in other data sources (Longley-Cook 1962). Aggregation theory, borrowed from the statistics discipline, was used to guide the techniques for combining individual elicited CYPD's into "representative" CYPD's which could be compared with CYPD's derived from county level crop yield data (Ijiri 1971).

Statistical goodness-of-fit (GOF) tests of the CYPD's were used to identify similarities and differences among the estimated CYPD's. The GOF tests required that pairwise comparisons of the CYPD's be

performed. Each pairwise comparison tested the null hypothesis that the alternative CYPD's were drawn from the same parent distribution.

The possible outcomes of the pairwise CYPD comparisons had implications for the methods used to analyze a producer's MPCI purchase.

If there were similarities among the subjective, capacity and historical-frequency CYPD's, then all three measures of yield variability would be equivalent in their ability to assess the risks created by natural crop yield hazards. The frequency distribution of historical county yield data was the simplest and least cost method for CYPD estimation. The historical-frequency CYPD's could be chosen as an economical source of information on perceived crop yield risk.

If the historical-frequency CYPD's were statistically similar to the subjective CYPD's, and if the capacity-derived CYPD's were determined to differ from both the subjective and historical-frequency CYPD's, then the historical-frequency CYPD's would again be the least expensive estimator of producer perceptions.

Suppose the capacity-derived CYPD's and historical-frequency CYPD's were similar to each other, but neither was similar to the subjective CYPD's. Such a result might indicate that the statistical procedures were unable to estimate producer perceptions. Alternative statistical estimation techniques could be sought. There also might be a re-examination of the methods used to elicit the subjective CYPD's from the producers.

One other possible outcome was a statistical similarity between the capacity-derived and subjective CYPD's, while the historical-frequency CYPD's were observed to be dissimilar to the both the

capacity and subjective CYPD's. Such a result would support the notion that producers adjust their subjective CYPD's for technological and environmental factors that influence their crop yield risks. In addition, The FCIC could use the capacity function technique to obtain estimates of producers' perceptions of crop yield probabilities.

1.4. Organization of the Dissertation

The justification, objectives and procedures for the research were presented in chapter one. A background on the economic and policy issues surrounding the MPCI program was provided in chapter two. Expected utility theory and its application to the crop insurance purchase decision were studied in chapter three. Techniques for crop yield probability distribution estimation were presented in chapter four. Procedures and results for the subjective CYPD elicitations and aggregations were explained in chapter five. Crop yield capacity functions and frequencies of historical crop yield data were used to derive CYPD's in chapter six. Comparisons of the subjective, capacity-derived, and historical-frequency CYPD's were also performed in chapter six. The MPCI purchase/no-purchase decision under the AREA and APH plans was modeled with an application of the EUH in chapter seven. The conclusions and implications of the analyses and estimation procedures were presented in chapter eight.

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Chapter Two

The Origins, Problems and Goals of USDA's Multiple Peril Crop Insurance Program

The U.S. Congress passed the FCI Act in 1980 to expand and improve USDA's MPCI program. MPCI was changed from an experimental insurance plan to a nationwide form of federal crop disaster assistance under the FCI Act.

The FCI Act was the frame of reference used in this chapter to examine the FCIC's AREA and APH Coverage Plans for MPCI. The development of the AREA Coverage Plan was described. Congressional objectives for MPCI contained in the FCI Act were examined. The details of how the FCIC changed MPCI under the APH Plan were discussed. Implications of the current MPCI policy environment for this research were identified in the chapter's conclusion.

2.1. MPCI's AREA Coverage Plan

Prior to 1985, the crop yield which a producer insured under MPCI was primarily an area mean yield determined within a county. The combination of FCIC policies and procedures used to determine MPCI crop yield coverages for county areas was referred to in this study as the "AREA Coverage Plan" (or AREA Plan).

The FCIC's decision to insure a crop under MPCI's AREA Plan was made on a county-by-county basis. Each MPCI crop-county combination was known as a "county program." There were 375 county programs for

six different crops in 1948. By 1978, over 3,989 county programs were in place for twenty-six different crops (FCIC 1980).

Yield coverages for MPCI county programs were based on historical county crop yields, soil surveys, rainfall maps, topography maps and other related data sources (FCIC 1983b). The FCIC's Actuarial Division initially determined a crop's mean county yield using the USDA's Statistical Reporting Service (SRS) data. The mean historical county crop yield derived for MPCI purposes was simply referred to as "the SRS Yield."

An FCIC field actuary used soil surveys and other information to subdivide a county into separate insured areas. The fictional county used as an example in Figure 2.1 was divided into three areas. Areas with productivity ratings above the county mean level were assigned yield guarantees above the SRS yield, while lower-rated areas received guaranteed yield coverage less than the SRS yield (FCIC 1984).

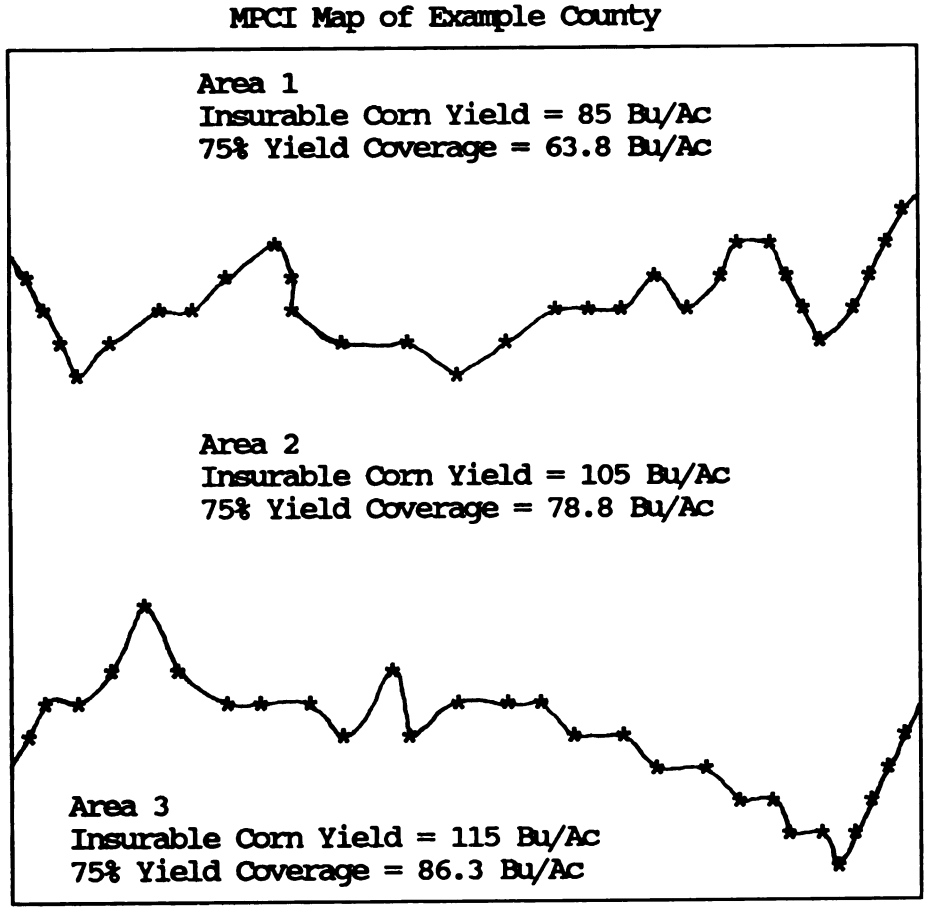

Figure 2.1 Hypothetical Example of MPCI's AREA Coverage Plan (FCIC 1983b).

The term "insurable yield" for each area referred to the mean yield used to calculate the yield coverage. For example, the insurable corn yield in Area 1 was 85 Bu/Ac, and the 75% yield coverage was 63.8 bu/ac (75% x 85 Bu/Ac) (See Figure 2.1). A producer in Area 1 had to experience a corn yield below 63.8 Bu/Ac before an indemnity was paid. The indemnity would be based on the difference between the yield coverage and the actual yield. The mean of the area yield coverages, weighted by each area's production, equalled 75% of the county's overall production (see Table 2.1).

A distinct method was used to determine coverages for area yields within a county. The FCIC multiplied the SRS yield by the mean historical crop acreage to calculate the county's production. Only 75 percent of a county's production, in terms of total bushels, could legally be guaranteed by the FCIC (see Table 2.1 and Figure 2.1). There was an important consequence of this legal requirement: an increased guaranteed yield to one county area automatically meant a decreased guarantee in another area of the same county.

Table 2.1 Example Calculation of Insurable Production for MPCI's AREA Coverage Plan (FCIC 1983b).

	Area Number 1	2	3	Totals	Weighted Yield
(A) Area's Planted Corn Acres	30,000	60,000	10,000	100,000	N/A
(B) FCIC Area Corn Yield in Bu/Ac	85.00	105.00	115.00	N/A	100.00
(C) 75% Guaranteed Yield in Bu/Ac [0.75·(B)]	63.75	78.75	86.25	N/A	75.00
(D) Area's Insurable Production in Thousands of Bushels [(A)·(C)]	1,912.5	4,725.0	862.5	7,500.0*	N/A

* The county's insurable production could not be exceeded. If the guaranteed yield were to rise in Area 1, then the guaranteed yield in Areas 2 and/or 3 would be reduced to maintain the same level of insurable production in the county. See Figure 2.1.

The producers most likely to purchase MPCI under the AREA Plan had farm-level mean yields which were less than or equal to the yield level actually insured (Larson 1967). Producers with farm-level mean crop yields that exceeded the area mean yield could not obtain additional coverage. For example, a corn producer in Example County's Area 1 with a 100 bu/ac yield mean could only obtain coverage based on the area's 85 bu/ac yield (see Table 2.1). Producers with yields above the MPCI area mean yield were less likely to join the program because the insurance coverage was not high enough to justify the premium being charged. Some of these better producers indicated they would pay an increased premium rate if they could somehow obtain a higher coverage level (Cole 1967). Participation in MPCI was diminished by the adverse selection of producers with low mean yields.

2.2. Participation in MPCI under the AREA Plan

Participation rates -- the percentage of eligible cropland acres enrolled in MPCI -- were persistently low throughout the 1948-1980 period (Halcrow 1984). In addition, The FCIC incurred occasional large net losses occurred when MPCI premiums did not keep pace with indemnities (Kramer 1983). MPCI could not be relied upon to provide much economic stabilization in the event of a major crop disaster (GAO 1977).

Major causes of MPCI's low participation were outlined and subsequently discussed below:

1. competition from hail/fire crop insurance, other federal crop disaster programs, and self-insurance,
2. limitations placed on the MPCI's availability and delivery system,
3. the need for subsidies to encourage producer participation, and
4. the adverse selection problem in MPCI.

2.2.1. Competition Between MPCI and Its Alternatives

Hail/Fire Crop Insurance (H/FCI). H/FCI and MPCI often competed for the producer's limited premium dollar because of overlapping coverage. Income protection was provided against the perils of hail and fire in H/FCI policies, whereas MPCI covered hail and fire in addition to many other perils. Producers could not substitute H/FCI in place of MPCI's hail/fire coverage under the pre-1980 MPCI program (AACI 1987).

MPCI's coverage method was not always well designed to meet producers' hail/fire income protection needs. Problems developed because MPCI's indemnity payments were based on "farm unit" yields. Farm units did not have a uniform interpretation, but were determined by applying a general set of guidelines to specific situations. A farm unit was sometimes defined as a producer's entire farm acreage devoted to a particular crop. A farm unit could also have been a separate land section owned by the producer in an adjacent county.

Unit definition was traditionally a source of contention between the FCIC and its MPCI policy holders (FCIC 1985). Producers who had

damaged crops sometimes did not collect the MPCI indemnities that they expected. If specific fields were "hit hard" by hail or fire, the reduced yields could not be used as the sole basis for receiving an MPCI indemnity. MPCI indemnities were calculated only after the damaged yields were averaged with the yields from the remaining portions of the farm unit. After averaging, some producers found that no indemnity could be paid under MPCI, even though a crop yield loss had occurred.

H/FCI provided a choice between unit and "spot" coverage. Spot coverage allowed producers to insure a specific field. Spot coverage was unavailable in MPCI because of risk estimation difficulties and a high potential for insured producers to abuse the program. Spot coverage was insurable under H/FCI because the fields most susceptible to hail/fire damage could be identified with relative ease. H/FCI per acre premiums for spot coverage were adjusted to reflect the chance of crop yield damage.

The contrast between unit area and spot coverage was partly a reflection of the differences in the goals of MPCI and H/FCI programs. MPCI was developed to provide insurance protection against numerous perils which could threaten producers' entire farm operations. H/FCI was designed to provide coverage against limited and narrowly defined crop perils.

H/FCI was more flexible than MPCI in terms of the producer's time of purchase. A producer was able to buy H/FCI anytime during the growing season. There was a 24-48 hour delay between the H/FCI

purchase and activation of its coverage. A producer was required to buy MPCI before the planting season began.

There also was a difference between H/FCI and MPCI in their indemnification methods. Yield levels were insured under MPCI. A crop was insured for up to its "Actual Cash Value" with H/FCI (e.g., a producer could use H/FCI to insure his corn crop for $100/ac, usually with a 5% deductible. If a producer lost 20% of his mean historical crop yield to hail damage, he would receive $15/ac in indemnities) (Toland and Pflueger 1988).

Federal Disaster Programs. Researchers observed a tendency for the Congress to create ad hoc disaster programs following major catastrophes (Dacy and Kunreuther 1969; CBO 1978; GAO 1977). Ad hoc disaster programs removed producers' incentives for insurance program participation. Disaster programs also proved to be a much larger tax burden than a subsidized insurance program such as MPCI (CBO 1978).

The USDA's Disaster Payment Program (DPP), Farmers Home Administration's (FHA's) Disaster Loan Program (DLP) and Small Business Administration's (SBA's) loan program were examples of subsidized crop disaster programs which competed with MPCI. During the 1970's, producers in the USDA production control programs were eligible for benefits from the DPP without paying a premium.

The FHA's DLP and the SBA's loan program permitted producers to recover from crop failures at below-market interest rates. The interest charges were often less costly to producers than MPCI participation (CBO 1978). The programs also made the option of self-insurance more attractive.

Self-Insurance. Self-insurance techniques were more prevalent among producers than either H/FCI or MPCI. Self-insurance was defined here to include approaches to risk management that did not involve the formal purchase of crop insurance. Such methods included the accumulation of cash reserves, geographic dispersion of crops, enterprise diversification, risk-reducing technologies (e.g., use of drought and disease resistant varieties), share-rent agreements, and weed and pest control measures (Jose 1986).

A number of hypotheses were proposed in this study to explain why producers chose self-insurance over MPCI. These hypotheses were based on the theory of risk-bearing (Arrow 1971).

First, enterprise diversification and other risk management methods could cause some producers to view the MPCI purchase as unnecessary or irrational. Risk management techniques other than MPCI were used by producers to accomplish the same goal as an MPCI purchase: a reduction in the size of negative deviations from mean net income.

It was also possible that many producers were not risk averse. Low risk aversion implied that a producer preferred an uninsured net income distribution with a higher coefficient of variation (CV) than the CV associated with an insurance purchase (Arrow 1971). The CV of a distribution was the standard deviation divided by the mean.

The wealth position of the producer was posited as an important variable in the decision to self-insure. Net equity was considered as a measure of wealth. If a producer increased his net equity position, he increased his ability to financially withstand a crop failure. Pratt (1963) and Arrow (1963) indicated that a decision maker's risk

aversion decreased as his net wealth increased. Self-insurance was associated with growth in a decision maker's net wealth.

The amount of insurance coverage a producer could purchase with the available MPCI program was also a possible factor in the self-insure decision. If a risk averse producer could not obtain sufficient risk reduction with MPCI for the premium charged, then he would self-insure.

One institutional reason for the dominance of self-insurance was the congressional restriction on MPCI's availability prior to 1980. Many producers were unable to insure their crops simply because no MPCI program existed in their county.

2.2.2. MPCI's Limited Availability and Delivery System

Product availability and an effective distribution system were observed to be critical factors in the marketing of any product (Evans and Berman 1987). MPCI was no exception. Before 1980, the number of crops and counties covered under MPCI were limited. FCIC employees were primarily responsible for selling MPCI prior to the FCI Act.

MPCI's competition often had superior delivery systems. For instance, H/FCI agents often had regular contacts with producers. These agents frequently sold property, casualty and other conventional insurance products to producers. Government programs such as the DPP and DLP were administered by the ASCS and FHA offices which were routinely used by many producers. In contrast, FCIC representatives sold only the MPCI product, and generally did not have advantage of

operating from an office frequented by producers who were potential MPCI users.

Even if producers had better access to the MPCI product, there was still some question of whether a producer perceived MPCI's worth the premium being charged by the FCIC.

2.2.3. The Need to Subsidize MPCI Premiums

Agricultural economists studied MPCI and concluded that premiums must be subsidized to attract enough producers for the insurance system to have a sizable impact on farm income stabilization (Nieuwoudt, et. al. 1985; Gardner and Kramer 1982). Similar recommendations were made by economists investigating other types of disaster relief programs such as flood insurance (Dacy and Kunreuther 1969; Kunreuther and Slovic 1978).

If the MPCI studies were representative of actual producer behavior, then pre-1980 MPCI participation was reduced because Congress did not directly subsidize MPCI's premiums. For example, Gardner and Kramer (1982) specifically estimated that a 50% premium subsidy was necessary to attract a majority of the U.S. crop acreage into MPCI.

MPCI's administrative costs were subsidized prior to and after the FCI Act. Such government support indirectly reduced the premiums charged to producers and helped increase MPCI participation rates to some degree.

Lemieux, Richardson and Nixon (1983) simulated MPCI use under the AREA coverage plan. Their analysis was applied to Texas cotton and grain sorghum farms. It was determined that MPCI would be purchased

when there was a 30% subsidy on the 50% and 65% coverage levels. It was also predicted that MPCI's 75% coverage level would not be purchased when the 30% subsidy was discontinued above the 65% level.

2.2.4. MPCI's Adverse Selection Problem

Adverse selection contributed to MPCI's participation problem (see section 2.1 of this chapter). The AREA Plan's problems were associated with the FCIC's history of crop yield data collection procedures. Farm-level data were originally used during 1938-1943 to set premium rates. These farm-level yield data were obtained from individual producers and ASCS Offices, and often consisted of a short crop yield history (Clendenin 1942). A data base with more than twenty years of farm-level yield records was actually needed to measure yield variability (Kramer 1983). The inability to accurately estimate downside yield risk from the existing data contributed to MPCI's 1938-1943 record of indemnities exceeding premiums.

During the years 1946 to 1980, the FCIC sought more reliable data sources. The AREA Plan was devised by the FCIC during this time. The FCIC used the SRS county-level data because a longer time series was available and the method of reporting crop yields was similar from year-to-year. The FCIC was successful in balancing premiums and indemnities under the AREA Plan. The FCIC's overall ratio of indemnities to premiums from 1948 to 1978 was 0.98, which meant that producers paid slightly more in total premiums than they received in indemnities (FCIC 1980).

If the FCIC offered MPCI coverage for the first time in a county for a particular crop under the AREA Plan, the premium rates were initially estimated using SRS yields. The frequency of different crop yields were be modeled with a normal probability distribution (Botts and Boles 1958). Crop yields were assumed to be normally distributed about the historical mean yield for the county. The yield standard deviation was assumed to be 25 percent of the county mean yield. After MPCI was allowed to operate in a county for a number of years, the process of setting the premium rates became based on a moving average of the county's loss history (Ray 1981).

The moving average procedure resulted in increased MPCI premiums when adverse selection occurred in the AREA Plan. The county loss history would eventually reflect the indemnity collections of producers who frequently experienced insurable yield damages. Increased premiums were needed to offset the growth in indemnities. Inflating premiums were a disincentive for new producers to join the MPCI program. Increased MPCI participation was an important goal identified in the FCI Act.

2.3. The Federal Crop Insurance Act of 1980 (FCI Act)

GAO (1977) and CBO (1978) studies were used to indicate that the market for MPCI would increase if: (1) other competing programs were removed, (2) MPCI's coverage were extended to more crops and a larger geographic area, (3) MPCI premiums were subsidized and (4) producers were enabled to insure their own mean yields.

The Congress responded to the various MPCI studies and its own budgetary pressures by legislating the FCI Act. The title of the FCI Act of 1980 was: "An Act to Improve and Expand the Federal Crop Insurance Program, and for Other Purposes" (U.S. Congress 1980). The FCI Act was enacted to significantly increase MPCI's participation and phase out the other crop disaster programs (Gardner and Kramer 1982).

The content of the FCI Act was described by outlining its goals, policies and plans for implementation (see Table 2.2).

Table 2.2 A Summary of the Federal Crop Insurance Act of 1980.

Goal A:

To establish MPCI as a primary government program for crop disaster protection.

Policies to Achieve Goal A:

1. Crop disaster relief programs other than MPCI were to be discontinued.
2. Increased participation in MPCI was strongly encouraged.
3. MPCI coverage was made available to as many crops and areas as was possible.
4. Public awareness of MPCI was to be enhanced.

Plans of Action for Implementing Policies:

1. The Disaster Payment Program was discontinued.
2. A subsidy, not to exceed 30% of a producer's premium, was established to increase MPCI participation.
3. The FCIC utilized information available in other government agencies to classify more areas and crops for MPCI coverage.
4. The FCIC designed MPCI public education programs.

Goal B:

To improve the actuarial soundness and stability of the MPCI program.

Policies to Achieve Goal B:

1. Premiums were adjusted until they adequately covered indemnities.
2. MPCI coverage was limited to be no more than 75% of an approved mean yield.
3. The FCIC was empowered to create programs to increase participation while maintaining MPCI's soundness.

Plans of Action for Implementing Policies:

1. The FCIC sponsored research on how to set premium rates which offset indemnity payments.
2. The FCIC provided producers the option to select a coverage level which was 75%, 65% or 50% of an average yield level.
3. The FCIC devised coverage and premium plans to increase MPCI's marketability.

Table 2.2 (Cont'd.).

Goal C:

To encourage the private insurance industry to market MPCI.

Policies to Achieve Goal C:

1. Private firms were authorized to market MPCI. The FCIC was to serve as a source of actuarial data and advice for firms selling MPCI.
2. The FCIC shared the financial burden with private insurers to meet the cost of catastrophic losses.

Plans of Action for Implementing Policies:

1. MPCI was sold by licensed representatives of full-service crop insurance companies. The FCIC hired limited-service Master Marketers to provide another channel to sell MPCI. Actuarial tables developed by the FCIC were used by all the private insurers.
2. The FCIC acted as a re-insurance company for the full-service companies who marketed MPCI. The FCIC was the insurance company represented by the Master Marketers.

Participation Objectives for MPCI. One goal of the FCI Act was to have MPCI become the primary government-subsidized crop disaster program (Table 2.2, Goal A). Implementation of this goal meant that MPCI participation was to be increased. The methods chosen to increase MPCI use by producers included reduction or elimination of MPCI's competing programs and the creation of a direct MPCI premium subsidization program.

Ad hoc disaster programs were more expensive for taxpayers and sometimes less equitable for producers than MPCI (CBO 1978; GAO 1977). Pressures for budget austerity throughout government created a congressional desire for a unified and efficient system to manage crop yield risk. Ideally, the diminished use and availability of

other crop disaster programs was expected to induce higher producer participation in MPCI (see section 1.1 of chapter one).

Congress also hoped to increased MPCI participation with the premium subsidization plan initiated under the FCI Act. The three yield coverage levels which could have received a subsidy were 50%, 65% or 75% of an insurable mean yield. The 50% and 65% coverage levels received a maximum 30% subsidy. The additional coverage between the 65% and 75% coverage levels was not subsidized.

MPCI's Actuarial Basis. Another congressional goal in the FCI Act was to improve the actuarial soundness and financial stability of the MPCI program (Table 2.2, Goal B). This goal was focused on the insurance system's long term viability.

Congress discontinued the MPCI program in the 1940's after large losses were incurred. Ongoing congressional support for MPCI was conditional. Congress expected MPCI to remain actuarially sound as efforts were made to expand producer participation in the program.

The definition of a "sound" MPCI program differed from its conventional usage in the private insurance industry. Actuarial soundness in most lines of private insurance meant that client premiums alone would cover indemnities and operational costs. A private insurance firm would also expect to earn a net profit as a return for risk-bearing.

The definition of actuarial soundness as it applied to MPCI did not require the client premiums to cover all costs and generate a return. Congress authorized the FCIC to adjust premium rates to achieve an indemnity/premium ratio (loss ratio) of 1.0. The premium

measure in the MPCI loss ratio was the sum of producer's premium plus the government subsidy (FCIC 1987). MPCI's administrative costs were completely supported by government subsidies to the FCIC.

MPCI's financial stability included FCIC's access to and maintenance of a financial capital base. FCIC needed the base for borrowing when catastrophic events over large geographic areas created large MPCI indemnity outlays. Congress recognized FCIC's need for capital by allocating $500 million to the FCIC to pay producer claims during years when indemnities exceeded collected premiums (U.S. Congress 1980). The Congress also granted the FCIC authority to borrow additional money from the Commodity Credit Corporation to pay producers' indemnity losses (FCIC 1987).

MPCI's financial stability ultimately depended on its actuarial soundness, because the FCIC could not service its debts if MPCI's indemnities consistently exceeded its premiums. Maintaining actuarial soundness was also an important issue for the private insurance firms who were given the opportunity to sell MPCI.

MPCI's Marketing Plan. The private insurance industry was offered a new role under the FCI Act: the marketing of MPCI to producers (Table 2.2, Goal C). This goal was ultimately aimed at improving MPCI's promotion and delivery system for MPCI. Private sector firms were considered to have a comparative advantage over the FCIC for developing and maintaining customer contacts.

Congress established a cooperative effort between the private sector and the government (FCIC) under the FCI Act. Private firms became sales agents for MPCI. The FCIC's primary functions were to

perform actuarial, underwriting, administrative and reinsurance services. FCIC employees were phased out of MPCI sales.

Two types of private insurers were authorized to market the MPCI product. One was classified as a Master Marketer (MM). The MM's entered into legal contracts with the FCIC solely for sales and sales servicing responsibilities. The FCIC performed underwriting and other insurance functions in conjunction with the sales efforts of the MM's. The second MPCI delivery system consisted of full service private insurers who were re-insured through the FCIC. The FCIC's re-insurance service meant that the private firms who sold MPCI limited their own potential losses by purchasing insurance from the FCIC.

2.4. MPCI: 1981-1986

MPCI was made available in practically every county where significant crop production occurred after the FCI Act's passage. The American Association of Crop Insurers (AACI) indicated that MPCI coverage purchased by producers had increased to 60 million acres by the end of the 1981-1986 period. The 1986 U.S. planted principle crop acreage was measured as 328 million acres, of which 255 million acres were classified as potentially insurable (FCIC 1987). The 1986 MPCI coverage accounted for 24% of the potentially insurable acres.

The FCIC was empowered to make significant alterations in MPCI under the FCI Act, as long as those changes were to expand and improve the program. A modification of MPCI was the Individual Yield Coverage (IYC) program in 1984 (FCIC 1984). The IYC was a transitional program between the AREA and APH Plans. Under the IYC,

producers were allowed to choose between their own production records or the FCIC's area crop yield averages as the basis for MPCI's coverage. The IYC was initiated by the FCIC to encourage producers with higher mean yields to buy MPCI (FCIC 1984).

The AREA and IYC programs were superseded by the Actual Production History (APH) Plan in 1985 (FCIC 1985). Producers relied exclusively on their own yield records and ASCS yield data under the APH Plan to determine their coverage. The AREA yields were no longer a producer option for most crops and counties.

2.5. A Description of the APH Plan for MPCI

The FCIC introduced the APH Plan to enhance MPCI's economic attractiveness to producers whose historical mean yields exceeded the AREA Plan's insurable yields. Ideally, MPCI participation was to be broadened under the APH Plan by attracting an increased number of superior producers, while not losing too many of the producers who had frequently purchased MPCI under the AREA Plan.

MPCI's indemnity and premium structure was modified with the APH Plan to try to achieve the program's participation goals. This section of the chapter was used to outline how MPCI was changed under APH. The APH rules for determining a producer's potential MPCI indemnity payments were examined first. Then the process for calculating a producer's MPCI premium was described.

2.5.1. APH Rules for MPCI Indemnities

Producers collected MPCI indemnities when one or more of fourteen specified natural hazards reduced the actual yield below the yield coverage. The fourteen perils covered under MPCI were: drought, excessive moisture, hail, wind, frost/freeze, tornado, lightning, flood, insect infestation, plant disease, wildlife damage, fire, earthquake, and excessive temperature during pollination. MPCI also provided insurance protection against decreases in crop yield quality caused by natural factors (Toland and Pflueger 1988).

The potential MPCI indemnity received by a producer with the APH Plan was based on three factors:

1. an Actual Production History (or APH) yield,
2. a yield coverage, which was 50%, 65% or 75% of the APH yield on a farm "unit", and
3. an indemnity crop price, which was 60%, 70% or 90% of a predetermined base price.

The APH yield was a ten-year average of a producer's own production records. When a producer did not have a ten year crop yield record, then a factored ASCS yield (transitional yield) was substituted for the missing yield data. If a producer participated in APH over a number of years, then the transitional yields were gradually replaced by each new year's actual yields.

The MPCI yield coverages were comparable to the "deductibles" commonly used in other lines of insurance. The term deductible referred to the percent of the insured product value not covered by the insurance policy. Mathematically, the reported MPCI coverage was equal to 100% of the APH yield minus the percent deductible (e.g., a

65% coverage meant there was a 35% deductible). Deductibles provided the FCIC a limited safeguard against moral hazard. Moral hazard was the incentive for an insured to be careless or use substandard production practices to increase the likelihood of indemnity collection (Greene and Trieschmann 1981).

A producer collected an MPCI indemnity when the "disaster" yield fell below the chosen insured level. For example, if a producer had a 100 bu/ac APH yield, selected a 65% coverage level, and experienced a 45 bu/ac disaster yield, then his indemnity payment was based on the 20 bu/ac difference (65 bu/ac - 45 bu/ac).

MPCI's coverage was based on a yield per unit area. Sometimes a unit area was a producer's entire farm. There was no single definition of a unit area. Each producer's circumstances were interpreted using a set of FCIC guidelines to determine how unit areas were to be defined. Producers could separately insure non-adjacent sections within a county if adequate independent production records were available for the different crop locations. Producers with multiple unit areas on a farm were required by the FCIC to pay a 10% surcharge on their premium. The FCIC had estimated that higher indemnities were associated with the practice of insuring multiple unit areas (FCIC 1987).

Bushel indemnities were converted into cash amounts using one of three price elections. These price elections were 60%, 70% or 90% of the FCIC's pre-determined indemnity base price. The indemnity base price was partly based on an econometric projection of a crop's average national price. The FCIC also consulted with other USDA

agencies to arrive at the indemnity base price before the MPCI sales season began.

The indemnity base price was the same nationwide. This set price did not fluctuate with market prices. The constant base price meant that a MPCI buyer did not have price risk when collecting indemnities. However, crop insurance was not price insurance. Producers benefitted from MPCI only when disaster yields caused them to be indemnified. Producers who purchased MPCI had at least nine permutations of prices and yields to consider (i.e., three insured yield elections multiplied by three price elections).

2.5.2. APH Rules for MPCI Premiums

Once a producer selected an option among the nine insured yield and price combinations, the premium per acre was determined. The premium calculation required access to the FCIC's county MPCI actuarial table. The actuarial table had percentage premium rates, which decreased as a producer's APH yield increased. The formula used with the table was:

$$\begin{aligned}\text{Premium/Acre} = {} & (\text{APH Yield}) \times (\%\ \text{Coverage}/100) \times \\ & (\text{Price Election}) \times \\ & (\text{Actuarial Premium Rate})\end{aligned} \qquad \text{Equation 2.1}$$

The actuarial premium rate in Equation 2.1 was primarily derived from the historical county record of MPCI indemnity payments. The premium rate was also adjusted for the estimated risk associated with an individual producer's mean crop yield.

Producers whose mean crop yields were greater than the county mean yield were considered to be superior managers. Superior managers were assumed to adopt technologies to decrease their risk of an insurable yield loss. MPCI premium rates were consequently reduced as the producer's APH yield rose. Premium rates were also adjusted for those producers who used special crop production practices (fallowing, irrigation, etc.).

MPCI could be purchased with its hail/fire coverage excluded. If a producer did eliminate MPCI's hail/fire coverage, then he paid a lower MPCI premium and was required to purchase H/FCI insurance. The producer had to buy enough H/FCI to at least equal the insured yield coverage that would have been in the MPCI policy.

Private insurers took advantage of this opportunity to combine the MPCI and H/FCI crop insurance products. The blended crop insurance products they devised could sometimes provide producers with more coverage for their premium dollar (AACI 1987). Such innovations demonstrated how MPCI and H/FCI could be considered complements rather than substitutes.

Direct government subsidies were another impact on producers' premiums rates. There was a 30% FCIC subsidy which reduced premium rates on the 50% and 65% insured yields. The premium charged for the additional coverage between the 65% and 75% received no subsidy.

At least two purposes were served by the FCIC's decision to maintain the full 30% subsidy at or below the 65% coverage level. First, the FCIC used probabilities and a marginal cost analysis to demonstrate that the 75% coverage level was expensive to insure (FCIC

1984). The extra cost of insuring the yield between the 65% and 75% levels was larger than a 10% increase; that is, the cost of covering expected indemnities was increasing at an increasing rate in the 65% to 75% crop yield coverage interval. A second and related cost consideration was that a producer who insured at the 75% level was more likely to be susceptible to moral hazard.

The FCIC managed its indemnity costs by attempting to control problems such as moral hazard. The FCIC also had to devise methods to improve the likelihood of successful premium collection. Premium payments were usually due after the crop had been harvested. Producers had time to market the crop and obtain the capacity to pay the premium under this arrangement.

The premium paid by a producer was a function of the APH actuarial premium rate for the county (see Equation 2.1). The FCIC used a moving average procedure to convert a county's annual indemnity payments into actuarial premium rates. The premium rates that developed among MPCI users under the AREA Plan were carried over into the APH Plan with the moving average procedure.

If the composition of producers purchasing MPCI were to change over time, then the FCIC could slowly modify the APH county premium rates. After a ten-to-twenty year period of operation, the APH premium rate structure would eventually conform to the crop yield risks of a reconstituted insurance pool.

The FCIC's decision to permit only gradual change in the APH Plan's actuarial MPCI premium rate had important implications. One of the major questions raised was whether the FCIC had sufficiently

changed MPCI to encourage additional producer participation in the program.

2.6. MPCI in Transition: Implications for this Research

A variety of changes were initiated under the FCI Act to improve the marketability of MPCI to producers. This study was primarily designed to analyze the APH Plan's impact as a new method for determining producers' yield coverages.

There were three reasons for concentrating on the change in yield coverage represented by the APH Plan. First, a major role of the APH Plan was to allow producers to alter their yield coverages. Producers insured their own historical mean yields with MPCI's APH Plan. Producers who previously bought MPCI under the AREA plan were required to use mean yields derived from county level yield data.

Second, the change in yield coverage was undertaken without a large change in the underlying actuarial basis for setting premiums. An important question was whether the new yield coverage plan was able to attract additional producers into the program if the premium rates continued to be based on the AREA Plan's insurance pool. The null hypothesis would be stated as follows: "the APH yield coverage plan did not make a difference in a producer's plans to purchase MPCI, as compared to the AREA Plan."

Third, the impact of the alternative coverage plans on a producer's MPCI purchase decision was a well defined problem. Economic and statistical tools could be applied to gain usable insights into the potential outcomes of the AREA and APH plans.

2.7. Summary and Conclusions

Congress changed MPCI with the 1980 FCI Act. MPCI was designated as the federal government's primary crop disaster program. Competing programs were to be eliminated or restricted. MPCI premiums were directly subsidized. The FCIC was charged with maintaining MPCI as a stable and sound program while producer participation was increased. Private insurance firms were authorized to market MPCI. The FCIC was granted new powers to improve the MPCI program under the FCI Act.

The FCIC used its authority to modify MPCI by creating the APH Plan in 1985. The APH Plan replaced the AREA Plan, and was initiated to spur producer participation in the MPCI program. The FCIC hoped to achieve its goal of increased participation by changing its approach to determining yield coverages. The APH Plan's underlying MPCI premium rates were primarily based on the producer pool who had purchased MPCI under the AREA yield coverage plan. Research was needed to determine whether the APH Plan made a difference in producers' MPCI purchase decisions as compared to the AREA plan.

Economic and statistical tools were used in this study to model a producer's MPCI purchase decision. The results of the modeling effort had implications for the both the AREA and APH yield coverage plans. A particular concern was to identify whether the APH Plan was expected to have an impact on the MPCI purchase decisions of producers. The model's outcomes could be used to develop some recommendations for present and future FCIC policies that pertained to yield coverage determination.

The foundation for the modeling effort was to represent a producer's decision process for the MPCI purchase. The MPCI purchase was analyzed as a decision made under risk, and the expected utility hypothesis (EUH) was applied to develop the model. The EUH and its application for modeling the MPCI purchase was the topic of chapter three.

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Chapter Three

Applying Risk-Bearing Theory to Develop an MPCI Purchase Decision Model

A model of a producer's MPCI purchase decision was developed in this chapter using an application of the expected utility hypothesis. The roles of a producer's risk attitude and wealth level in the MPCI purchase decision model were discussed. Empirical observations of producers' risk attitudes in previous research were examined. Risk attitudes were specified in the MPCI purchase decision model by selecting parametric utility functions to evaluate alternative distributions of net wealth and income. A framework for analyzing the welfare impacts of MPCI purchases was derived from the model. The model's intended use as a tool for analyzing MPCI's AREA and APH Plans was presented in the chapter's conclusion.

3.1. Basic Premises for Modeling an MPCI Purchase Decision

The first step for modeling an MPCI purchase was to represent a producer's decision making process. The process was initially examined under the assumption of producer certainty about a decision's outcome. Then the analysis was expanded to consider decision making under risk.

Producer choices were examined under the certainty assumption to review the utility function concept and its application in this analysis. The model of the decision making process was broadened to

include the element of risk because of the business risk involved with an MPCI purchase decision.

3.1.1. Decision Making with Certain Outcomes

Producer preferences were modeled with a utility function. Decision making with certain outcomes was assumed to be a problem of utility maximization. A producer's utility function was specified with the producer's subjective satisfaction as a dependent variable. The independent variable was the sum of his initial net wealth plus the net income earned from a crop enterprise. "Ending net wealth" was the term used in this chapter to indicate the sum of initial net wealth and net income. Ending net wealth was a proxy variable for the factors that determined a producer's satisfaction with the results of operating a crop enterprise.

Initial net wealth was treated as a producer's endowment in the model. The endowment was based on the assumption that a producer's initial net wealth was derived from past accumulated profits of the crop enterprise (see chapter seven). The net income component of the ending net wealth variable was approximated by using the net cash flow of the crop enterprise. An example of an enterprise budget used to calculate net cash flow for an enterprise was presented in Table B.1 of Appendix B.

The utility function was expressed algebraically as:

$$U = U(W_0 + z) \qquad \text{Equation 3.1}$$

Where:

$U(\cdot)$ = utility function
W_0 = initial net wealth level
z = net income from a crop enterprise
(W_0+z) = ending net wealth level
$U' > 0$, marginal utility positive
$U'' < 0$, diminishing marginal utility

Marginal utility, the first derivative (U') of the utility function with respect to ending net wealth, was assumed to be positive (Equation 3.1). Under this formulation, producers preferred more ending net wealth to less.

Diminishing marginal utility ($U'' < 0$) was assumed. As ending net wealth increased, the last extra dollar of ending net wealth produced a smaller gain in utility than did the previously generated dollar. The ($U'' < 0$) assumption was considered plausible because the producer's recognition of equal increments in satisfaction was considered to be a function of proportionate increases in wealth (Hirshleifer 1976). In other words, the first certain $1,000 gain in ending net wealth was subjectively perceived by a producer as creating greater satisfaction than the twentieth certain $1,000 gain.

Changes in ending net wealth were assumed to be generated by the crop enterprise's net cash flow. The net cash flow of the crop enterprise was derived from a production function, input prices and output prices. The production function was a representation of the process for combining inputs such as land, fertilizer and a producer's

managerial skill to produce a crop yield output. The production function's crop yield output, as well as input and output prices, were known in advance by the producer under the certainty assumption. The producer was also assumed to be a price-taker in a competitive market.

Crop insurance was considered an unnecessary input in a model of certain outcomes, since crop insurance was a device to modify the impacts of crop yield risk on ending net wealth. The role of MPCI in the model was explained below after the certainty assumption was relaxed.

Specification of a producer's utility as a function of ending net wealth implied that maximization was constrained by the endowed initial net wealth level and by the crop enterprise's net cash flow. Initial net wealth was treated as a given value, whereas net cash flow was determined by the producer's decisions for managing the crop enterprise. The producer could select and organize the appropriate enterprise to maximize net cash flow. Ending net wealth was maximized as a consequence of maximizing the crop enterprise's net cash flow.

The decision situation facing the producer under certainty was summarized mathematically as:

$$\text{Maximize: } U = U(W_0 + z) \qquad \text{Equation 3.2}$$

$$\text{Subject to: } W_0 = \bar{k}$$
$$z = \pi[\, f(y, x1, \ldots, x_n),\ P_y,\ p_1, \ldots, p_n \,]$$

Where:
- $\bar{k}$ = assumed constant initial net wealth
- z = net income measured as enterprise's net cash flow
- $\pi[\cdot]$ = net cash flow function for the crop enterprise
- $f(\cdot,\cdot)$ = production function
- y = crop yield output
- x_i = i_{th} productive input
- P_y = output price
- p_i = i^{th} input price

The net cash flow function ($\pi[\cdot]$) in Equation 3.2 was used to derive a maximum net cash flow (π_{max}) under the first order condition that marginal revenue equalled marginal cost (Robison and Barry 1987). Since utility was specified as a positive function of ending net wealth ($U' > 0$), then the utility maximizing condition under certainty was identical to the π_{max} condition in the net cash flow function.

A variety of decision making models could be developed from Equation 3.2, once the assumption of certainty was relaxed for the independent variables. The source of uncertainty of primary concern in this study was the variability in ending net wealth associated with uncontrollable crop yield fluctuations. MPCI was investigated as an input or "tool" that producers might use to moderate such uncertainty in ending net wealth.

3.1.2. Decision Making Under Risk

A producer's option to buy MPCI was modeled in this study as a decision made under the risk of crop yield loss. Crop yield risk meant that a producer managed a crop enterprise without advance knowledge of what his exact crop output would be.

The Expected Utility Hypothesis (EUH) was applied to the model of the MPCI purchase decision under the crop yield risk condition. The discussion below was used to: (1) describe the characteristics of this EUH application, and (2) to discuss the overall role of the EUH as a model of decision making under risk.

Characteristics of this EUH Application. An extension of the EUH, known as the theory of risk aversion, was used to represent the risk management behavior of producers under alternative wealth assumptions (Arrow 1971). A producer was considered to be governed by three basic factors under the EUH and risk aversion theory (Robison and Barry 1987; Arrow 1971):

1. the producer formulated a subjective probability distribution of outcomes,
2. the producer possessed an attitude towards risk, and
3. the producer's wealth level was a primary factor in determining risk attitude.

Four additional assumptions of the EUH were (Anderson, Dillon and Hardaker 1977):

1. Producers ordered their choices from most preferred to least preferred.
2. The ordering of a producer's choices was transitive.

3. The ordered choices were independent.

4. A producer could remain indifferent by willingly accepting some cash amount for certain in exchange for a risky choice.

Producers were modeled as maximizers of expected utility if the above conditions were met. Expected utility was defined as the mathematical expectation of utility, where each outcome's utility was multiplied by its respective subjective probability and then summed (Savage 1954).

Ending net wealth (ENW) was the independent variable used in determining expected utility. A producer's crop enterprise decision was associated with an ENW probability distribution, rather than a single known ENW value that would prevail if outcomes were certain.

Expected utility maximization with respect to ENW was algebraically described as:

$$\text{Maximize:} \quad U_e = \int_{w_l}^{w_u} U(w) \cdot p(w) \cdot dw \qquad \text{Equation 3.3}$$

$$\text{Subject to:} \quad w = W_0 + Z$$

Where:
- U_e = expected utility
- $U(\cdot)$ = utility function
- w = ending net wealth (ENW)
- w_l = lower bound of w
- w_u = upper bound of w
- $p(w)$ = probability of w
- W_0 = initial net wealth
- Z = net cash flow defined as a random variable with a differentiable probability density function.

The utility function $U(\cdot)$ in Equation 3.3 was different from the standard utility function of traditional economic theory. Standard

utility functions could be subjected to any monotonic transformation without changing the conditions for maximization. The $U(\cdot)$ function could only be subjected to transformations which changed the origin and/or scale of the vertical axis (Machina 1987). Monotonic transformations which did not alter the shape of $U(\cdot)$ were of the form $[a \cdot U(w) + b, a > 0]$ (von Neumann and Morgenstern 1953).

The MPCI purchase decision was modeled into the net cash flow variable (Z) of Equation 3.3. The choice to buy or not buy MPCI would change the characteristics of the Z density function, and therefore influence the expected utility level.

One of the purposes of applying the EUH in this study was to predict circumstances under which a producer would buy MPCI. The general model in Equation 3.3 was used to develop the specific conditions for MPCI demand. The formulation of the model was partly based on the derivations for decision making with insurance presented in Robison and Barry (1987). First, Equation 3.3 was modified to illustrate the how the ENW distribution was derived under the assumptions of constant prices, variable crop yields, and no MPCI. Second, Equation 3.3 was altered to demonstrate the calculation of expected utility with MPCI purchased. Finally, the expression for expected utility without MPCI was set equal to the function with MPCI, and the result was solved for an indifference MPCI premium rate. The indifference MPCI premium rate was the maximum premium a producer would pay for a given level of MPCI coverage. If the actual MPCI rate charged by the FCIC was greater than the calculated indifference

rate, then a producer would be predicted to self-insure (not buy MPCI).

The expected utility level associated with a crop enterprise where the producer did not use MPCI was presented in Equation 3.4.:

$$U_e(w_{NI}) = \int_{w(y=0)}^{w(y=y_{max})} U[w(y)] \cdot p[w(y)] \cdot dw \qquad \text{Equation 3.4}$$

Where:

$U_e(w_{NI})$ = expected utility of the ENW distribution with no insurance (NI)
$U[\cdot]$ = utility function
w = ending net wealth (ENW) = $W_0 + Z$ (see Equation 3.3)
$w(y=y_{max})$ = ENW at maximum possible crop yield, assuming ideal weather and efficient production
$w(y=0)$ = ENW when crop yield equals zero (lowest possible yield)
$p[w]$ = probability of w
y = crop yield defined as a random variable with a differentiable probability density function.

Expected utility was determined as a function of ENW in Equation 3.4. ENW changed as crop yield varied from the lowest to the highest value of the producer's CYPD. Each ENW level in Equation 3.4 was assumed to be associated with a particular crop yield level. Equation 3.4 was also derived under the assumption that no MPCI was purchased, and that the production function, output prices and input prices were held constant.

Expected utility was additionally determined for the case where MPCI was purchased in Equation 4.5. Price and production function assumptions were maintained as before:

$$U_e(w_I) = \int_{w(y=0)}^{w(y=y_{cov})} U[w(y) + (y_{cov}-y)\cdot\phi - \pi] \cdot p[w(y + (y_{cov}-y)\cdot\phi - \pi)] \cdot dw$$

$$+$$

$$\int_{w(y=y_{cov})}^{w(y=y_{max})} U[w(y) - \pi] \cdot p[w(y) - \pi] \cdot dw \quad +$$

Equation 3.5

Where:

$U_e(w_I)$ = expected utility of the ENW distribution with insurance (with MPCI)
$U[\cdot]$ = utility function
w = ending net wealth (ENW) = $W_0 + Z$ (see Equation 3.3)
$w(y=y_{max})$ = ENW at maximum possible crop yield, assuming ideal weather and efficient production
$w(y=y_{cov})$ = ENW at insured crop yield coverage level
$w(y=0)$ = ENW when crop yield equals zero (lowest possible yield)
$(y_{cov}-y)$ = bushel basis for insurance indemnity payment (yield coverage level minus actual yield)
ϕ = predetermined MPCI price election for converting bushel indemnity into a cash amount
π = MPCI premium at insured crop yield level
$p[\cdot]$ = probability function
y = crop yield defined as a random variable with a differentiable probability density function

The expected utility associated with particular MPCI coverage and premium levels was predicted with Equation 3.5. The equation was

comprised of two integrals. The expected utility for the "insured" portion of the ENW was derived in the first integral of Equation 3.5. The lower part of the ENW distribution was considered insured because an indemnity could be collected when the actual crop yield (y) was less than the insured yield coverage level (y_{cov}). A producer obtained an indemnity payment equivalent to the difference between the yield coverage and the actual yield ($y_{cov}-y$), multiplied by the MPCI price election (ϕ). The indemnity payment supplemented the ENW level (w(y)) associated with the disaster yield.

The MPCI premium (π) reduced the expected value of both the ENW distribution's insured and uninsured components in Equation 3.5. The expected utility for the "uninsured" portion of the ENW distribution was predicted with the second integral. The upper part of the distribution was classified as uninsured in the sense that a producer would not be indemnified if the actual crop yield equalled or exceeded the crop yield level covered with MPCI.

A model for evaluating the MPCI purchase decision was developed using Equations 3.4 and 3.5. A mathematical expression was formed where the $U_e(w_I)$ value in Equation 3.5 would be equal to the $U_e(w_N I)$ value in Equation 3.4. The value of the MPCI premium (π) in Equation 3.5 was varied until the expected utility with MPCI was just equal to the expected utility without MPCI. The premium that equated the

expected utilities was designated as the "indifference MPCI premium" or (π_{indif}). Equation 3.6 below was used to demonstrate the expression for determining (π_{indif}):

$$U_e(w_{NI}) = U_e(w_I)$$

$$\int_{w(y=0)}^{w(y=y_{max})} U[w_{NI}(y)] \cdot p[w_{NI}(y)] \cdot dw = \int_{w(y=0)}^{w(y=y_{cov})} U[w_I(y)+\theta-\pi_{indif}] \cdot p[w_I(y)+\theta-\pi_{indif}] \cdot dw$$

$$+ \int_{w(y=y_{cov})}^{w(y=y_{max})} U[w_I(y)-\pi_{indif}] \cdot p[w_I(y)-\pi_{indif}] \cdot dw$$

Equation 3.6

Where:

$U_e(w_{NI}(y))$ = expected utility without MPCI
$U_e(w_I(y))$ = expected utility with MPCI
$U[\cdot]$ = utility function
$w_{NI}(y)$ = ending net wealth (ENW) without MPCI (see Equation 3.4)
$w_I(y)$ = ending net wealth (ENW) with MPCI (see Equation 3.5)
$w(y=y_{max})$ = ENW at maximum possible crop yield, assuming ideal weather and efficient production
$w(y=y_{cov})$ = ENW at insured crop yield coverage level
$w(y=0)$ = ENW when crop yield equals zero (lowest possible yield)
θ = total dollars worth of MPCI indemnity payment(s) (determined with yield coverage level, actual yield, and predetermined MPCI price election. See Equation 3.5)
π_{indif} = indifference MPCI premium at insured crop yield level
$p[\cdot]$ = probability function
y = crop yield defined as a random variable with a differentiable probability density function

A producer was predicted to buy MPCI with Equation 3.6 when his $U_e(w_I(y))$ was greater than or equal to $U_e(w_{NI}(y))$. The condition, $[U_e(w_I(y)) \geq U_e(w_{NI}(y))]$, would occur when π_{indif} was greater than or equal to π_{actual}. The value π_{actual} was the actual MPCI rate for a given coverage level and price election calculate from the FCIC actuarial tables.

The demand function for MPCI could be directly derived from Equation 3.6, under certain assumptions about the producer's utility function and underlying ENW probability distribution (Robison and Barry 1987). For example, if it were assumed that ENW was normally distributed, and a producer's utility function were modeled with constant absolute risk aversion, then an expression was could be derived which could be analytically solved for π_{indif}. The exercise in Appendix A was used to demonstrate how the demand for insurance could be determined under the above assumptions about the utility function and probability distribution.

The ENW probability distributions in this research were empirical and based on interval estimates of crop yield probabilities rather than the continuous functional form of the normal distribution. Numerical integration techniques were used to solve for π_{indif} in this study because of the difficulty in deriving an analytical solution from the empirical probability distirbutions. The numerical integration techniques were implemented by applying an algorithm written as a computer program (see chapter seven). The computer program was designed to search for the indifference MPCI premium (Black 1988).

The model in Equation 3.6 was restricted to analyze the role of crop yield variability in the MPCI purchase decision. The MPCI purchase was represented as a producer choice made for an isolated enterprise under the assumptions that crop yields were stochastic and prices were deterministic. The ENW distribution was derived from the producer's subjective CYPD in the model.

The implications of MPCI decision model were restricted by the assumption of deterministic prices. For example, if prices were modeled as stochastic, and if prices were perceived to be negatively correlated with yields by producers, then the impact of yield reductions on ending net wealth would be mitigated. Under such conditions, the predictions of MPCI purchases with the model in this study would tend to be too optimistic. The impacts of ad hoc disaster programs would also tend to reduce the perceived need for MPCI below what would be predicted by the model. The modeling results in chapter seven were interpreted to account for the potential impacts of stochastic prices and other factors on producer decisionmaking.

The crop enterprise decisions predicted with Equation 3.6 did not generally require that a producer maximize his ENW distribution's expected value to maximize his expected utility. A producer could willingly trade-off a portion of his ENW distribution's expected value to decrease the risk of occasional large decreases in his ENW. The producer's attitude toward risk was a critical factor in his expected-utility-maximizing decision to make such a trade-off (see Section 3.2 below).

The EUH as a Risk Decision Model. Maximization of expected utility was a basic premise for most applications of the EUH. When the EUH was used in economic research, it was determined to be an acceptable and useful approach to analyze decisions made under risk (Hirshleifer and Riley 1979). Theoretical and empirical research results were often supportive of the EUH as a model of risky decisions. For example, the EUH was shown to be a better predictor of actual producer behavior than profit maximization (Officer and Halter 1968; Lin, Dean and Moore 1974; and SriRamaratnam, et. al. 1987).

Even though the EUH was successfully applied in past studies, there was not a universal acceptance of the EUH as a basis for risk decision analysis. Economists and psychologists raised questions about the usefulness of the EUH (Machina 1987).

Observed behavior was not always determined to be consistent with the definition of "rational behavior" contained within the assumptions and the decision making processes of the EUH. Linearity in probabilities, transitivity of preferences, and subjective probability formulation were aspects of the EUH challenged in previous research (Allais 1953; Lichtenstein and Slovic 1971; Payne and Braunstein 1971; Kahneman and Tversky 1979). However, the various criticisms did not form a distinct pattern. Also, no unified theory was offered that could explain the all the deviations from the EUH's predictions of risk behavior (Machina 1987).

The inability to modify the EUH for every potential modeling problem did not preclude the EUH from serving as a beneficial

analytical tool. The EUH could still be successfully employed to learn more about people's risk attitudes and behaviors (Arrow 1971). Insights into decision making could be gained by first applying the EUH to obtain predicted results. Then the decision making implications of relaxing EUH assumptions could be analyzed.

In summary, producers' MPCI decisions were modeled in this EUH application by: (1) using subjective CYPD's to generate alternative ENWD's, and (2) evaluating the ENWD's with a utility function representative of a producer's risk attitudes. Producers with different risk attitudes would not generally select the same ENWD to maximize expected utility, ceteris paribus.

3.2. The Role of Risk Attitudes in an MPCI Purchase Decision Model

An important component in an EUH decision making model was the set of risk attitudes associated with a producer's utility function (Pratt 1964). Theoretically-derived risk attitudes in the MPCI purchase decision model were described below. Theoretical considerations concerning the use of risk attitudes in the model were discussed by: (1) reviewing risk attitude measures, (2) examining the relationship between wealth and risk attitudes, (3) distinguishing global from local risk aversion, (4) discussing the distribution of risk attitudes among producers, and (5) identifying how the MPCI purchase decision was influenced by risk attitudes.

3.2.1. Risk Attitude Measures

A producer's risk attitudes were classified into one of three categories: risk averse, risk neutral, or risk preferring.

A producer classified as a risk averter did not necessarily avoid all crop enterprises because they were risky. A risk averter engaged in a risky enterprise if the expected return was higher than on a comparable investment with a certain return. A risk neutral individual invested when the expected risky return was equal to the return under certainty. Risk preferring producers invested in a risky enterprise when the expected return was less than a certain return.

Risk premiums and certainty equivalents were measures which increased the precision of the risk attitude definitions. A risk premium (RP) was a non-stochastic amount of money subtracted from a risky decision's expected return (μ_w). An individual was indifferent between the mean value (μ_w) for a risky decision and a certain return equal to the value: (μ_w - RP). A certainty equivalent (CE) was the result when a risky decision's expected return was reduced by the RP (i.e., CE = μ_w - RP). The CE was the non-stochastic "amount of cash" an individual would accept in exchange for a risky decision and remain indifferent (Pratt 1964).

A risk averter had a positive risk premium, and his certainty equivalent was less than the value of an expected risky return. A risk neutral individual had a zero dollar risk premium, and a risk preferring individual had a negative risk premium. The definition of risk preferring meant that a producer paid extra to obtain a risky investment.

If a linear transformation of the U(·) function from Equation 3.3 was performed, the value of the risk premium remained unchanged (Pratt 1964). Consequently, the utility function itself and the risk premium were not unique indicators of risk preferences. Risk premiums could not be used to compare or classify the risk attitudes of producers with different utility functions.

Pratt (1964) and Arrow (1963) independently derived a unique determination of risk preference known as the absolute risk aversion function. The absolute risk aversion function was referred to as the Pratt-Arrow Absolute Risk Aversion Coefficient (PARAC), and was defined as:

$$R(w) = \frac{-U''(w)}{U'(w)} \qquad \text{Equation 3.7}$$

Where:

$R(w)$ = PARAC
w = ending net wealth
$U(w)$ = utility function
$U'(w)$ = first derivative
$U''(w)$ = second derivative

The risk attitudes of producers with similar wealth and income levels could be compared and classified with the PARAC (Equation 3.7). When the PARAC value was negative, then a risk preferring producer was indicated. A zero PARAC implied a risk neutral individual, and a positive value was associated with risk aversion. Such interpersonal comparisons applied only to risk attitudes and not to utility levels (Robison and Barry 1987).

Theoretical PARAC values were used in this study as a means of identifying a producer's characteristics in the MPCI purchase

decision model. For example, if a producer was predicted to buy MPCI at a particular yield coverage level, then the PARAC would be a way to describe the risk attitude of such a producer. If the distribution of risk attitudes among producers were known, then the model could be used to research the larger policy question of MPCI participation. Even if the risk attitude distribution were not known, the sensitivity of a producer's purchase decision to alternative MPCI coverage plans and premium subsidies could be examined at different PARAC values. Policy analyses would be assisted by a better understanding of the producer characteristics which influenced the decision to buy MPCI.

Risk attitudes in previous empirical studies were usually identified with intervals of PARAC values rather than with exact point estimates. PARAC intervals were used because elicitation techniques were subject to measurement error. For example, producers were empirically categorized as risk neutral even though their elicited PARAC's not exactly equal to zero. The theoretical PARAC estimates obtained in this study were classified by intervals to make use of the previous empirical studies in the interpretation of the model's results.

A summary of risk attitudes classified by PARAC intervals was published by Raskin and Cochran (1986). Subsequent empirical investigations by Thomas (1987) and Zering, et. al. (1987) had PARAC measurements which were within the range of PARAC interval estimates reviewed in Cochran and Raskin's article. Interval boundaries for the risk attitudes were constructed below by taking simple averages of

the interval boundaries identified by Cochran and Raskin (1986) and by Thomas (1987) (see Table 3.1).

Table 3.1 Risk Behavior Indicated by PARAC Intervals (Thomas 1987; Cochran and Raskin 1986).

Pratt-Arrow Absolute Risk Aversion Coefficient	Behavior Towards Risk Implied by Coefficient's Values
-0.0005 to -0.00011	Risk Preferring
-0.0001 to 0.00014	Risk Neutral
0.00015 to 0.02	Risk Averse

Interval classifications of risk attitudes in Table 3.1 were used to make hypotheses about producers' MPCI purchase decisions. If a producer had a PARAC value between -0.0001 and 0.00014, he was hypothesized to have little interest in buying MPCI.

A risk neutral producer (PARAC $\approx$ 0) had a risk premium which was close to zero (RP $\approx$ \$0). In an EUH model, the risk premium was the equivalent of an insurance premium (Pratt 1964). The closer a producer was to being truly risk neutral, the lower the risk premium (MPCI premium) would be. In other words, a completely risk neutral producer had a certainty equivalent which was equal to the mean of an ENWD with no MPCI purchased. If the MPCI purchase decreased an ENWD's mean and/or variance, a producer classified as risk neutral was not as likely to buy MPCI as a risk averse producer with a positive risk premium. A risk neutral producer had a preference for a ENWD with a higher mean value, as opposed to one with a lower variance, ceteris paribus.

The properties of the producer's utility function determined whether his PARAC was fixed or changeable. Producer risk attitudes were hypothesized to be sensitive to changes in a producer's net wealth and income in this study and in previous research (Arrow 1963).

3.2.2. The Effects of Wealth and Income on Risk Attitudes

Pratt (1964) and Arrow (1963) asserted that the PARAC was a decreasing function of wealth and income, i.e. $R'(z)<0$. Their assertion was known as decreasing absolute risk aversion (DARA). As a producer with DARA became wealthier, the risk premium he required to be protected from the income losses of a risky decision would become smaller relative the expected potential income gain.

The DARA principle was not conclusively validated in other theoretical and empirical research. Some researchers argued that the PARAC was increasing for some income levels and decreasing for others (Friedman and Savage 1948; Kahneman and Tversky 1979). When the PARAC's of agricultural producers were empirically estimated, increasing absolute risk aversion ($R'(z)>0$) was measured when producers had low incomes or if they planned to increase their net worth (King and Robison 1981; Patrick, Blake and Whitaker 1981). If some producers were characterized by increasing absolute risk aversion, then they would have an increased tendency to buy MPCI as wealth rose.

DARA was observed for producers with high income levels or with increasing after-tax net incomes (Halter and Mason 1978; Wilson and Eidman 1983). Age and education variables had conflicting impacts on

the PARAC value, primarily because of interdependence with other factors such as percent debt and future income expectations (Wilson and Eidman 1983; Halter and Mason 1978). If producers were classified as having the DARA property, they would be less likely to buy MPCI as their wealth increased.

There were arguments to support the use of DARA in a risk analysis. DARA was logically consistent with the theoretical concept of a diminishing marginal utility of money. A producer's risk attitude was variable, rather than fixed, when modeled with the DARA assumption. Producer choices with stochastic yields were investigated under the assumption of a constant absolute risk aversion coefficient in previous studies (Yassour, Zilberman and Rausser 1981; Collender and Zilberman 1985). Risk attitudes were determined to be variable in past empirical research efforts (King and Robison 1981; Tauer 1986).

The DARA assumption was used in this study to model the MPCI purchase decision. Parametric utility functions were selected which possessed the DARA property. The implication of this assumption was that producers with higher net wealth levels were less likely to purchase crop insurance.

Producers with large net wealth levels had an increased financial capacity to self-insure. The DARA assumption was used to imply that wealthy producers were not only able, but also willing, to consider self-insurance as an alternative to purchasing MPCI.

3.2.3. Global and Local Risk Aversion

When the PARAC value was used to identify a producer's risk aversion level, the measurement only applied at that particular income level. Pratt (1964) defined this limited concept of risk attitude as "risk aversion in the small" or "local risk aversion". A point estimate of the risk premium associated with a particular net wealth level was calculated using a local risk attitude equation derived by Pratt (1964). Pratt's equation was:

$$RP_{loc} = \tfrac{1}{2} \cdot R[E(W_0+z)] \cdot \sigma^2 \qquad \text{Equation 3.8}$$

Where:

RP_{loc} = local risk premium
$R[\cdot]$ = PARAC measure
$E(W_0+z)$ = expected value of the ENWD
(W_0+z) = ending net wealth = sum of initial net wealth (W_0) plus net income
σ^2 = variance of the ENWD

Local risk attitudes were a function of an ENWD's mean and variance, given an initial net wealth level (see Equation 3.8). Such local measures could be used to predict producer decisions, but the predictions would be restricted to the locus of the net wealth level.

Approximations to global risk aversion were used in this study to predict the MPCI decision based on an entire distribution of ending net wealth levels.

Producer "A" was defined as <u>globally</u> more risk averse than producer "B" if A's PARAC value was larger at every possible net wealth level. One way to be sure that "A" was globally more risk averse than "B" was to perform a concave transformation of B's utility function,

and assign the transformed function to "A". The concave transformation caused A's utility function to have a rate of change in slope which was everywhere more negative than B's (Pratt 1964). In graphical terms, A's utility function bends down faster as a function of net income than does B's (see Figure 3.1) (Robison and Barry 1987).

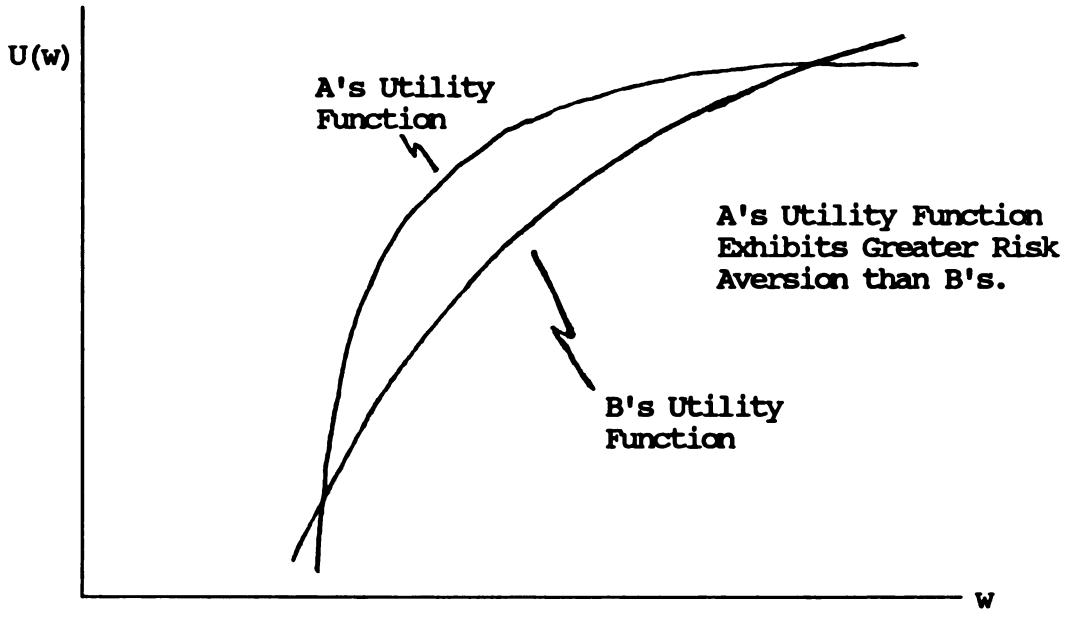

Figure 3.1 Utility Functions with Alternative Bending Rates.

The utility functions in Figure 3.1 were constructed to demonstrate one producer as being globally more risk averse than another. If the chosen utility functions had been irregular in shape, then the strict requirements identifying an individual as globally more risk averse would not have been as easily demonstrated.

A less restrictive and less precise measure which approximated global risk aversion was the average risk aversion measure (ARAM). The ARAM was mathematically derived as (Robison and Barry 1987):

$$U[CE_i(W_0+z)] = \Sigma\ [U(W_0+z)\cdot p(W_0+z)] \qquad \text{Equation 3.9}$$

$$ARAM = CE_i = U^{-1}\{\Sigma\ [U(W_0+z)\cdot p(W_0+z)]\} \qquad \text{Equation 3.10}$$

Where: $U(\cdot)$ = utility function
$CE_i(W_0+z)$ = certainty equivalent of the the ENWD for individual i
(W_0+z) = ending net wealth = sum of initial net wealth (W_0) plus net income
$p(\cdot)$ = probability function of the ENWD
$U^{-1}(\cdot)$ = inverse of the utility function

Equation 3.9 was based on the premise that a producer was indifferent between an ENWD's expected value and its certainty equivalent (i.e., the utility of an ENWD's certainty equivalent was equal to the utility of its expected value). The ARAM was the certainty equivalent for the ENWD (Equation 3.10). The certainty equivalent, $CE_i(W_0+z)$, was derived from the inverse of the utility function (Equation 3.9) evaluated at the ENWD's expected value. As the value of $CE_i(W_0+z)$ grew larger for a given ENWD, producer "i" became less and less risk averse.

The ARAM presented in Equation 3.10 was a more general measure of a producer's risk attitude than the local risk attitude value in Equation 3.8. The ARAM was limited in the sense that its value was sensitive to the accuracy of the probability measures for the p(y) function (Robison and Barry 1987). The usefulness of the ARAM was the ability to estimate the general risk attitude of a producer, once the probability and utility functions were known.

The ARAM concept was applied in this study to determine a producer's preference among ENWD's under alternative assumptions of (1) self-insurance, (2) purchased-insurance under MPCI's AREA Plan and (3) purchased-insurance under MPCI's APH Plan.

An important question for MPCI participation was the distribution of global risk attitudes among producers. In other words, the size of the potential market for MPCI was likely to be dependent on the proportion of producers who were risk averse, risk neutral or risk preferring.

3.2.4. The Distribution of Risk Attitudes

The observed facts of asset diversification, preferred stock holdings and insurance markets were used to support the hypothesis that people were predominantly risk averse (Hirshleifer and Riley 1979; Arrow 1971). However, people also frequently engaged in various forms of gambling where the expected value of the net income distribution was less than its cash equivalent.

Two reasons were cited to explain why the assumption of predominant risk aversion was consistent with risk preferring behavior of

gambling. First, risk preferring behavior was displayed more often when the cost of entering the gamble was a small proportion of a person's wealth level (Friedman and Savage 1948). Second, if a divergence arose between subjective and objective probabilities, then an individual could display behaviors which were objectively judged as risk preferring, but were perceived as risk averse by the producer (Arrow 1971).

Empirical investigations of the risk attitudes of agricultural producers elicited all three types of risk attitudes. Halter and Mason (1978) interviewed 44 Oregon crop producers and observed that roughly an equal number of their sample fell into each of the risk preferring, risk neutral and risk averse categories. King and Robison's (1981) elicitations of 17 Michigan farmers revealed preferences ranging from extremely risk preferring to extremely risk averse. Wilson and Eidman (1983) obtained survey responses from 47 Minnesota swine producers and reported 22% as risk preferring, 34% as risk neutral and 44% as risk averse. Tauer (1986) elicited responses from 72 New York dairy producers, and the distribution of this sample was 26% risk preferring, 39% risk neutral and 34% risk averse.

There were a variety of questions raised by the empirical studies of agricultural producers' risk attitudes. The research results did not fit closely with the hypothesis of predominant risk aversion proposed by Arrow and others. Davidson and Mighell (1963) suggested that a producer's past experiences condition whether survey responses were risk preferring, risk neutral or risk averse. They also discussed the likelihood of a divergence between: (1) the responses to

the hypothetical risks posed by a survey question and, (2) the actual risk behavior of the respondent when faced with a real decision.

The distribution of risk attitudes among producers was not a fully resolved issue. Since the knowledge of how risk attitudes were actually dispersed was not complete, an alternative was to model the sensitivity of an individual producer's MPCI purchase decision to changes in his risk attitude.

3.2.5. Risk Attitudes and the MPCI Purchase Decision

The purchase of insurance was most closely associated with a risk averse attitude (Arrow 1971). The level of risk aversion where a producer was predicted to buy MPCI in the model was partly dependent on the relationship between MPCI's actual premium and the producer's expected indemnities.

One component of an actual MPCI premium was the "pure premium rate". The pure premium was defined as the rate charged to just offset the expected indemnity. An actual MPCI premium not only included a calculation of the pure rate, but also had additional charges called load factors. The load factors accounted for phenomena such as catastrophic losses (e.g., a regional drought) and unmeasured risks (Driscoll 1986).

An actual MPCI premium was the sum of a pure premium rate plus load factors. If the risk estimations for an MPCI policy holder were accurate, then the policy holder's actual premium was greater than the expected value of MPCI indemnities. Under these circumstances, a producer who purchased MPCI gained greater income stability at the

expense of a reduced mean net income. The indemnity payments moderated the periodic negative income impacts of crop failures on a producer, and the annual insurance premium decreased a producer's net income.

Pflueger and Barry (1986) demonstrated that MPCI could increase expected net income when credit availability considerations were taken into account. An issue not explored in this study was the distribution of producers' risk attitudes under alternative assumptions about the financial circumstances which influenced a producers' operations.

If an MPCI purchase decreased a producer's expected net mean income (financial risks held constant), then the decision to buy MPCI would be made by producers who had a positively-valued PARAC (i.e., those who were risk-averse).

The majority of agricultural producers were not risk averse, if the empirical studies cited above were correct. One-third to two-fifths of the respondents in the various studies were categorized as risk-averse. Such findings indicated that MPCI was not an economically attractive alternative for all producers.

Other factors which decreased MPCI marketability were noted in chapter two. These included self-insurance techniques and government farm programs which mitigated producers' overall risk and probably lessened the incentive to buy MPCI.

There were some factors, however, which could cause MPCI's market potential to be underestimated if they were not considered in an MPCI

purchase analysis. These factors were listed below and were more thoroughly discussed in subsequent paragraphs:

1. Elicitation instruments probably underestimated the risk-averse behavior of agricultural producers in real world decision making.

2. Factors other than wealth and income that were possibly associated with a higher level of risk aversion.

3. Policy changes in MPCI, such as the yield coverage rules introduced under the APH Plan, could have caused MPCI to be a more attractive product for individuals who were on the margin between purchasing and not purchasing MPCI.

Elicitation of Risk Attitudes. Producers' actual behavior was possibly more risk averse than the risk attitudes indicated by elicitation methods (Davidson and Mighell 1963). Tauer (1986) expressed doubts that dairy producers who were elicited as risk preferring would behave that way in a real decision making situation.

Raskin and Cochran (1986) explained that inappropriate use of the PARAC caused the risk-averse attitudes of some producers to be underestimated. The measured PARAC value changed with the scale of operation being examined. The PARAC had to be properly adjusted to the outcome scale before a risk analysis could reveal a risk efficient choice that maximized expected utility (Raskin and Cochran 1986).

If scaling problems were not resolved, then a major type I error occurred in a stochastic dominance analysis. The type I error was the rejection of risk averse strategies that belonged in the risk efficient choice set (Raskin and Cochran 1986). The implication of the scaling problem for producer decision analysis was the tendency

to underestimate the level of risk aversion if no adjustments were made for the size of operation.

Regional Influences on Risk Attitudes. Previous research results indicated that producers' risk attitudes were conditioned by factors other than wealth and income. Tauer (1986) noted that his sample of New York dairy producers were measured as more risk preferring than Wilson and Eidman's (1983) sample of Minnesota hog producers. Tauer suggested that the New York dairy farmers had not experienced the production and price risk associated with hog production in Minnesota. Minnesota hog producers might be expected to be more cautious (risk averse) because of their heightened awareness of business risks. Producers who operated on the western edges of the Corn Belt or in the Great Plains often had higher production risk due to weather and other uncontrollable factors (Miller 1975). A plausible hypothesis was that MPCI had a greater potential market in the Great Plains than in less risky production areas.

MPCI Policy Rules and Risk Attitudes. The FCIC created the APH Plan to increase MPCI participation. Producers were able to base the insured crop yield coverage on their own crop yield history under the APH rules. Producers who consistently produced a larger crop yield than could be insured under the AREA Plan were allowed to use their own records to increase their coverage.

The change in yield coverage would alter the ENWD associated with an MPCI purchase. An EUH model, such as the one used in this study, could be used to measure whether the new APH policy rules made a difference in the MPCI purchase decision.

Changes in the MPCI premium schedule also had some potential to influence the MPCI purchase. Congress, under the FCI Act, provided up to a 30% subsidy on MPCI premiums, reinsured private providers of MPCI and shared their expenses, and covered the FCIC's administrative costs to help market the MPCI product.

Subsidization increased MPCI's economic attractiveness for a larger cross-section of producers. Subsidization specifically expanded MPCI's marketability to producers who were "marginal" MPCI purchasers. Suppose a large proportion of marginal MPCI users were in the group classified as risk neutral in previous research. Producers elicited as risk neutral comprised anywhere between 33% to 39% of the samples obtained in past research (Tauer 1986; Wilson and Eidman 1983; Halter and Mason 1978). Premium subsidies would have some potential to increase MPCI participation by attracting the marginal user from the risk neutral group.

Summary. Risk attitudes were likely to be an important factor in MPCI purchase decisions. New efforts were being made to learn more about risk attitude distributions (Antle 1987). But until more conclusive research was available on risk attitudes within populations, it was sensible to model the sensitivity of MPCI purchases to changes in a producer's net wealth position and risk attitude.

The DARA assumption was used to test the sensitivity of the MPCI purchase decision to different risk attitudes associated with different wealth levels and income distributions. Utility functions were specified in this study to incorporate the DARA assumption into

the MPCI purchase decision model. These utility functions and their associated properties were discussed below.

3.3. Criteria for Specifying Utility Function Parameters

Various functional forms of utility functions were reviewed to analyze producer decision making under risk. The article by Lin and Chang (1978) was used to help select the utility functions for analyzing the MPCI purchase. Empirical utility functions were determined by Lin and Chang to be the best predictors of producer behavior. However, empirically estimated utility functions were unavailable in this study. The alternative chosen was to select parametric utility functions with certain "desirable" properties. These properties were (Arrow 1971):

1. diminishing marginal utility of money, ($U''(z) < 0$),
2. decreasing coefficient of absolute risk aversion (DARA), ($R'(z) < 0$), and
3. risk aversion inversely related to marginal utility, ($R(z) \tilde{=} (1/U'(z))$).

The first property meant that the law of diminishing marginal utility applied to producer perceptions of money (Samuelson, 1973). Each successive increment in the amount of money obtained reduced the rate of increase in total utility. The second property was adopted because producers were assumed to become less risk averse as their net wealth increased (see also section 3.2.2). The third property implied that a producer became more risk averse as producer's marginal utility for the last dollar earned decreased.

The inverse relationship between risk aversion and marginal utility was one way to explain why a risk averse producer could remain indifferent when he exchanged a CE for an ENWD which had an expected value (μ_Y) larger than the CE. The risk averse producer assigned less additional utility to probable gains above (μ_Y), and also perceived greater utility losses for reductions below (μ_Y).

Building upon the assumptions of DARA and diminishing marginal utility outlined above, a parametric utility function's properties were further specified to evaluate the MPCI purchase decision over a range of net wealth levels and PARAC values.

The EUH was used to determine the boundaries of the PARAC range relevant for analyzing the marginal MPCI user. An individual was identified as risk averse in the EUH when the theoretical risk premium was a positive dollar amount. The EUH's risk premium was the analytical equivalent of the MPCI premium.

It was assumed in this study that producers paid an MPCI premium to transfer crop yield risk away from their operations. The MPCI premium decreased the expected mean net income, because the load factors increased the MPCI premium above the pure rate that would have just "broken even" with expected indemnities. The effect of government subsidies on the actual MPCI premiums was generally not enough to offset the impact of the load factors.

The EUH was used to formulate hypotheses about the risk attitudes of producers who would be part of the potential MPCI market. If MPCI reduced both the mean and standard deviation of a producer's net income, then the EUH was used to predict that producers with a PARAC

greater than zero (i.e., risk averse producers) would consider MPCI an economically viable choice.

If a producer were completely risk neutral, he would self-insure and attempt to maximize the expected value of ENW without concern for the variance of the ENW distribution. If a producer had a risk preferring PARAC, he would not be predicted to buy MPCI. Risk preferring producers had negative risk premiums. Theoretically, a risk preferring individual had to receive a bonus, rather than pay a premium, to use MPCI.

3.4. Alternative Forms of the Utility Function

Two functional forms of the utility function were proposed for analysis of the MPCI purchase decision in this study:

1. a logarithmic utility function, and
2. a constant elasticity of substitution (CES) utility function

The logarithmic utility function was a special case of the CES function. The CES function received its name because its parameters were specified in a manner similar to the production function proposed by Arrow, et. al. (1961).

Both the logarithmic and CES utility functions possessed the three "desirable" properties discussed earlier. The logarithmic utility function was originally proposed by Bernoulli (1738) as being representative of most people's risk attitudes. Samuelson (1974, 1977) observed that the logarithmic utility function could not explain everyone's response to risk. Nevertheless, use of the logarithmic

utility function was seen as more defensible than using linear functions (Anderson, Dillon and Hardaker 1977).

The logarithmic function (LF) was selected as one of the utility functions for the MPCI purchase analysis in this study. There were two reasons for this selection. First, the LF had the properties of diminishing marginal utility and DARA. Second, the strengths and limitations of the LF were known from previous research (Robison and Barry 1987). The impacts of the LF's properties on the predicted MPCI purchase decision were examined. The LF results were compared to the outcomes obtained using the CES function.

A CES utility function was also chosen for investigating the MPCI purchase decision. The CES function had parameters which could be altered to change its overall risk aversion level. In this study, parameter values were specified to calculate utility and PARAC values from the functional form of the CES function published in Lin and Chang (1978).

The notation used to describe the LF and CES utility functions were presented in Table 3.2. Both utility functions were only defined for positive values of the ENWD. Interval estimates of the PARAC's for the LF and CES utility functions were used to classify risk attitudes. Attitudes in both functions changed from risk averse to risk neutral as the ending net wealth value increased.

Table 3.2 Properties of the LF and CES Utility Functions.

Notation Common to both the LF and CES Functions:

Let: w = ending net wealth
$U(w)$ = utility function
$U'(w)$ = marginal utility
$U''(w)$ = rate of change of marginal utility
$R(w) = -U''(w)/U'(w)$ = Pratt-Arrow Absolute Risk Aversion Coefficient or PARAC

Properties of the Logarithmic Utility Function:

Let: $U(w) = \ln(w)$ (logarithmic utility function)
restriction: $w > 0$

Then: $U'(w) = 1/w$

$U'(w) > 0$ (marginal utility always positive)

Then: $U''(x) = -1/w^2$

$U''(x) < 0$ (diminishing marginal utility)

Then: $$R(w) = -\left[\frac{(-1/w^2)}{(1/w)}\right]$$

$R(w) = 1/w$ (PARAC for the log. utility function)

Then: $R'(w) = -1/w^2$

$R'(w) < 0$ (PARAC decreases as ending net wealth increases, i.e., the DARA condition.)

(Table 3.2 continued on next page.)

Table 3.2 (Cont'd.)

Properties of the CES utility function:

Let: $U(w) = (\beta \cdot (w)^{-\delta} + \alpha)^{-(1/\delta)}$ (CES utility function)

Restrictions:

$(w) > -1$
$\beta > 0$
$\alpha > 0$
$\delta > 0$

Then: $U'(w) = \beta \cdot \delta \cdot \{ [\beta \cdot w^{-\delta} + \alpha]^{-(1+\delta)/\delta} \} \cdot w^{-(1+\delta)}$

$U'(w) > 0$ (marginal utility always positive)

Then: $$U''(w) = \{\frac{\beta \cdot \delta \cdot (1+\delta)}{[\beta \cdot w^{-\delta}+\alpha]^{(1+\delta)/\delta} \cdot w^{(1+\delta)}}\} \cdot \{\frac{\beta}{[\beta \cdot w^{-\delta}+\alpha] \cdot w^{(1+\delta)}} - \frac{1}{w}\}$$

$U''(w) < 0$ (Diminishing marginal utility occurs when all above-mentioned restrictions are met).

Then: $$R(w) = (1+\delta) \cdot \{ \frac{1}{w} + \frac{\beta}{[\beta \cdot w^{-\delta}+\alpha] \cdot w^{(1+\delta)}} \}$$

$R(w) > 0$ (Pratt-Arrow Absolute Risk-Aversion Coefficient or PARAC)

Then: $$R'(w) = -(1+\delta) \cdot \beta \cdot \{ \frac{1}{\beta \cdot w^2} + \frac{\beta + \alpha \cdot (1+\delta) \cdot w^{\delta}}{[\beta + \alpha \cdot w^{(1+\delta)}]^2} \}$$

$R'(w) < 0$ (PARAC decreases as ending wealth increases, i.e., the DARA condition)

Values for the α, β and δ parameters of the CES Utility Function were selected to create a specific functional form (see Table 3.2). When these values were substituted into their respective parameters, the CES utility function became:

$$U(w) = (40 \cdot w^{-2.5} + 0.0000000005)^{(-1/2.5)} \qquad \text{Equation 3.11}$$

An iterative process was used to test alternative values for the CES function. The CES parameter values in Equation 3.11 were changed until a function was created which was everywhere more risk averse than the logarithmic utility function. The rate of change for DARA in the CES was higher than in the LF: the PARAC valued changed from risk averse to risk neutral more rapidly in the CES than in the LF, as net wealth and/or mean net income increased. Within a comparable range of ENWD levels for this analysis, the CES function was expected to predict an MPCI purchase more often than the LF.

3.5. Overview of the MPCI Purchase Decision Model

The MPCI purchase decision was analyzed as a process where a producer used his subjective beliefs and his risk preferences to decide whether to buy or not buy MPCI. The producers subjective beliefs were represented by alternative ENWD's derived from a personalistic CYPD. Each ENWD was associated with a particular producer decision made about the use of MPCI within a particular crop enterprise. For example, one ENWD would result from the non-purchase of MPCI, while another ENWD would result form the purchase of MPCI at the 65% coverage level under the APH Plan.

The model of the MPCI decision could be broken down into definable and logically-connected steps. The steps in the model of the decision process were outlined below:

1. An assumption was made about the functional form of the utility function, $U = U(W_0+z)$.

2. A subjective CYPD was estimated (see chapter five). Alternative ENWD's were derived from the CYPD, assuming that the production function, output prices and input costs for a crop enterprise were known with certainty. The ENWD's were determined under different assumptions about the producer's use or non-use of MPCI.

3. An ARAM was first calculated for the ENWD from the assumed utility function, under the condition that MPCI was not purchased. Then each of the ENWD's that corresponded to an MPCI purchase were altered by changing the MPCI premium. The MPCI premiums were adjusted until the ARAM's with MPCI purchased were equal to the ARAM without MPCI purchased. The premium that equated the ARAM with and without MPCI was labelled as the "indifference MPCI premium."

4. The indifference MPCI premiums were compared to the actual MPCI premium rates reported in the FCIC actuarial tables. If the indifference premium were greater than the actual premium, then the model predicted that MPCI was purchased; otherwise MPCI was not purchased.

5. The initial wealth position (W_0) was altered to examine the impacts on the ARAM value, the indifference MPCI premium and ultimately on the MPCI purchase decision.

6. The purchases and non-purchases of MPCI were modeled under the AREA and APH coverage plans. The model results were interpreted for their implications about MPCI participation under the alternative coverage plans.

One part of the procedure described above was the estimation of an indifference MPCI premium. Another premium rate, one which would just break-even with the indemnities implied by the subjective CYPD, was also calculated.

The break-even premium rate was equal to the indifference premium rate for a risk neutral producer. A risk averse producer had an

indifference premium rate greater than the break-even rate. The relationships among the actual, indifference and break-even premium rates were used to estimate producers' net welfare gains and losses associated with their MPCI purchases under the AREA and APH Plans.

3.6. The MPCI Purchase: Evaluating Net Welfare Changes

The net economic value accruing to a producer who purchased MPCI was approximated by examining the relationship between the MPCI premium and the probability of receiving an indemnity caused by an insurable loss.

Gardner and Kramer (1982) and Nieuwoudt, et. al. (1985) modeled the demand for MPCI, and used the ratio of the MPCI premium to the maximum liability as a proxy for the net value of MPCI to a producer. The use of a ratio as a measure of MPCI's net value was analogous to expressing the cost of a lottery ticket as a percent of the maximum prize (Gardner and Kramer 1982).

Ratios were also used in this study to estimate a producer's net gains or losses from an MPCI purchase. The ratios were expressed as a

percent of the break-even premium rate. The actual and the indifference MPCI premium rates were measured relative to the break-even rate in the ratio. Algebraically, the ratios were represented as:

$$\frac{Pr_{[indiff.]}}{BE} = \text{net MPCI Value at the indifference premium rate} \qquad \text{Equation 3.12}$$

$$\frac{Pr_{[actual]}}{BE} = \text{net MPCI Value at the actual premium rate} \qquad \text{Equation 3.13}$$

Where:

$Pr_{[indiff.]}$ = indifference premium rate, bushels/acre
$Pr_{[actual]}$ = actual premium rate, bushels/acre
BE = Break-Even Premium Rate, Bushels/Acre

The model described in section 3.5 of this chapter was designed to discover the MPCI premium rate ($Pr_{[indiff.]}$) where a producer was indifferent between insuring and not insuring. The indifference ratio ($Pr_{[indiff.]}/BE$) was the maximum premium a producer would pay as a percent of the expected value of the MPCI's indemnities (Equation 3.12).

The ratio ($Pr_{[indiff.]}/BE$) was compared to the ratio of the actual MPCI premium rate to the break-even premium rate ($Pr_{[actual]}/BE$) (Equation 3.13). If ($Pr_{[actual]}/BE$) exceeded ($Pr_{[indiff.]}/BE$), then the producer was not predicted to purchase MPCI. If ($Pr_{[indiff.]}/BE$) were greater than ($Pr_{[actual]}/BE$), then the producer was predicted to purchase MPCI, and the positive difference between the ratios was an indicator of the net welfare gain of purchasing MPCI.

The switch from the AREA plan to the APH plan within MPCI was a costly changeover for the FCIC. The FCIC was required to demonstrate to the U.S. Congress that the APH plan had caused MPCI to be a more

marketable that would increase program participation. If the CE analysis revealed that there were net welfare gains created by the APH plan relative to the AREA plan, then it could be argued that APH was more valuable to producers than the AREA plan. However, the welfare gains would have to be very large to offset the cost of creating the APH Plan. It was anticipated that the net gains (if any) to producers of the APH Plan would not be very large. Since the economic efficiency gains of the APH plan were expected to be small (Myers and Oehmke 1987), greater significance was attached to other issues such as equity and property rights in the evaluation of the APH Plan (Schmid 1978).

3.7. Chapter Summary

The Expected Utility Hypothesis (EUH) was used in this chapter to develop a theoretical model of the MPCI purchase decision. PARAC intervals were identified to classify producers as risk averse, risk neutral or risk preferring decisionmakers. The DARA assumption was used to specify risk aversion as inversely related to net wealth and income. ARAM's were examined as an approximate measure of global risk aversion. ARAM's were derived to determine an MPCI premium rate where a producer with a given PARAC was indifferent between insuring and not insuring. If the actual MPCI premium was greater than the indifference premium, the model predicted that MPCI was not purchased; otherwise, an MPCI purchase was predicted.

Logarithmic and CES utility functions were specified to test the sensitivity of the MPCI purchase/not purchase decision to alternative

PARAC values and net wealth levels. The logarithmic and CES utility functions exhibited the DARA property and a diminishing marginal utility of money.

The decision making model was developed to analyze the FCIC's AREA and APH Plans and their impacts on the producer decision to buy or not buy MPCI. The role of a producer's wealth level, risk attitude and perceived CYPD in an MPCI purchase decision could be examined with the model. The results of the model would have implications for the ability of the FCIC to foster MPCI participation under the alternative coverage plans.

Measures of net welfare for MPCI purchasers were derived using the EUH model. The net welfare measures could be used to evaluate the net economic impact of an MPCI purchase. The relative value of MPCI for producers under the AREA and APH Plans could be compared using the net welfare measure.

The value that producers placed on MPCI not only depended on the structure of the insurance program, but also upon the underlying CYPD perceived by the producer. Properties and measures of CYPD's were presented and discussed in Chapter Four.

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Chapter Four

Crop Yield Estimation Techniques for an MPCI Purchase Decision Analysis

The expected utility hypothesis was applied in this study to develop a model of a producer's MPCI purchase decision. One dimension of that decision making model was a subjective crop yield probability distribution (CYPD) perceived by a producer. A subjective CYPD was the basis for deriving alternative net wealth and income distributions associated with the MPCI purchase decision (see chapter three).

Recent advances in CYPD estimation procedures were examined in this chapter. The approaches, assumptions and properties of CYPD estimation were identified. Estimation problems associated with technological yield trends and aggregated data sources were examined. Subjective CYPD elicitation was reviewed as a tool to measure a producer's personalistic views of his crop yield risks. Crop yield capacity functions (CYCF's) and frequency distributions of historical crop yields were discussed as statistical models which could be used to approximate producers' subjective CYPD's. The potential application of the various CYPD estimation techniques for analyzing the producer MPCI purchase was discussed in the chapter's concluding section.

4.1. The Usefulness of CYPD's in an MPCI Purchase Analysis

An MPCI purchase decision model was designed in this study to evaluate the AREA and APH yield coverage plans. Actual MPCI premium rates under both plans were compared to a producer's perceived probability that crop yield perils would create insurable losses.

Producers developed their personal perceptions about crop yield variability through acquired knowledge and experience. These personal beliefs about the occurrence of crop yields were referred to as subjective CYPD's. Estimates of producers' subjective CYPD's were needed if the decision to buy MPCI under the alternative yield coverage plans were to be modeled using the EUH.

A CYPD approximation also had other uses. Potential MPCI participants could better evaluate the MPCI purchase if they were supplied with information which improved their personal CYPD estimates. FCIC administrators could develop a more marketable MPCI product if the CYPD's perceived by producers could be measured accurately and economically.

CYPD measurement issues and their associated MPCI implications were discussed in this section of the chapter. The concept of a CYPD was defined and the randomness of crop yield fluctuations was discussed.

4.1.1. Definition and Modeling Application of a CYPD

A CYPD was a statistical model of random crop yield fluctuations. The full range of a producer's possible crop yields, and the corresponding frequencies of occurrence, were summarized with a CYPD.

A producer's subjective CYPD was used in the MPCI decision making model to generate alternative net wealth and income distributions (NWID's) associated with different choices for managing a crop enterprise. Since the alternative NWID's were ultimately derived from the CYPD, the implicit assumptions and measurable properties of CYPD's were important to an EUH analysis of the MPCI purchase decision. One of those assumptions was the randomness of the crop yield variable represented by the estimated CYPD.

4.1.2. Assumption of Randomness in Crop Yields

The agricultural economics and agricultural meteorology literature were reviewed for evidence that the crop yield variable was random. Some researchers used non-parametric statistics and correlations to demonstrate that crop production was subject to weather trends, cyclical variations, and bunchy patterns (Black and Thompson 1978; Harrison 1976; Thompson 1973; Lin, Hildreth, and Tefertiller 1963). Others found insufficient statistical evidence of non-random environmental influences in crop yield data (Luttrell and Gilbert 1976; Day 1965; Foote and Bean 1951). One implication of the debate was that crop yield randomness should be tested, rather than just assumed. Tests of randomness in the CYPD's were performed in chapter six.

Another consideration was that a random data series would exhibit occasional runs or bunchiness. Such "non-random" variation was expected to occur in a random variable. Furthermore, tests of randomness were similar to other statistical tests in the following respect: a power function described the tradeoffs between the type I

and type II errors in hypothesis testing. For example, when trends were intentionally incorporated into artificially created data series in previous research, the null hypothesis that the data series were random could not be rejected (Foote and Bean 1951). Such a result raised the possibility that the null hypothesis was being accepted when it was actually false (a type II error).

If "random" crop yields exhibited bunchy or cyclical properties, then producers could face successive years where MPCI indemnity payments would be triggered. A producer concerned with business survival might operate under the following null hypothesis: that crop yield variability was not random, and the burden of proof for the statistical test was to reject the non-random hypothesis. Such producers might evaluate the MPCI purchase as an important alternative to self-insurance. In addition, the FCIC had an interest in non-random crop yield variations because its financial stability would likely be strained by successive years of indemnifiable losses.

If a producer believed crop yields to be non-random, then his decisions were likely to reflect that belief. The statistical question of whether the yields were actually random was not as important to a producer's choices as were his perceptions. In this sense, the randomness issue was just one aspect of a more general topic: comparisons of subjective and so-called objective probabilities.

4.2. Alternative Methods for Developing CYPD's

Two fundamentally different approaches were available for constructing a probability distribution. One involved the application of

basic statistical rules to derive a distribution from a set of actual observations. The other was based on a decision maker's probabilistic beliefs. The laws of statistics were also applicable in the latter method.

The two approaches were evident in this research. One way to estimate a CYPD was to derive a distribution from published time-series or cross-sectional crop yield data. The alternative technique was to obtain a producer's subjective CYPD.

CYPD's derived from actual crop yield data were referred to as objective CYPD's. Subjective CYPD's were defined earlier.

Producers were assumed to make choices based on their subjective CYPD's in this MPCI analysis. This assumption was consistent with the traditional EUH approach (Savage 1954). Subjective CYPD's were typically obtained by conducting elicitations with individual producers. Elicited CYPD results were desirable because they were a direct estimate of perceived farm level crop yield variability.

A problem with CYPD elicitation was the relatively high cost of performing individual interviews. Another difficulty, which particularly applied to CYPD elicitation for MPCI purposes, was the willingness of a producer to reveal his CYPD. A producer might be reluctant to reveal his subjective CYPD if he perceived the information was to be used in MPCI premium determination.

Two objective CYPD measurement techniques were also investigated. These alternative CYPD estimations were examined to determine whether producers' subjective CYPD's could be approximated at a lower research cost. The FCIC could improve the marketing of MPCI if

economical procedures for estimating perceived crop yield risks were available.

Objective CYPD's were discussed directly below as possible approximations to subjective CYPD's. Methods for obtaining subjective CYPD's were described subsequent to the objective CYPD discussion.

4.2.1. Objective CYPD's

Whether a probability distribution could be objectively formulated was open to question (Anderson, Dillon and Hardaker [ADH] 1977). If a CYPD were based on actual historical data, then subjective value judgments were still involved. For example, the size of the data set used to formulate a probability distribution had to be selected by the researcher. In addition, if historically-based CYPD's were used to estimate the likelihood of crop disasters, then it was assumed that future climatic conditions would continue to follow the patterns of the past.

Despite their limitations, objective CYPD estimates were preferred by the FCIC over the use of subjective CYPD's in many MPCI applications. Recorded yields, even at the county-level, were considered to be "hard data" by the FCIC because methods were available to check the reliability of the estimates. Observed data were seen as a necessary foundation for developing sound programs in all forms of insurance (Mehr and Cammack 1976).

The value of an objective probability distribution in this research was the ability to economically approximate a subjective CYPD. Estimates of the subjective CYPD were needed because it was a

component in the MPCI purchase decision model. Statistical tests could be used to determine whether an objective CYPD was similar to a CYPD elicited from a producer. The direct elicitation of subjective CYPD's was described below.

4.2.2. Subjective CYPD's

If a subjective probability distribution were to be a correct assessment of a person's views towards the likelihood of uncertain events, there were two basic requirements (Norris and Kramer 1986; Anderson, Dillon and Hardaker 1977):

1. consistency with the three coherence axioms, and
2. compatibility of the quantitative estimates with the person's true beliefs about the uncertainty.

The three coherence axioms were summarized as:

$$1.) \quad 0 \leq P(\Phi_i) \leq 1$$

$$2.) \quad P(\Phi_i \text{ or } \Phi_j) = P(\Phi_i) + P(\Phi_j)$$

$$3.) \quad \sum_i [P(\Phi_i)] = 1$$

Where:

$P(\Phi_i)$ = probability of the i^{th} event of variable Φ

$\{\Phi_i, \ldots, \Phi_j, \ldots, \Phi_n\}$ = the full set of mutually exclusive events.

The three coherence axioms were used to ensure that subjective probability distributions complied with the laws of probability. First, the probability of a single uncertain event was positive and less than one. Second, the combined probability of two or more independent events was equal to the sum of their respective prob-

abilities in the second axiom. Finally, the sum of probabilities for an entire set of mutually exclusive events was equal to one.

The compatibility condition meant that an individual perceived his/her subjective probability distribution to be an accurate representation of his/her beliefs about the frequency of chance events. The compatibility condition was determined to be as important as the coherence axioms in empirical investigations of people's subjective probability distributions (Norris and Kramer 1986).

The coherence and compatibility conditions were standards for evaluating the validity of elicitation techniques. Psychological principles and other factors were investigated by researchers to develop and validate new elicitation techniques (Pease 1987; Norris and Kramer 1986; Bessler 1984; Nelson and Harris 1978).

Innovative elicitation techniques were recently developed and applied to obtain a subjective CYPD (Pease 1987). An interactive computer program (ELICIT) was written as part of an overall elicitation protocol (Pease and Black 1987). The protocol was a set of guidelines for conducting an interview. The protocol's purpose was to encourage a respondent to reveal his actual probabilistic beliefs. A basic component of the protocol was an elicitation technique known as conviction weights (Nelson and Harris 1978). Conviction weights were a method used to elicit coherent and compatible responses from people untrained in probability concepts (see chapter five).

New areas of study were opened up with CYPD elicitation techniques. One research opportunity was to provide quantitative feedback to MPCI administrators on the attractiveness of their program to

producers. CYPD properties perceived by producers could be estimated from the results of the elicitation procedure. Standard measures of those CYPD properties were the next topic of discussion.

4.3. Measurements of CYPD's

A producer's crop yield was conceptually a continuous random variable. That is, for any two possible yields, it was always possible to imagine a yield value that lay in between them (Rowntree 1981). A CYPD was also theoretically continuous: a probability was assigned to every possible crop yield level between zero and a maximum value determined by current environmental and technological conditions.

However, a continuous function could not be directly obtained in subjective CYPD elicitation. Producers best expressed their beliefs about a CYPD by assigning probabilities to crop yield intervals rather than to a particular yield. Interval estimation was also a convenient method used to construct objective CYPD's from observed data.

If necessary, a CYPD comprised of interval probabilities could be converted into a continuous function using interpolation methods. Linear interpolation for crop yield intervals of 10 bu/ac or less were used in this research to approximate the characteristics of a continuous CYPD. An alternative to interpolation was to specify a functional form to estimate the CYPD as a continuous distribution.

Empirical CYPD's estimated by interpolation methods and CYPD's specified with functional forms had properties which could be

described mathematically. The functions used to quantify those CYPD properties were described below.

4.3.1. CYPD's Represented as Density Functions

A density function for a CYPD was defined as a quantifiable relationship between possible crop yield levels and their corresponding probabilities of occurrence (Silverman 1986). The density functions discussed below met the three coherence requirements discussed earlier (see section 4.2.2).

A density function was a useful device in this study. A CYPD's properties were described with increased precision using a density function. Accuracy in measurement was helpful in determining the implications of a producer's subjective CYPD for the MPCI purchase decision.

Density functions were expressed algebraically and graphically to more precisely define a CYPD's properties. The perceived chance of an insurable crop yield loss could be algebraically measured using the moments of a subjective CYPD's density function. MPCI administrators, researchers and other interested parties could more easily grasp CYPD properties and their possible MPCI implications with graphical presentations of its density functions.

One important measurement derived from a CYPD's density function was a producer's perceived break-even MPCI premium rate. The break-even (BE) premium rate was the rate that would cause expected indemnities to just equal the premium charged for the MPCI coverage. The BE premium rate was equivalent to the term "pure premium" in the general insurance literature (Greene and Trieschmann 1981). A risk

neutral producer was indifferent between the purchase of MPCI at the BE rate and self-insurance (see chapter three).

The estimated BE premium rate was a valuable measure for two reasons. First, the size of the differential between the BE rate and the actual MPCI premium rate was an estimate of the risk premium that a risk averse producer would need to pay to obtain MPCI coverage. Second, the BE rate was used as a basis for quantifying producers' economic welfare losses and gains associated with the purchase of MPCI (see chapter three).

BE premium rates and other information relevant to the MPCI purchase decision were derived from a CYPD with crop yield probability density functions (CYPDF's) and crop yield cumulative density functions (CYCDF's).

If a CYPDF was derived for a continuous CYPD, then each possible yield level was assigned a probability in the resulting function (e.g., a 0.10 chance of 56 bu/ac). If the CYPD were a range of equal sized crop yield intervals (e.g., 10-20 bu/ac, 20-30 bu/ac, etc.), then a probability was estimated for each interval in the CYPDF.

If a CYCDF was derived for a CYPD, then the probability that a crop yield would be at or below a given level was estimated with the function (e.g., a 0.25 chance that the crop yield was $\leq$ 40 bu/ac). The differences in the continuous and interval-based CYCDF's were similar to the distinctions made between their corresponding CYPDF's.

CYPDF's and CYCDF's were discussed in more detail below. The density functions were used to describe CYPD characteristics that were important to the MPCI purchase decision. A producer's expected

mean yield and BE premium rate for a given coverage level were estimated with the density functions.

CYPDF's: Description and Uses. A CYPDF was used to identify the estimated chance that a given crop yield level or interval would occur. If a CYPD were a continuous function, then the CYPDF could be described with algebraic expressions similar to those in Table 4.1. If the CYPD were alternatively estimated as a set of crop yield intervals, then the $g(y_t)$ function in Table 4.1 would be estimated with interpolation methods, and the integral ($\int$) notation would be replaced by the summation (Σ) notation. The summation notation would mean that a numerical approximation was being performed to find the area underneath the function instead of the direct use of the rules of calculus.

Table 4.1 Algebraic Definition of a Continuous Crop Yield Probability Density Function.

Let the CYPDF of Y_t be defined as: $g(y_t)$

CYPDF Requirements:

$$0 < g(y_t) \leq 1$$

$$\int_0^{ycap_t} g(y_t) \cdot dy_t = 1$$

$$P(l \leq y_t \leq u) = \int_l^u g(y_t) \cdot dy_t$$

Where:

Y_t = crop yield variable
y_t = observed crop yield at time t,
$ycap_t$ = capacity or maximum yield, given technological and economic conditions at time t
$g(y_t)$ = probability of y_t
l = lower bound of yield interval
u = upper bound of yield interval
$P(l \leq y_t \leq u)$ = probability that y_t lies within the yield interval (l,u), where $l < u$

Random crop yields were represented in Table 4.1 as the variable (Y_t). The CYPDF of (Y_t) was a continuous and integrable function which summed to one. The ordinate ($g(y_t)$) of the CYPDF was the estimate of a specific crop yield's probability. The probability that a crop yield would lie within a given crop yield interval (l,u) was the integral of the ($g(y_t)$) function within the bounds of that interval. A graphical example of a continuous CYPDF was presented in Figure 4.1.

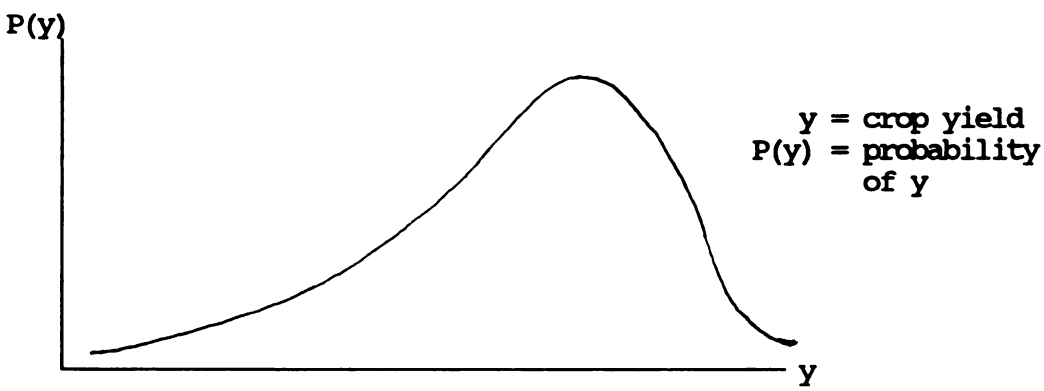

Figure 4.1 Graphical Example of a Continuous Crop Yield Probability Density Function.

It was not practical to expect that elicitation methods could be directly used to obtain a CYPDF as depicted in Figure 4.1. A producer was not likely to conceptualize a probability for every conceivable crop yield level. The alternative in subjective CYPD elicitation was for the producer to reveal his probabilistic beliefs for crop yield intervals (Pease 1987). An example of a CYPDF which might be elicited from a producer was presented in Figure 4.2.

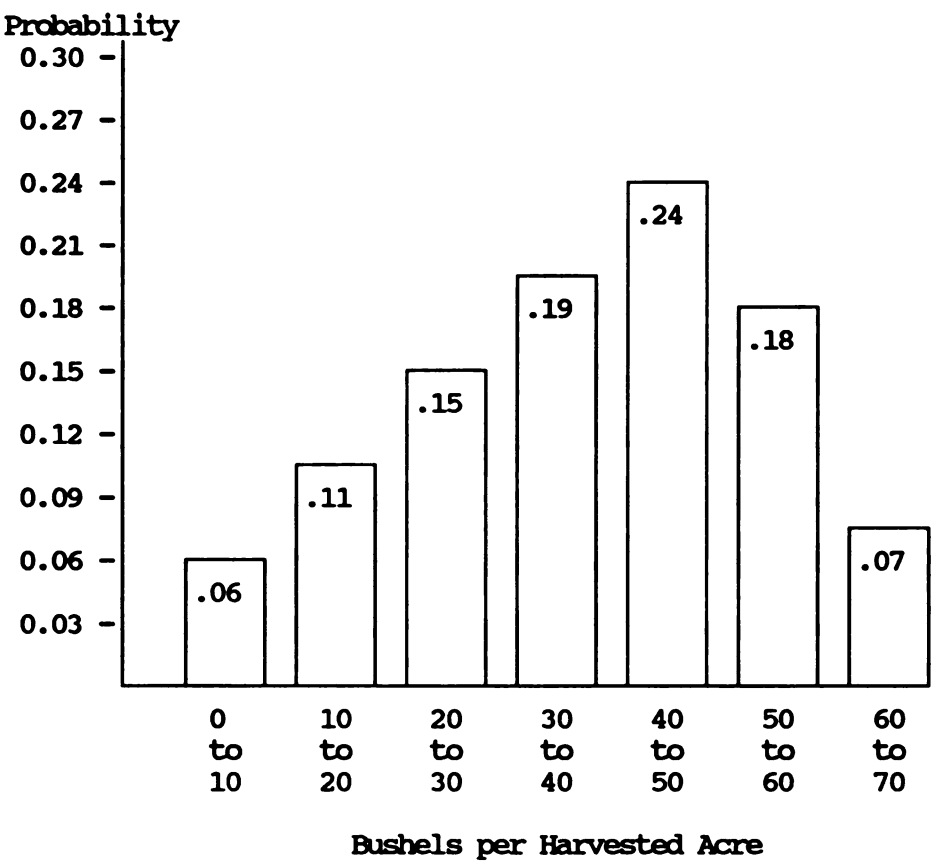

Figure 4.2 Example Histogram of a CYPDF ($g(y_t)$).

The probability that a crop yield was within a given ten bushel interval was labeled within each bar of the CYPDF histogram in Figure 4.2. The interval probabilities were used to provide estimates of useful crop yield information for the MPCI purchase decision. For example, the mean (expected value) of the CYPDF in Figure 4.2 was estimated as 37.6 bu/ac (see Table 4.2).

Table 4.2 Expected Value Estimate of a CYPDF Frequency Distribution (see also Figure 4.2)

Yield Interval (bu/ac)	(A) Interval Frequency	(B) Mid-Point of Interval	(A) x (B) Expected Value of Interval
0 to 10	0.06	5	0.30
10 to 20	0.11	15	1.65
20 to 30	0.15	25	3.75
30 to 40	0.19	35	6.65
40 to 50	0.24	45	10.80
50 to 60	0.18	55	9.90
60 to 70	0.07	65	4.55

Expected Value of Distribution = Σ [(A) x (B)] = 37.60

Suppose the expected crop yield value in Table 4.2 was derived from a producer's subjective CYPD. The relationship between this expected value and MPCI's measure of the producer's mean yield had a bearing on the MPCI purchase decision.

The yield levels which a producer could actually insure were referred to as yield coverages. MPCI's yield coverages were calculated as a percentage of a mean crop yield estimate. In the APH Plan, the yield coverages were based on the APH yield. The APH yield was the mean of the producer's last ten years of yield data or its equivalent (see chapter two). In the AREA Plan, the yield coverages were a percentage of the historical mean yield of an area within a county.

If a producer's perceived mean yield were greater than the APH yield (or the AREA mean yield), then yield coverages based on the subjective CYPD's expected value were larger than what would be insured with MPCI. There were at least two reasons why a producer might choose to self-insure instead of buying MPCI if he perceived the available yield coverages as deficient. First, the producer might consider the amount of coverage and the likelihood of indemnity collection to be small in comparison with the cost of the MPCI premium. Second, a producer might view MPCI indemnities as a way to prevent business failure in the event of a crop disaster. If the MPCI coverage level fell short of a producer's expectations, then the producer might not be convinced that an MPCI purchase would increase his chance of business survival.

Another way to use the CYPDF in Figure 4.2 for analyzing the MPCI purchase was to estimate a coverage level's BE premium rate. If the APH yield were equal to the mean yield in Figure 4.2, a producer who selected a 65% coverage level would be insuring a 24.4 bu/ac yield with MPCI. The perceived BE premium rate for the 65% coverage level in Figure 4.2 was estimated to be 2.35 bu/ac (see Table 4.3).

Table 4.3 Estimated Break-Even MPCI Premium Rate from a CYPDF Frequency Distribution (see also Figure 4.2).

Mean Yield = 37.6 bu/ac
Insured Yield = 65% x 37.6 bu/ac = 24.4 bu/ac

Yield Interval (bu/ac)	(A) Interval Frequency	(B) Insured Yield Minus Interval Mid-Point (bu/ac)	(A) x (B) Expected Indemnity from Yield Interval (bu/ac)
0 to 10	0.06	(24.4 - 5.0)	1.17
10 to 20	0.11	(24.4 - 15.0)	1.03
20 to 24.4	0.07	(24.4 - 22.2)	0.15

Expected Value of Indemnity = Σ [(A) x (B)] = 2.35

The BE estimate for the CYPD from Table 4.3 was based on sample crop yield information, rather than the parent distribution from which the sample was drawn. An improved estimate of the BE premium rate for the parent CYPD would be obtained using simulation techniques (see chapter seven). If the simulated BE estimate had actually been 2.35 bu/ac, and if the insured value of the crop were $2.00 per bushel, then a producer who paid a $4.70 per acre premium would

expect to receive an equal amount in indemnity payments over the long run.

In the MPCI purchase decision model developed for this study, a risk neutral producer would be indifferent between buying and not buying MPCI at a 2.35 bu/ac premium rate in the above example. Risk averse producers would pay more than the 2.35 bu/ac rate. The actual MPCI premium rate would likely be higher than 2.35 bu/ac because of the FCIC's need to include load factors and other adjustments (see chapter two).

BE premium rates were derived for given coverage level using the CYPDF's in the above examples. If a producer were considering a change in coverage levels (e.g., from 50% to 65%), the calculations were more easily performed with a cumulative density function. CYCDF's were examined in more detail below.

CYCDF's: Description and Uses. A CYCDF was another representation of a CYPD. A principle use of a CYCDF was to determine the cumulative chance that a crop yield would occur at or below a certain level (Hogg and Tanis 1977). CYCDF was derived from a continuous CYPDF in Table 4.4. If a CYCDF were derived from an interval-based CYPDF, then summation notation would replace the integrals as indicated earlier in the discussion of Table 4.1.

Table 4.4 Algebraic Definition of a Continuous Crop Yield Cumulative Density Function.

Let the CYCDF of Y_t be defined as: $G(y_t)$

CYCDF Requirements:

$$G(y_t) = P(Y_t \leq y_t) = \int_0^{y_t} g(t) \cdot dt$$

$$G'(y_t) = g(y_t)$$

Where: $g(y_t)$ = the CYPDF of Y_t (see Table 4.1 for other variable definitions)

The $(g(y_t)$ function was integrated to generate the CYCDF in Table 4.4. The cumulative probability of a given crop yield level was estimated by integrating the $(g(y_t)$ function over the appropriate interval. The first derivative of the CYCDF was the ordinate $(g(y_t))$.

A CYCDF was derived from the CYPDF in Figure 4.2. The analysis of MPCI was facilitated when a CYCDF was presented as a continuous function. An individual could use the graphical display of a continuous CYCDF to quickly identify the cumulative probability below a desired yield crop level. For this reason, linear interpolation was used to convert the CYPDF histogram of Figure 4.2 into a continuous CYCDF function. The resulting CYCDF was displayed in Figure 4.3.

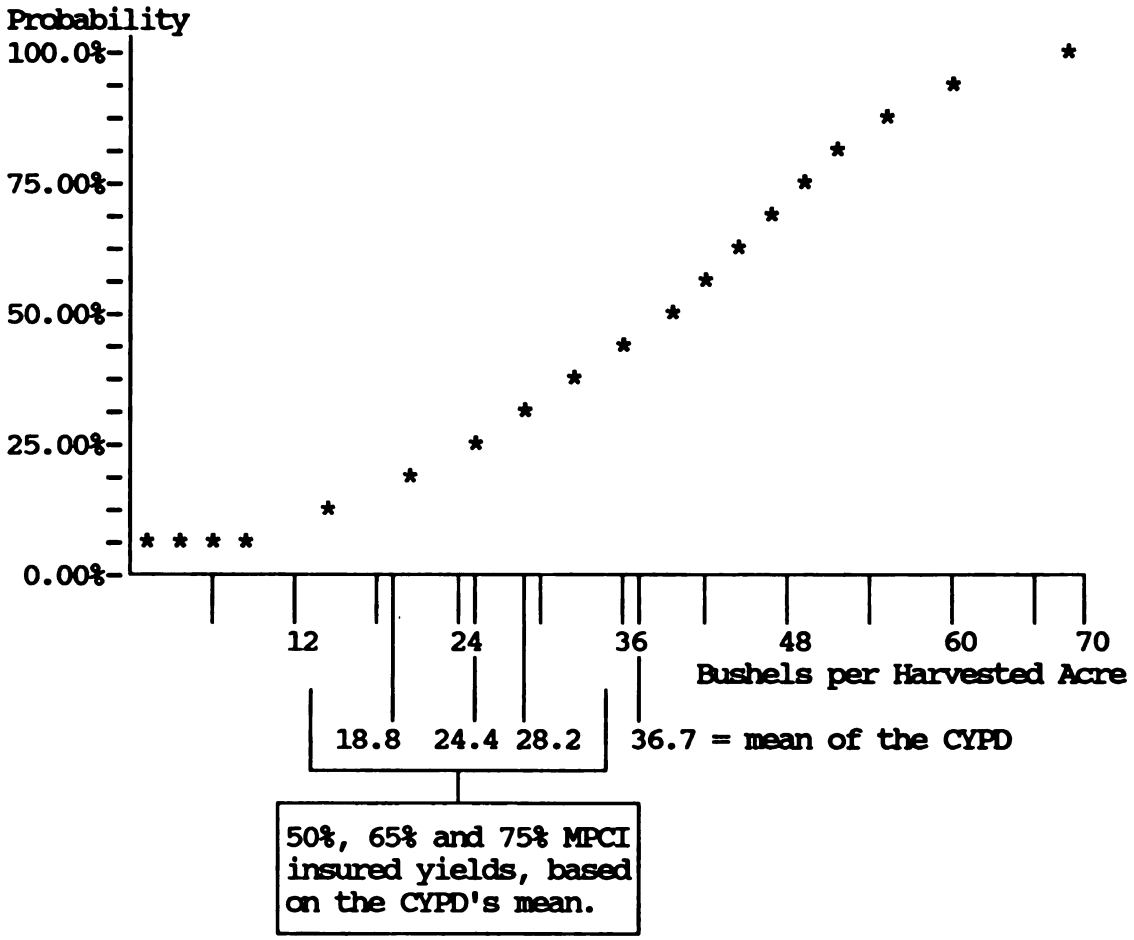

Figure 4.3 Example Graph of a Crop Yield Cumulative Density Function.

CYCDF's could be used to estimate the cumulative probability that a crop yield fell below a given MPCI coverage level. For example, a producer using the CYCDF in Figure 4.3 perceived an approximate 25% probability that his crop yield would be less than or equal to 24.4 bu/ac (65% coverage multiplied by the 36.7 bu/ac mean yield).

The CYCDF ($G(y_t)$) could also be used to estimate the probability that a crop yield occurred within various sized intervals. For

example, the CYCDF would be useful if a producer was considering an increase in the coverage level of his MPCI policy. If a producer wanted to know the expected value of increasing his coverage from 50% to 65% of his mean yield, the value of the additional insurance could be determined algebraically (see Table 4.5).

The value of the extra MPCI coverage in Table 4.5 was again based on sample information. A simulation was necessary if an estimate for the parent CYPD was to be obtained.

Table 4.5 Example of Estimating the Expected Value of a 50% to 65% Increase in MPCI Coverage.

Mean Yield = 37.6 bu/ac
65% Yield Coverage = 65% x 37.6 bu/ac = 24.4 bu/ac
50% Yield Coverage = 50% x 37.6 bu/ac = 18.8 bu/ac

Estimated Value of increasing coverage from 50% to 65%

$$= \left[(24.4 - y_t)\cdot[G(y_t)]\right] - \left[(18.8 - y_t)\cdot[G(y_t)]\right]$$

$$= \left[(24.4 - y_t) \cdot \int_0^{y_t} g(t)\cdot dt\right] -$$

$$\left[(18.8 - y_t) \cdot \int_0^{y_t} g(t)\cdot dt\right]$$

$\approx$ 2.35 bu/ac - 1.26 bu/ac (Using technique in Table 3.2)

Estimated Val. $\approx$ 1.09 bu/ac

An additional premium of 1.09 bu/ac was estimated as the charge that would offset the extra indemnities expected when MPCI coverage was increased from 50% to 65% of the mean yield (see Table 4.5). The 1.09 bu/ac approximated the increase in the BE premium rate that would cause a risk neutral individual to be indifferent between the lower and higher coverage levels.

Perceived BE premium rates were a function of a subjective CYPD's moments. The moments of a distribution were derived from the density function, and were used to determine CYPD characteristics such as central tendency, dispersion and symmetry. The moments of a CYPD were reviewed in the next section to develop applications for the MPCI purchase decision analysis.

4.3.2. Moments of a CYPD

The moments of a CYPD were technically defined as the expected values of the powers of the crop yield variable (Hogg and Tanis 1977). The types of CYPD's examined in this study were limited to the cases where the moments were estimable. Algebraically, a CYPD's moments were represented as:

$$E(Y_t^r) = \int_0^{ycap_t} y_t^r \cdot g(y_t) \cdot dy_t$$

Where:

$E(Y_t^r)$ = expected value of variable Y_t raise to the r^{th} power

y_t^r = observed or actual crop yield at time t, raise to the r^{th} power

$ycap_t$ = capacity or maximum yield, given technological and economic conditions at time t

The value of using a CYPD's moments was to have a standard set of measures for describing a CYPD's properties and for making logical comparisons to other CYPD's. Estimating a CYPD's moments was important in the model of the MPCI purchase developed for this study. Expected MPCI indemnities for a crop were determined using the moments derived from the CYPD's density function.

Central Tendency. The mean (μ) of a CYPD was defined as its first moment (i.e., the expected value of variable Y_t raised to the first power) (Hogg and Tanis 1977). The mean was also referred to as a measure of the CYPD's central tendency. The central tendency of any distribution was defined as the distribution's representative or average value. A distribution was often described in terms of its central tendency and the type of variation that occurred about that representative value.

A CYPD's expected value was represented as:

$$\mu = E(Y_t) = \int_0^{ycap_t} y_t \cdot g(y_t) \cdot dy_t$$

Where:

$E(Y_t)$ = expected value of variable Y_t

y_t = observed or actual crop yield at time t

$ycap_t$ = capacity or maximum yield, given technological and economic conditions at time t

The expected value was sensitive to the extreme values of the distribution. Exceptionally high values of y_t increased μ, and very low values decreased μ.

The median (θ) and the mode (ϕ) were alternate measures of central tendency. The median was defined as the distribution's mid-point or

50th percentile. The mode was the most frequently observed value of the distribution (Sachs 1982). If the distribution was symmetric, then the mean, mode and median were all equal to one another.

The CYPD's central tendency was important in an MPCI analysis because the yield coverages (50%, etc.) were calculated as a percentage of a producer's historical mean yield. If a producer's perception of the CYPD's central tendency differed from the historical mean, then the insurance coverage a producer would expect to gain for his crop with MPCI would be over- or under-estimated.

Dispersion. The variance of a distribution was the most commonly used measure of a distribution's dispersion. The variance was the probability distribution's second moment about the mean (Hogg and Tanis 1977) and was defined as:

$$\sigma^2 = E[(Y_t - \mu)^2]$$

The variance was measured by calculating the sum of squared deviations about the mean. Dispersion was measured with the standard deviation in the same units as the mean, and was defined as the square root of the variance (Hogg and Tanis 1977):

$$\sigma = \sqrt{(E[(Y_t - \mu)^2])}$$

The ratio (σ/μ) was the "coefficient of variation", and was a measure of the standard deviation as a percent of the mean. It was also possible to calculate the standard deviation as a percent of a CYPD's median or mode. There latter ratios were alternative estimates of relative variability within a distribution.

The estimates of a CYPD's dispersion discussed above were an indication of a producer's potential need for MPCI. As the CYPD's variance increased, the occurrence of extreme values became more likely. MPCI was designed to protect a producer's net wealth and income from large negative deviations in the NWID associated with large decreases in crop yields.

Skewness. The symmetry or asymmetry of a distribution was the distribution's third moment about the mean (Sachs 1982). If a distribution was not symmetrical, it was said to be "skewed." Algebraically, skewness was defined as:

$$\alpha_3 = [E(Y_t - \mu)^3]/\sigma^3$$

Where: α_3 = Coefficient of Skewness
σ = Standard Deviation of $Y_t = \sqrt{[E(Y_t-\mu)^2]}$
μ = Mean of Y_t

The skewness coefficient (α_3) equalled zero for symmetric distributions, was less than zero for negative skewness and greater than zero for positive skewness. The value of α_3 was a dimensionless measure, since it was the distributions's third moment about the mean scaled relative to the standard deviation.

There were two types of asymmetry:

1. Positive Skewness - graphically, the CYPDF had a steep, positive slope on the left side, and a long, negatively sloped tail to the right (See Figure 4.4). Positive skewness was defined as (Sachs 1982):

$$\alpha_3 > 0$$

Where: Mean (μ) > Median (θ) > Mode (ϕ)

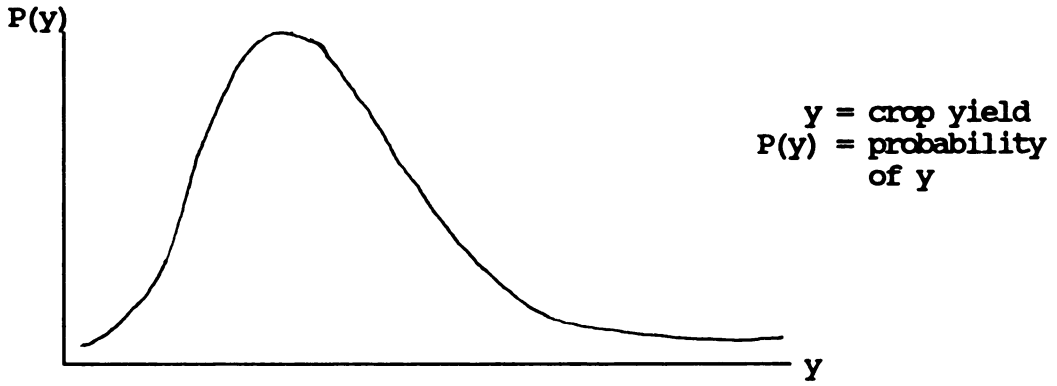

Figure 4.4 Example of a Positively Skewed CYPDF.

If a CYPD were positively skewed, then a large proportion of the area underneath the CYPDF was concentrated on the left hand side of the distribution (See Figure 4.4). The mean was also the largest of the CYPD's central tendency measures, because the extreme values on the right side of the distribution increased the mean's value.

A producer who perceived his CYPD to be positively skewed, and whose MPCI coverage was based on his mean yield, would have a large subjective BE premium rate. A "large BE premium rate" was defined relative to the BE rate derived from a symmetrical CYPD with comparable first, second and fourth moments for the density function.

2. Negative Skewness - graphically, the PDF had a steep, negative slope on the right side, and a long, positively sloped tail to the left (See Figure 4.5). Negative skewness occurred when (Sachs 1982):

$$\alpha_3 < 0$$

Where: Mode (ϕ) > Median (θ) > Mean (μ)

Figure 4.5 Example of a Negatively Skewed CYPDF.

Negative skewness (see Figure 4.5) meant that a large proportion of the distribution's probability density was concentrated at levels where MPCI coverage was unnecessary. As compared to a symmetrical distribution, lower BE premiums for insured MPCI yield levels would be associated with a negatively skewed distribution, ceteris paribus.

Kurtosis. Kurtosis of the distribution was the fourth moment about the mean. Kurtosis specifically referred to the peakedness of the distribution's PDF relative to its tailedness (Sachs 1982). Algebraically, kurtosis was represented as:

$$\alpha_4 = \{[E(Y_t - \mu)^4]/\sigma^4\} - 3$$

The α_4 value equalled zero for the normal distribution. If the distribution were bimodal, then the value of α_4 was strongly negative. If a distribution were multi-modal, then the modes were considered better estimates of a distribution's "representative values" than the mean.

There were two types of non-normal kurtosis:

1. Leptokurtic - graphically, the CYPDF had a higher peak than the normal distribution. If the leptokurtic distribution had the same mean and variance as the normal, then the leptokurtic curve was more peaked, its sides (flanks) were more compressed, and its tails were thicker than the normal (see Figure 4.6) (Sachs 1982). This was positive kurtosis, and was represented as:

$$\alpha_4 > 0$$

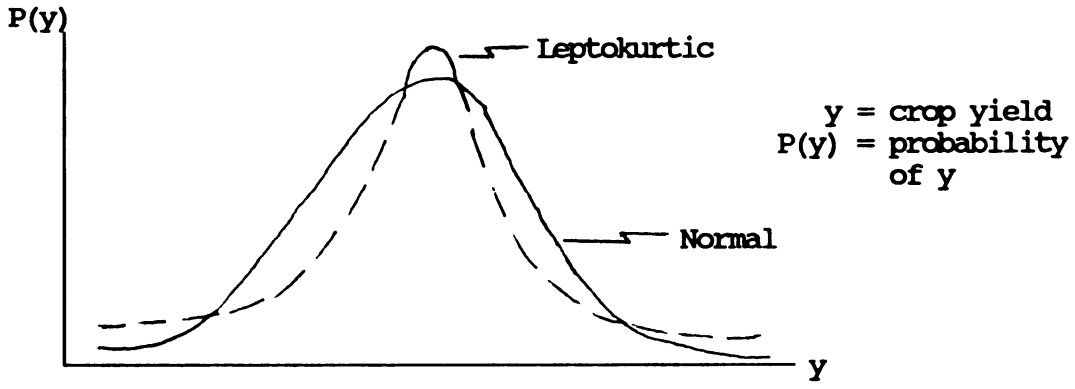

Figure 4.6 Example of a Leptokurtic (Positive α_4) CYPDF.

If a CYPD were leptokurtic, then the extreme values of the distribution occurred more often than they would in a similarly specified normal distribution. A higher frequency of a complete crop disaster (e.g., a zero crop yield) meant a larger BE premium rate for MPCI than would be estimated with the normal distribution. If a crop were determined to have a perceived or "objective" leptokurtic CYPD, and assuming that the NWID would reflect the increased frequency of total disasters, then a greater need for MPCI as a "disaster recovery" instrument would exist to the extent that producers could not self-insure as easily against such phenomena.

2. Platykurtic - graphically, the PDF had a lower peak than the normal distribution. If the platykurtic distribution had the same mean and variance as the normal, then the platykurtic curve was more squat, its flanks were broader, and its tails were thinner than the

normal (See Figure 4.7) (Sachs 1982). This was <u>negative kurtosis</u>, and was represented as:

$$\alpha_4 < 0$$

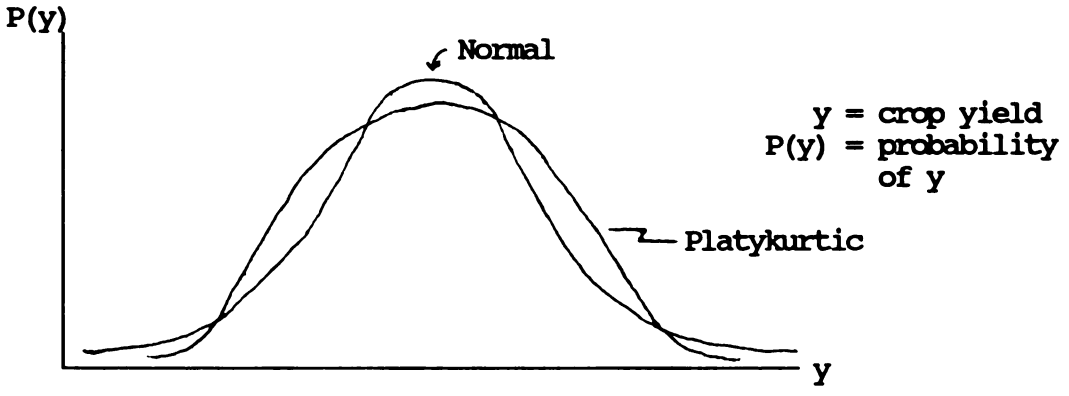

Figure 4.7 Example of a Platykurtic (Negative α_4) CYPDF.

A platykurtic CYPD would have the opposite implications of a leptokurtic CYPD. A platykurtic CYPD would be used to predict extreme values as occurring less frequently than under the assumption of a normally distributed CYPD. If the majority of subjective CYPD's were found to be platykurtic, producers' perceived BE premium rates for MPCI would be low compared to a set of actual BE rates estimated on the basis of a normal CYPD.

<u>CYPD Moments: A Summary.</u> The various measures of central tendency, dispersion, symmetry and kurtosis were used to identify and describe a CYPD. Each CYPD moment had implications for the BE premium rate associated with an MPCI purchase. For pedagogical reasons, the above

discussion was predicated on the notion that a CYPD's properties could be determined at a point in time. Factors that could alter the a CYPD's moments were held constant. The next section in this chapter was designed to address the conditions under which the moments of a CYPD would be expected to change.

4.4. Factors Affecting CYPD Properties

Estimated CYPD properties such as the mean and variance were determined to be sensitive to factors such as technological change and data aggregation in previous research (Gallagher 1986; Eisgruber and Schuman 1963). A review of technological and data impacts on CYPD estimations, and their implications for MPCI analysis, were presented in this section of the chapter.

4.4.1. Impacts of Technology on CYPD's

Improved crop varieties, tillage techniques, pesticides and other technologies contributed to increased U.S. crop production potential over the past fifty years (Cochrane 1979; Tweeten 1979). South Dakota producers also experienced an upward trend in their crop production in the past few decades (Schmiesing 1987).

Changes in the mean and variance of CYPD's were associated with technological advances. The increase in mean crop yields caused by the adoption of new production technologies was extensively documented in previous research (Griliches 1957; Thompson 1969, 1970). Aggregate crop yield variances were observed to be increasing with

time and technological improvements in other studies (Gallagher 1983, 1986, 1987; U.S. Department of Defense 1980).

The symmetry and kurtosis of CYPD's were found to have changed with fertilizer usage (Day 1965). A producer belief that fertilizer use reduced farm level crop yield variability was also reported (Sri-Ramaratnam, et. al. 1987).

The effects of technology on crop yield distributions had a variety of implications for this study. Modelling efforts had to account for the upward trend in mean crop yields. It was also necessary to test for any relationship that existed between crop yield variability and production technology.

MPCI programs under the APH Plan were predicted to experience adverse selection (see chapter two) when crops that had measurable technology trends (Skees and Reed 1985). Adverse selection in MPCI also occurred under the AREA Plan. The question of how severe the adverse selection would be under either program was not completely resolved in previous research.

4.4.2. Impacts of Data Aggregation on CYPD's

Another important issue in the discussion of adverse selection was the availability and usefulness of crop yield data.

The USDA's Statistical Reporting Service (SRS) compiled mean county crop yields for each crop year from the reports of individual producers. The SRS techniques for developing county-level data were similar to those used to estimate farm-level yield variability (Black 1988). Farm-level CYPD's could theoretically be approximated using

the SRS data collection techniques. However, aggregation problems were still associated with the use of county-level crop yield data.

Eisgruber and Schuman (1963) compared historical crop yield data from individual farms with SRS historical county-level data reported by the SRS. They found the ratios of farm-level crop yield variances to county-level crop yield variances ranged from 2:1 to 4:1. The importance of gathering farm-level data for the design of agricultural policies was emphasized in other studies (Black, et. al. 1985). Various hypotheses were proposed as possible explanations for the aggregation problems associated with county-level crop yield data.

One hypothesis for the observed difference in county- and farm-level crop yield data was that individual producers could have highly localized environmental factors impact on their crops. Rain storms could produce hail damage on one producer's field and bring needed moisture to another's. Some producers could have selected crop varieties which were more drought or disease resistant than others. Differences in management goals and practices among producers could also cause crop yield variability to differ between farm-level and SRS county-level data.

The Central Limit Theorem (CLT) was used to demonstrate that measures of variability derived from aggregated data underestimated population variances. The distribution of sample means would be less dispersed (have a smaller variance) than: (1) the variance within individual samples, and (2) the variance of the raw values of the entire population (Hogg and Tanis 1977). If county-level crop yield data were considered a distribution of sample means, then the CLT

would be an explanation for the reduced variance of CYPD's derived from county-level crop yield data.

Published SRS reports were often employed to estimate a CYPD based on a time-series of mean county crop yields. The SRS data collection procedures involved the use of cross-sectional yield data within a county during any given year. The reported crop yield for the county in a particular year was the mean yield of the county cross-sectional data. Access to the cross-sectional observations might provide the basis for developing better estimates of farm-level crop yield variability. However, the individually-sampled crop yield data were not permitted to be released for research purposes in South Dakota (SDCIRS 1988).

Another issue in estimating CYPD's using SRS county-level data was the ability to measure higher moments of the CYPD's such as skewness or kurtosis. There was a potential for CYPD asymmetry or other non-normal distributional properties to be masked with data aggregation. Further application of the CLT demonstrated that a distribution of sample means became a normal distribution as the number of samples drawn (with replacement) from a population became large (Sachs 1982). The shape of the population distribution itself had no effect on the results of the CLT.

Problems in estimating the moments of farm-level CYPD's had implications for MPCI programs. If actual premium and coverage rates for MPCI were primarily based on a historical time series of mean county-level crop yield data, then the resulting MPCI product might not be well designed to meet the crop disaster insurance needs of

producers. For example, if CYPD's based on county-level crop yield data had less variance than a producer's subjective CYPD, then the BE premium rate would be underestimated. If the subjective CYPD were negatively skewed, the BE rate derived from county data would be overestimated. It was not clear how the estimation problems associated with aggregated data would ultimately influence the actual MPCI premium level relative to the perceived BE rate.

Aggregated data still served useful purposes in estimating CYPD's, despite the limitations noted above. Farm-level data were typically not as readily available as aggregated data. Aggregated crop yield data were used in past research to estimate weather impacts on local, regional or national crop production (Thompson 1969, 1970, 1973). Aggregated data were also used to analyze crop yields as a random variable created by fluctuations in environmental factors (Gallagher 1983).

There were at least two important conclusions that could be drawn from the above discussion:

1. Data aggregation created estimation problems for MPCI. Farm-level data collection efforts were needed to approximate the CYPD properties which influenced a producer's MPCI purchase decision.
2. Aggregated data were still useful for estimating the effect of pervasive environmental influences on CYPD's.

Both individual and aggregated crop yield data were needed for validation purposes in this study of CYPD's and their MPCI implications. Alternative methods to approximate the farm-level CYPD's perceived by producers were discussed below.

4.5. Alternative CYPD Estimation Procedures

Subjective CYPD's were determined to be important tools for predicting producers' MPCI purchase decisions in past studies (Zering, McCorkle and Moore 1987). Producers' subjective CYPD's were often measured using elicitation methods (see chapter five).

Each CYPD elicitation in this study required an hour to an hour-and-a-half to complete. Once an elicitation was performed, an average of one-hour of research time was needed to summarize, analyze and interpret the results. The research time necessary for each CYPD analysis was eventually economized with the assistance of a set of applicable microcomputer programs. Overall, the interview and analysis time could be an important obstacle to implementing a subjective CYPD elicitation program for premium determination in MPCI.

The validity of the elicitations and their analysis in this study depended on the interviewed producer being assured that the elicited CYPD would be used anonymously and only for research purposes. If elicitation methods were considered for direct use in the design of the MPCI program, then validation and cost questions arose. Validation of the elicited CYPD would be difficult if producers thought that their MPCI premiums would be tied to their perceived potential for crop yield losses. Producers would have an incentive to

underestimate the downside yield variability in a CYPD elicitation performed for MPCI purposes.

Alternative methods were needed which improved the economic feasibility and validity of estimating subjective CYPD's for an MPCI purchase analysis.

One possibility was to begin with the hypothesis that a producer's subjective CYPD could be approximated by using a simple frequency distribution of historical crop yields. Such a hypothesis would imply that producers formulated their subjective CYPD's with a heavy reliance on the yield record. Producers would make little or no adjustment in their personal CYPD's to account for changes in distributional moments associated with new management practices or technologies.

A researcher might expect the "historical yield frequency hypothesis" to be rejected, if producers were assumed to be Bayesian decisionmakers who modified their beliefs as new information about the current CYPD became known (Winkler 1972). However, the historical frequency hypothesis could be used as a starting point to establish whether more sophisticated models were needed to approximate the CYPD's perceived by producers.

Statistical models of crop yield variability were proposed to estimate MPCI premiums and indemnities in earlier research (Halcrow 1949, 1978). Crop yield capacity function (CYCF) estimation techniques were recently introduced to model both technological and environmental impacts on crop yields (Gallagher 1983). CYPD's could be derived from CYCF's. These CYCF-derived CYPD's were a statistical

representation of the yield fluctuations created by the environmental conditions for crop production.

CYCF's had not been applied in MPCI research prior to this study. The research opportunity of particular interest in this part of the investigation was to develop a relatively inexpensive proxy measure for subjective farm-level CYPD's.

If the CYCF technique were to produce useful estimates of subjective CYPD's, producers' perceived crop yield risks could be approximated at a lower research cost.

4.6. Crop Yield Capacity Functions and Probability Distributions

Crop yields were modelled as functions of prices, technology and environmental factors with CYCF's (Gallagher 1983). Capacity yields were defined in CYCF's as maximum yield levels that occurred when environmental conditions were ideal and production was assumed economically efficient.

Capacity and sub-capacity crop yields were assigned probabilities because environmental growing conditions were considered chance events. The CYCF-derived CYPD was defined as the set of probabilities that describe the size and frequency of crop yields occurring at or below the capacity yield.

An increase in capacity yields over time was specified as the result of a technological trend. Capacity yield trends and the associated CYCF-derived CYPD's were visually represented in the form of a graph (see Figure 4.8).

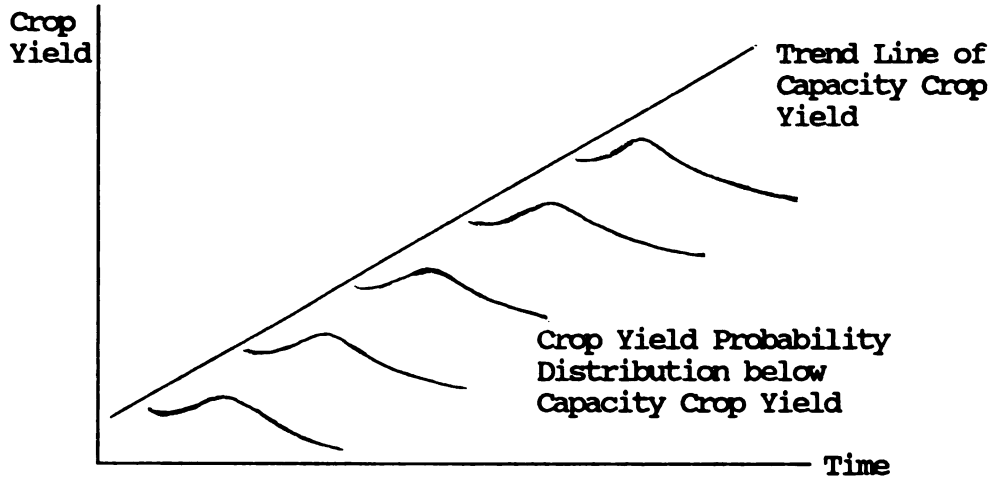

Figure 4.8 Technology Trend in Capacity Crop Yields.

An assumption of the CYCF was that the properties of the CYPD beneath the capacity yield did not change over time (see Figure 4.8). The CYPD assumption meant that the CYCF could not be used to explicitly model any trends that existed in the environment-crop yield relationship (see this chapter, section 4.4.1).

An advantage of using the CYCF was the ability to estimate the CYPD's moments and its upper crop yield limit. If CYPD properties such as skewness and the capacity limit were ignored, and if a normal CYPD centered on the mean yield were assumed, then a model of the MPCI purchase decision could either be overly optimistic or overly pessimistic about a producer's incentive to acquire MPCI coverage as part of his crop enterprise.

4.6.1. CYCF Specification

The following CYCF was used to formally derive a CYPD (Gallagher 1983):

$$YCAP_t = f_t(X1, X2, \ldots, Xn) + U_t \qquad \text{(Equation 4.1)}$$

Where: $YCAP_t$ = optimum crop yield output at time t, if environmental growing conditions were ideal. This was known as the "capacity crop yield" at time t.

$f_t(\cdot)$ = crop yield response function assuming economically efficient production and current technology, at time t.

Xi = ith explanatory variable in the crop yield response process.

U_t = downside yield variation at time t, caused by less-than-ideal environmental growing conditions, where $U_t \leq 0$.

The impacts of inputs, prices and technology on crop yields were specified in the CYCF functional form [$f_t(\cdot)$] of Equation 4.1. The properties of the U_t variable in the above CYCF equation were described with CYPD's.

4.6.2. Estimation Procedures for CYCF-derived CYPD's

The U_t error term in Equation 4.1 was modelled as a CYPD with measurable properties that were important in the analysis of MPCI.

The traditional econometric methods for estimating an equation were not directly applicable to CYCF's. The typical econometric equation had a symmetric error term with its distribution centered on the mean value being estimated. The CYCF required that a one-sided

error term be used in the econometric estimation procedure (Gallagher 1983). The term "one-sided" meant that the maximum value (not the mean value) was being estimated, and that all other values would necessarily be negative deviations below the maximum.

The U_t error term was a distribution of stochastic deviations below a capacity yield level. The Ut distribution could be skewed or have other non-normal properties. Procedures for measuring the one-sided error term were called "frontier production function (FPF) estimations" in the econometric literature (Afriat 1972).

There were two important distinctions between Gallagher's work on crop yield capacity functions (CYCF's) and the typical application of the FPF estimation technique:

1. Sub-optimal production was assumed to occur in the FPF error term because controllable inputs were misallocated, while sub-optimal output in the CYCF was attributed to random and uncontrollable environmental factors. An assumption was made in the CYCF that agricultural production was economically efficient. On the other hand, an FPF error term was most often used to estimate how economic inefficiency was distributed among firms in an industry.
2. CYCF estimations were performed with aggregated time series data, whereas FPF's were modelled with cross-sectional industry data. Aggregated time series data were used in CYCF's to measure the historical influence of environmental factors on crop yield variability. An

industry's "average" amount of inefficiency was measured in the FPF by the mean deviation from an industry's optimum production level.

The estimation procedures for CYCF's and FPF's were often the same, despite the differences in the "philosophy" and data requirements of the two functions. CYCF and FPF estimations both benefited from theoretical and practical developments in econometrics (Richmond 1974; Schmidt 1976; Greene 1980; Gallagher 1987). Forsund, Lovell and Schmidt (1980) published an excellent review of the history, techniques and meaning of FPF estimation in an issue of the Journal of Econometrics devoted almost entirely to the topic.

The FPF was theoretically founded on the production possibilities concept (Farrell 1957). An optimum output was generated in an FPF when inputs and technologies were used efficiently. Farrell's model was first applied with mathematical programming techniques (Aigner and Chu 1968). Maximum likelihood estimation was the initial statistical technique used to measure an FPF (Afriat 1972). The models constructed before 1977 all specified optimum output as a deterministic value (Afriat 1972; Richmond 1974; Schmidt 1976). A typical deterministic frontier production function for econometric estimation was (Forsund, Lovell and Schmidt 1980):

$$y = \ln[f(x)] - u \qquad \text{(Equation 4.2)}$$

Where:

y = deterministic frontier output level
$\ln[f(x)]$ = Cobb-Douglas functional form
x = input(s)
u = error term representing production below the frontier, where $u \geq 0$

The u error term in Equation 4.2 was specified to assume the shape of probability distributions such as the half-normal, beta, gamma or exponential.

Estimation problems existed when deterministic frontier production function were used for forecasting. Actual output could exceed the predicted capacity level. These forecasting problems were attributed to:

1. heteroskedasticity in the error term, and
2. statistical "noise" and measurement error in estimating the capacity yield.

Gallagher (1986, 1987) encountered heteroskedasticity when modelling CYCF's with national corn and soybean yield data. He adjusted the coefficients of the explanatory variables in his CYCF model for an increasing variance trend in the error term.

Optimal output levels were modeled as a random variable in a stochastic frontier production function (stochastic FPF) (Aigner, Lovell and Schmidt 1977; Meeusen and van den Broeck 1977). The stochastic FPF estimation procedure had an error term composed of two parts. One part of the error term was a normal probability density function (PDF) which was used to represent statistical noise encountered in the measurement of the frontier itself. Measurement errors on either side of the frontier were assumed to be equally likely, so the normal PDF for the first part of the error term had its mean centered on the frontier. The second part of the error term was a PDF which measured the downside variation from the frontier. The "downside PDF" corresponded to the u error term in the

deterministic FPF model. An example of a stochastic FPF was presented in Forsund, Lovell and Schmidt (1980) as:

$$y = f(x) \cdot \exp(\tau) \qquad \text{(Equation 4.3)}$$

Where: $\tau = (v-u)$ (total disturbance term)
v = normally-distributed error, centered on the frontier output
u = error term representing production below the frontier, where $u \geq 0$
y = frontier output
x = input(s)

One weakness of the stochastic FPF was the inability to attribute the variation in the τ disturbance to its separate components. One remedy to the τ estimation problem was to derive the conditional distribution of u given τ (Jondrow, et. al. 1982).

Stochastic and deterministic FPF's were estimated with maximum likelihood (ML) methods or with a procedure known as corrected ordinary least squares (COLS) (Forsund, Lovell and Schmidt 1980). The requirements for ML estimation were: (1) the distribution of the u error term (and v for stochastic FPF's) had to be specified before the parameters were estimated, (2) x was exogenous, and (3) u and v were independent distributions (Stevenson 1980).

COLS was performed by adjusting the constant term of an ordinary least squares (OLS) estimation with the expected value of the u error term (Richmond 1974). If a given distribution were assumed for u, then the distribution's parameters were estimated consistently from the moments of the OLS residuals (Forsund, Lovell and Schmidt 1980).

Some distinguishing properties of the two estimation techniques were described in Table 4.6.

Table 4.6 Comparison of ML and COLS Methods for CYCF Estimation.

Assuming Either a Deterministic or Stochastic CYCF

Estimated Component of the CYCF	Maximum Likelihood Estimation	Corrected Ordinary Least Squares Estimation
Constant Term	Consistent and Asymptotically Efficient	Consistent Only
Coefficient(s) of the Explanatory Variables	Consistent and Asymptotically Efficient	Consistent and Unbiased
Variance, Skewness and Kurtosis of the the U_t Error Term	Consistent and Asymptotically Efficient	Consistent Only
Ease of Calculation	Relatively Difficult	Relatively Easy
Monte Carlo Simulation of Estimator Performance (Olson, et. al. 1980)	Similar to COLS, even for large sample sizes ($n \leq 400$)	Similar to ML, even for large sample sizes ($n \leq 400$)

ML estimation had properties which were theoretically desirable (see Table 4.6). However, when Monte Carlo simulations were used to test the ML and COLS techniques, the ML estimates were determined to create only a small efficiency gain as compared to the COLS estimates (Olson, Schmidt and Waldman 1980). The theoretical advantages of ML relative to COLS were not likely to justify the extra trouble required to perform the ML procedure (Olson, Schmidt and Waldman 1980). COLS procedures were selected in this study to estimate the CYCF-derived CYPD's (see chapter six).

4.7. Comparison of Alternatively Estimated CYPD's

Alternative CYPD estimations were examined in this study to determine whether the subjective CYPD's perceived by producers could be approximated at a reduced research expense. One method, direct elicitation of CYPD's from producers, involved individual producer interviews. CYPD's elicitations used in MPCI premium determination were subject to a producer incentive to understate personal beliefs about the probabilities of insurable crop yield losses.

Three alternatives for CYPD estimation were considered in this study. Frequency distributions were directly estimated from historical county-level crop yield data. CYPD's were derived from CYCF's. The CYCF-derived CYPD's were estimated using historical county-level crop yield data. Farm-level subjective CYPD's were elicited from individual producers for research purposes rather than for official use in MPCI. The historical frequency and CYCF-derived CYPD's were

tested as distributions which could approximate the subjective CYPD's perceived by producers.

Individual subjective CYPD results for each elicited crop were aggregated to produce a sample-wide CYPD. Theoretical and practical procedures for aggregating subjective CYPD's were adopted to compare the aggregated subjective CYPD's with the historical frequency and CYCF-derived CYPD's (Bessler 1980).

If the historical frequency CYPD's were determined to not be similar to the aggregated subjective CYPD's, and if capacity-derived CYPD's were shown to be similar to the aggregated subjective CYPD's, then CYCF estimation would be a relatively inexpensive technique for estimating CYPD's which were proxies for CYPD's obtained from individual elicitations.

4.8. Relevance of CYPD's for MPCI

Alternative methods for estimating producers' CYPD's were reviewed in this chapter. CYPD's were identified as a useful tool for summarizing stochastic fluctuations in crop yields. Subjective CYPD's were measures of producers' personalistic views of how random environmental forces influenced the likelihood of obtaining different crop yield levels.

Subjective CYPD's were obtained using elicitation procedures to interview individual producers. Subjective CYPD's were valuable for analyzing a producer's MPCI purchase decision. The design of the MPCI product could be improved if subjective CYPD information were available for producers who were potential MPCI users. However, practical

and economic considerations were important barriers to the direct use of subjective CYPD's in MPCI. There was a need for other CYPD measures which would be advantageous proxies for the subjective CYPD's.

A research opportunity existed to test the use of historical frequency and CYCF-derived CYPD's as proxy measures for subjective farm-level CYPD's. CYCF's were statistical models of technological and environmental crop yield impacts. CYCF's could be estimated inexpensively with COLS procedures and historical county crop yield data.

Producers were assumed to make decisions based on their personal view of the probabilities of events and their attitudes towards risk (Arrow 1971). Actual MPCI premiums could be compared to the theoretical premiums that producers would willing to pay, given their subjective CYPD's and risk attitudes. CYPD concepts and estimation procedures were the primary focus of this chapter. The results of elicitations conducted to obtain subjective CYPD's were presented and discussed in chapter five.

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Chapter Five

Empirical Estimations of Subjective Crop Yield Probability Distributions in Brookings County, South Dakota

Subjective probability distributions were an important component in an expected utility hypothesis (EUH) model of decision making under risk (Savage 1954). Elicitations of producers' subjective crop yield probability distributions (CYPD's) were investigated in this chapter. The term "elicitation" referred to a complete interview process used to obtain a subjective CYPD. The MPCI purchase decision was analyzed in an EUH model with elicited CYPD results (see chapter seven).

The chapter was organized to present subjective CYPD elicitation methods and results. The sampling procedure used to select producers for the CYPD elicitations was described. The elicitation protocol for obtaining individual CYPD's was presented. Methods and criteria for aggregating the individual CYPD elicitations were discussed. The aggregated-elicited CYPD results were interpreted. The implications of the aggregated-elicited CYPD's for MPCI were summarized in the chapter's conclusion.

5.1. Research Design for the CYPD Elicitations

The research problem in this chapter was to develop subjective CYPD's for an EUH analysis of the MPCI purchase in Brookings County, South Dakota. The problem was confronted by applying techniques to

elicit subjective CYPD's from randomly selected producers in the county. The results of the elicitations were aggregated to obtain subjective CYPD's which were representative of producers with similar crop management skills. The elicitations were also aggregated for comparison with alternatively estimated CYPD's (see chapter six).

Sampling theory was used to determine the number of Brookings County producers selected for the elicitations. Recent advances in crop yield probability elicitation procedures were applied to conduct individual interviews with producers to obtain their subjective CYPD's (Nelson and Harris 1978; Pease 1987). Aggregation theory was utilized to determine the methods for aggregating individual subjective CYPD's (Bessler 1980). The results of the aggregated-elicited CYPD's were examined for their potential implications in an EUH model of the MPCI purchase decision.

5.2. Application of Sampling Theory

Corn acreage and production volume were observed to be the largest of any crop in Brookings County (South Dakota Crop and Livestock Reporting Service [SDCLRS] 1987b). Corn was selected as the crop for determining the sample size for the elicitations in this study.

The sample size selected to estimate the mean corn yield for the population of Brookings County producers was determined by three statistical criteria (Mason 1978):

1. the corn yield standard deviation for the producer population,
2. the desired statistical confidence level, and
3. the allowable error of the sample mean crop yield as an estimate of the population mean.

The three sampling criteria were implemented by specifying the desired accuracy levels and using statistical formulas.[1] Different sample sizes required under various assumptions of standard deviation, statistical confidence and allowable sample mean errors were presented in Table 5.1. If sample size had been selected to estimate crop yield variances instead of means, the sample sizes for similar confidence intervals and allowable errors would have been larger by a factor of ten or more (Tiku 1967).

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[1] The statistical formulas used to derive a sample size were:

$$\text{Standard Error of the Sample Mean} = \frac{\text{Allowed +/- Error about the Population Mean}}{\text{Standardized Z-value of the Confidence Limit}}$$

$$\text{Sample Size} = \left[\frac{\text{Sample Standard Deviation}}{\text{Standard Error of the Sample Mean}}\right]^2$$

Table 5.1 Table of Sample Sizes.

Confidence Interval and Allowable Error	Size of Crop Yield Standard Deviations (#bushels/acre) 15	20	25
90% Confidence	Sample Size		
+/- 10 bu/ac	6.09	10.82	16.91
+/- 5 bu/ac	24.35	43.30	67.65
+/- 1 bu/ac	608.86	1082.41	1691.27
95% Confidence	Sample Size		
+/- 10 bu/ac	8.64	15.37	24.01
+/- 5 bu/ac	34.57	61.47	96.04
+/- 1 bu/ac	864.36	1536.64	2401.00

A rapid increase in the recommended sample size was observed as the allowable error about the mean was decreased (Table 5.1). Higher sample sizes generally required greater research expenditures. The tradeoff between accuracy and sample size was an important consideration because of the study's time and budget constraints.

The sample size for the Brookings County CYPD elicitations was ascertained using Table 5.1. A corn yield standard deviation estimate was obtained from historical county-level data. Historical Brookings County yield data were presented in Table 5.2.

Table 5.2 Statistical Characteristics of Brookings County Corn Yields.

Statistical Measure	Years 1965 - 1972	1973 - 1985	1965 - 1985
Mean Yield..... (Bu/Ac)	44.75	62.20	55.59
Standard Deviation..... (Bu/Ac)	8.66	18.09	17.42
Coefficient of Variation ..... (Unitless Ratio)	0.19	0.29	0.31

Source: South Dakota Crop and Livestock Reporting Service, 1965-1985.

Brookings County corn yield means and standard deviations increased over the past twenty years (see Table 5.2). The 1972 crop year was used to divide the data set because it was a transition year for acreage and production. Nationally, the pre-1972 years were characterized by acreage controls and the post-1972 years had crop acreage expansions (Cochrane 1979). Corn acreages in Brookings County also followed the national pattern.

Standard deviations estimated from aggregated data such as county-level yields were found to underestimate farm-level yield standard deviations in previous studies (Eisgruber and Schuman 1963). More precise estimations of farm-level yield variability in this study

would have required upward adjustment of the county-level standard deviation estimates.

Higher standard deviations increased the needed sample size for a given level of statistical confidence. Larger sample sizes were associated with time and budget demands which were beyond the study's constraints. The standard deviation used to determine the sample size was the county-level value during the 1973 - 1985 period (Table 5.2).

The sample size for the study was determined to be sixty-two. This number was derived from the statistical formulas, assuming an 18.09 bu/ac standard deviation, a 4.5 bu/ac allowable sample mean error, and a 95% confidence interval. The South Dakota Crop and Livestock Reporting Service stated that Brookings County had a population of 867 agricultural producers as of October 1986 (SDCLRS 1987a). The sample size was 7.15% of the reported producer population.

The sixty-two personal interviews were conducted during March-July 1987 in Brookings County, South Dakota. Agricultural owner-operators were randomly selected from the County's ASCS list of producers. The producers on the list were those who had previously or currently received payments from the USDA farm programs. All sixty-two interviewed producers were male.

5.3. Protocol for Subjective CYPD Elicitations

A protocol developed in earlier research was used to conduct the Brookings County elicitations (Nelson and Harris 1978; Pease and Black 1987; Pease 1987). The protocol was a systematic plan for questioning producers about their crop yield perceptions. The

structured interview approach contributed to consistency in the subjective CYPD elicitations.

One goal of the protocol was to gain the confidence of the interviewed producer. The initial part of the interview was used to familiarize the producer with the basic procedures, to develop a rapport and to clearly guarantee the interview's confidentiality.

The protocol for the Brookings County interviews included the use of risk-rated crop budgets (Schumaker, et. al. 1986) as a motivational device. Price, yield, and government program impacts on net income variability were illustrated to the interviewed producers with the risk-rated budgets. Representative risk-rated budgets were prepared for five crop enterprises (corn, soybeans, oats, spring wheat and barley). All the budgets were designed to be examples of typical crop and price probabilities faced by Brookings County producers.

The primary purpose of the protocol was to obtain subjective CYPD's for a producer's three major crops. Corn, soybeans and oats were the dominant crops in Brookings County, SD, and the CYPD's elicited from the producer sample consisted primarily of these three crops. The interviews averaged an hour-and-a-half in length. The sixty-two elicitations were conducted by this author.

The interview protocol was pre-tested by conducting a dry-run interview with a Minnesota farm owner-operator. A demonstration was also performed for the Brookings County Extension Agent. Letters were subsequently sent to the sampled Brookings County producers to explain the purpose of the personal interviews. The letters were followed in a timely manner by initial phone contacts. If a producer

responded favorably to the prospect of a personal interview, then an appointment was made. The interviewer visited the producer's home, and conducted the interview with the aid of a portable computer and printer.

5.3.1. Survey Instrument for the Elicitations

A microcomputer-based survey instrument, "Personal Probabilities of Crop Yields," (Pease and Black 1986) was used to elicit CYPD's from the sampled producers. The survey instrument was hereafter referred to as "the computer program". The conviction weights technique was used with the computer program to elicit scores from the interviewed producer for crop yield intervals (Nelson and Harris 1978; Pease 1987). The scores were entered into the computer program. Each score represented the producer's strength of belief that a given crop yield interval (e.g., 50-60 bu/ac) would occur.

The interviewed producer evaluated the likelihood of the crop yield intervals under the assumption that his current cropping practices were being employed. Then the producer assigned scores based on the uncontrollable risks (weather, etc.) that caused variation in yields.

The anchoring principle was used in the conviction weights technique. A frame of reference for eliciting the subjective CYPD was defined with the anchoring principle. The interviewed producer identified the modal crop yield interval as an anchoring value. The modal interval was the yield span the producer expected to occur most frequently.

The interviewed producer assigned conviction scores to every yield interval. A score of 100 was assigned to the modal interval. Then the producer designated scores between 0 and 100 for the other yield intervals to indicate the relative frequency of all possible yields for the farm.

Subjective probabilities were indirectly elicited with the conviction weights. The producer-assigned score for each yield interval was converted into a probability in the computer program. The computer program was written to be consistent with the laws of probability (Nelson and Harris 1978; Savage 1954).

The probabilities derived from the producer's responses were displayed instantaneously during the interview with the computer program. The resulting CYPD was checked for compatibility with the producer's beliefs. If the CYPD did not agree with the producer's beliefs, the producer was encouraged to revise his scores until he was satisfied with the resulting CYPD.

The elicited CYPD's expected mean yield was used as one basis to validate the elicitation results against the interviewed producer's beliefs. Mean crop yield, rather than modal yield interval, was checked for compatibility with the producer's subjective views for two reasons. First, the CYPD's expected mean yield was most directly comparable with the mean historical average yield for the producer's farm. Second, mean crop yield was the measure used in MPCI to determine the insured yield.

5.3.2. Measures of Mean Crop Yields in the Elicitations

Differences were observed to occur between the expected mean yields and historical mean yields of the interviewed Brookings County producers. The interviewed producers often stated that their recent yield history was not indicative of the average yield they expected to produce. Brookings County received above-normal precipitation in four of five years during the 1982-1986 period (SDCIRS 1982-1986). Moisture was a limiting factor for corn production in Brookings County. Above-normal precipitation was hypothesized to have a positive impact on the interviewed producers' recent historical yields.

The statistical significance of the difference between the historical and expected of mean corn yields was tested. The results of the statistical test was reported in Table 5.3.

Table 5.3 Difference of the Interviewed Producers' Expected Mean Corn Yield (μ_e) and the Historical Mean Corn Yield (μ_h).

Crop Yield Measure	CYPD-based Mean Corn Yield (μ_e)	Historically-Based Mean Corn Yield (μ_h)
Mean	71.4	76.7
Stand. Devia.	10.8	13.6
# of Observations	55	55

One-Tailed Test of the Difference of the Means:

H_o: $(\mu_e) = (\mu_h)$
H_1: $(\mu_e) < (\mu_h)$
Critical t-value, 0.05 level,
53 degrees of freedom: $t_{.05} > 1.68$
Calculated t-value: 1.80
Test Results: Reject H_o,
Not Reject H_1

The mean historical yields in Table 5.3 were calculated from producers with records from the previous five years. The interviewed producers often discounted their expected mean yields below their historical yields. This discounting reflected a belief that the climatic effects on their observed crop yields were temporary. The historical and expected mean yields were determined to be different at the 0.05 significance level (Table 5.3), and were treated as separate measures of the producers' average crop yields in the study.

5.4. Aggregation of the Elicited Crop Yield Probability Distributions

The discussion below was used to introduce the methods and the criteria for aggregating the elicited CYPD's.

A technique first applied by Bessler (1980) was used to convert individual CYPD elicitation results into aggregated-elicited CYPD's. Aggregated-elicited CYPD's were derived in Bessler's work by taking a simple average of the individual producer CYPD's (Ijiri 1971; de Finetti 1964).

The Brookings County elicitations were aggregated by using an averaging method which assigned equal weights to the interviewed producers' conviction scores. The conviction scores obtained from producers for each respective yield interval were summed. The yield interval with the largest sum was assigned a index value of 100. The sums of all the other yield intervals were scaled relative to the aggregated modal interval. The resulting set of indexed scores was used to derive an aggregated subjective CYPD.

Soil productivity, mean crop yield, and sample-wide criteria were the bases for aggregating the interviewed producers' subjective CYPD's. Attempts to aggregate the CYPD's according to the three criteria were hypothesized and tested.

Soils-based aggregations were performed to test the hypothesis that producers with better soils had higher mean yields. The aggregations' results were studied to determine implications for a soils-based MPCI program.

Mean yield-based aggregations served two purposes. First, an aggregated-elicited CYPD derived for a group of producers with similar

mean crop yields was considered to be the group's "representative subjective CYPD." Such a representative CYPD could be used to model the MPCI purchase decision for that producer group. Second, the aggregation was used to test the hypothesis that producers with higher mean yields were less likely to experience insurable yield losses. This last hypothesis was important because MPCI's premium rates decreased as a producer's historical mean yield increased.

A sample-wide aggregation for each of the corn, soybean and oats elicitations crops was performed with the scaled index approach mentioned above. The sample-wide aggregated CYPD's were developed to compare the results with the CYPD estimations obtained from county-level data (see chapter six).

5.4.1. Soil Productivity as a Basis for CYPD Aggregation

Aggregated CYPD's were developed for interviewed producers with similar whole-farm average soil productivities. The null hypothesis for this CYPD aggregation was that farms with different average soil productivities had the same mean crop yields. If the null hypothesis were rejected, then soil productivity indexes were considered a proxy for estimating a farm's average yields.

If the relationship between whole-farm soil productivity and mean crop yield were found to be statistically significant, then MPCI programs could be designed to use to soil information in determining a farm's insurable yield. If the null hypothesis were not rejected, then alternative methods could be sought to estimate producers' yields for insurance and other purposes.

A soil productivity index was developed for each farm in the sample. First, the Soil Survey of Brookings County, South Dakota (USDA, SCS 1959) was used to identify the variety of soil types and the acreage distribution of those soil types in the county. Then the publication, Rating South Dakota Soils According to Productivity (Malo and Westin 1978) was employed to develop a productivity index for each soil in Brookings County.

The soil type in Brookings County with the highest crop production potential (Moody Silt Loam) was assigned a productivity rating of 100 (Janssen and Malo 1987). A soil productivity index, scaled 0 to 100, was developed based on the Moody Silt Loam rating. A table and graph of the distribution of soil productivity in Brookings County was presented on pages 356-358 of Appendix C.

The location and size of the farm for each producer in the sample was determined by examining the Atlas of Brookings County, South Dakota (Midland Atlas Co. 1983). The acreage and section number(s) for each surveyed farmer were then used in conjunction with the Soil Survey of Brookings County to estimate an overall soil productivity index for the farm.

A weighted productivity index for each interviewed producer's farm was estimated. A transparent grid, divided into 10 acre intervals, was used on each soil "sheet map" to approximate the acreage of each soil type on the farm. Then the productivity of each soil type was weighted by its proportion of the total farm acreage. These weighted productivities were summed to provide a weighted average productivity index for the entire farm. A graph and table of the distribution of

soil productivities for the sample of Brookings County producers appears on pages 359-361 of Appendix C.

The distribution of soil productivities for the surveyed producers was divided into five intervals, each interval being five index points in size. The size of the interval was determined by taking the square root of the difference between the maximum and minimum index values (Sachs 1982).

Each surveyed producer's productivity rating was placed in the appropriate interval. The number of producers who were in each soil productivity interval was illustrated in Table 5.4.

Table 5.4 Distribution of Soil Productivities for Surveyed Brookings County Producers.

Soil Productivity Ratings Divided into Intervals	Number of Surveyed Producers Found to be in Each Interval
77.1 to 82.10	24
72.1 to 77.09	13
67.1 to 72.09	10
62.1 to 67.09	9
57.1 to 62.09	6
Sample's Entire Range: 57.1 to 82.1	62

The distribution of average soil productivities in Table 5.4 was negatively skewed. The majority of sampled producer's farms fell in the upper ranges of the soil productivity ratings. The sample's negative skewness was similar to the asymmetry in the distribution of all soils in Brookings County. The soil productivity distributions

for Brookings County and the sample were presented in tabular and graphical forms on pages 356-358 of Appendix C.

5.4.2. Results of the Soils-Based CYPD Aggregations

The next step in this research was to categorize producers' mean yields according to the estimated soil productivity rating for each farm. The purpose of this classification was to observe the relationship between the mean yield and the farm's average soil productivity.

The interviewed producers' expected and historical mean corn yields were categorized into their respective whole-farm soil productivity intervals. The mean and standard deviation of the elicited and historical mean corn yields within each soil productivity level were illustrated in Tables 5.5 and 5.6.

Table 5.5 Producers' Elicited Mean Corn Yield Distribution Parameters Arranged by Soil Productivity Intervals.

Distribution of Elicited Mean Corn Yields				
Soil Productivity Ratings Divided into Intervals	# of Surveyed Corn Producers in Interval	Avg. Elic. Mean Corn Yield Within Soil Pro. Interval	Average Std. Dev. of Elic. Mean Corn Yield Within Interval	Average Coeffic. of Variation Within Interval
77.1 to 82.10	24	70.9	10.4	0.147
72.1 to 77.09	12	76.0	10.8	0.142
67.1 to 72.09	8	73.0	14.0	0.192
62.1 to 67.09	7	66.3	6.7	0.101
57.1 to 62.09	4	69.0	4.7	0.068
Sample's Entire Range: 57.1 to 82.1	55	71.4	10.3	0.144

Table 5.6 Producers' Historical Mean Corn Yield Distribution Parameters Arranged by Soil Productivity Intervals.

Distribution of Historical Mean Corn Yields				
Soil Productivity Ratings Divided into Intervals	# of Surveyed Corn Producers in Interval	Avg. Hist. Mean Corn Yield Within Soil Pro. Interval	Average Std. Dev. of Hist. Mean Corn Yield Within Interval	Average Coeffic. of Variation Within Interval
77.1 to 82.10	24	77.3	15.5	0.201
72.1 to 77.09	12	79.3	11.1	0.139
67.1 to 72.09	8	72.4	14.7	0.203
62.1 to 67.09	7	74.1	10.1	0.136
57.1 to 62.09	4	78.5	7.2	0.092
Sample's Entire Range: 57.1 to 82.1	55	76.7	13.6	0.177

Hypotheses about the relationship between whole-farm average soil productivity and mean crop yield were tested with the information in Tables 5.5 and 5.6. A positive correlation between a farm's average soil productivity and its mean crop yield was expected, because the productivity ratings were an indicator of crop yield potential. The differences between the elicited mean corn yields in the first, third, fourth and fifth soil productivity intervals in Table 5.5 were relatively small. The historical mean yields were similar in the first, second, third and fifth soil productivity levels.

If the elicited corn yield standard deviations in the three intervals between the 67.1 to 77.1 soil productivity values were added or subtracted from their respective mean yields, then the elicited mean yields of all the soil intervals were within the range of values determined by the standard deviations (see Table 5.5).

The differences among the elicited and historical mean yields in the soil intervals were tested for statistical differences. The results of those tests were presented in Tables 5.7 and 5.8.

Table 5.7 Statistical Test of the Difference Between Elicited Mean Corn Yields by Soil Productivity Interval.

Yield Notation and Soil Productivity Ratings for each Soil Pro. Interval	Notation for Difference in Mean Yd. betw. Intervals	Reject or Not-Reject Null Hypothesis that Mean Corn Yields in Each Soil Prod. Interval were Equal
SP1: 77.1 to 82.10	(SP1-SP2)	Not-Reject (-1.24)*
	(SP1-SP3)	Not-Reject (-0.32)
	(SP1-SP4)	Not-Reject (1.62)
	(SP1-SP5)	Not-Reject (0.60)
SP2: 72.1 to 77.09	(SP2-SP3)	Not-Reject (0.51)
	(SP2-SP4)	Reject (2.50)
	(SP2-SP5)	Reject (1.68)
SP3: 67.1 to 72.09	(SP3-SP4)	Reject (2.05)
	(SP3-SP5)	Not-Reject (0.66)
SP4: 62.1 to 67.09	(SP4-SP5)	Not-Reject (-0.99)
SP5: 57.1 to 62.09	N/A**	N/A

* Standard normal values were placed in parentheses. This was a one-tailed test, because a higher soil productivity potential was expected to produce a higher mean yield. The critical value at the 0.05 level for rejecting the null hypothesis was +1.645.

** N/A = Not Applicable.

Table 5.8 Statistical Test of the Difference Between Historical Mean Corn Yields by Soil Productivity Interval.

Yield Notation and Soil Productivity Ratings for each Soil Pro. Interval	Notation for Difference in Mean Yd. betw. Intervals	Reject or Not-Reject Null Hypothesis that Mean Corn Yields in Each Soil Prod. Interval were Equal
SP1: 77.1 to 82.10	(SP1-SP2)	Not-Reject (-0.44)*
	(SP1-SP3)	Not-Reject (0.80)
	(SP1-SP4)	Not-Reject (0.63)
	(SP1-SP5)	Not-Reject (-0.26)
SP2: 72.1 to 77.09	(SP2-SP3)	Not-Reject (1.13)
	(SP2-SP4)	Not-Reject (1.03)
	(SP2-SP5)	Not-Reject (0.16)
SP3: 67.1 to 72.09	(SP3-SP4)	Not-Reject (-0.42)
	(SP3-SP5)	Not-Reject (-0.98)
SP4: 62.1 to 67.09	(SP4-SP5)	Not-Reject (-0.84)
SP5: 57.1 to 62.09	N/A**	N/A

* Standard normal values were placed in parentheses. This was a one-tailed test, because a higher soil productivity potential was expected to produce a higher mean yield. The critical value at the 0.05 level for rejecting the null hypothesis was +1.645.

** N/A = Not Applicable.

The results from Tables 5.7 and 5.8 were summarized as follows:

1. When the standard error of the difference between mean corn yields was smaller than the critical value, then the mean crop yields of the soil productivity intervals were not statistically different. The null hypothesis that elicited mean yields were equal on farms with different average soil productivities was rejected in seven of ten cases. The null hypothesis that historical mean yields were equal on farms with different soil productivities was rejected in ten out of ten cases.

2. Producers in the second soil productivity level had elicited and historical mean crop yields which exceeded those of producers with the highest average soil productivity level (SP1 < SP2 in Tables 5.7 and 5.8). These unexpected results were measured as negative standard errors in one-tailed tests of significant differences. Differences among producers' mean crop yields were hypothesized to exist for reasons other than average soil productivity.

3. An average soil productivity index was determined to be a poor indicator of a producer's mean corn yields. The notion that a farm's average soil productivity was a reliable proxy for mean crop yields was not supported when the null hypothesis could not be rejected in Tables 5.7 and 5.8.

The results of Tables 5.7 and 5.8 were interpreted with an alternative hypothesis: a farmer's management goals and skills were significant factors in determining mean crop yields. Soil was viewed as only one input to the production process. Farm managers were analyzed as decision makers who organized various soil and non-soil inputs to obtain a desired output level.

There was an important implication of the research results in Tables 5.7 and 5.8 for MPCI. Before 1982, MPCI's insurable yield was an "Area Crop Yield" based on local soils information and SRS county-average yield data. If insured yields were determined by using soil productivities, then some producers could obtain higher coverage than would be justified by their actual yields, while other producers would not find the premium cost to be economical because of the low yield coverage they would receive.

Since 1982, MPCI's APH Plan was based on an average of the producer's past yields rather than county-average yield data and soil information. An interpretation of Tables 5.7 and 5.8 was that average soil productivity was not a good indicator of a producer's mean yield. A testable hypothesis was whether the APH Plan would cause the MPCI purchase to be more economically attractive than it was under the AREA Plan (see chapter seven).

5.5. Mean Crop Yield as a Basis for CYPD Aggregation

Historical farm-level mean corn yields were selected as an alternative to soil productivity for aggregating the CYPD's. The producer's historical mean yield was viewed as a proxy for his

managerial skill. Historical, rather than elicited, mean yields were used as the basis for CYPD aggregation because the FCIC must rely historical records to classify producers for premium and coverage determination.

Equal intervals of historical mean corn yields were established. Individually-elicited CYPD's were aggregated within each interval according to their corresponding historical mean corn yields. Each aggregated-elicited CYPD was considered to be a representative subjective CYPD for its associated corn yield interval.

Fifty-five of the sixty-two interviewed producers provided CYPD's for dryland corn production. The intervals of historical mean corn yields from those producers were illustrated in Table 5.9.

Table 5.9 Historical Mean Corn Yield Intervals Used to Aggregate CYPD's.

Interval of Historical Mean Corn Yields (bushels/acre)	Number of Surveyed Producers in the Interval	% of Surveyed Producers Who Raised Corn
91 - 101	8	14.5%
80 - 90	15	27.3%
69 - 79	16	29.1%
58 - 68	11	20.0%
39 - 57	5	9.1%
39 - 101	55	100.0%

An aggregated CYPD was constructed for each yield interval in Table 5.9. The results of the aggregations were displayed in graphical and tabular forms for the five mean historical corn yield intervals on pages 362-366 of Appendix D.

The representative CYPD's for the five crop yield intervals were used in modeling the purchase of MPCI in chapter seven. The CYPD's were also used below to compare the MPCI premium structure to the perceived chance of insurable losses within each yield interval.

5.6. Implications of Mean-Aggregated CYPD's for MPCI

Corn CYPD's aggregated by historical mean yields were used to investigate producers' perceptions about the probability of insurable yield losses. Actual MPCI per bushel premium rates decreased as a producer's historical yield average increased. The CYPD's aggregated by mean yield were examined for evidence of diminishing downside crop yield probability with increasing mean corn yield. Each CYPD had a cumulative density function (CYCDF) which could be used to estimate the probability that a crop yield was less than or equal to a given yield level.

The expected mean yield of each aggregated CYPD was assumed equal to the APH yield in the tables and discussion below. The CYCDF value associated with the insurable yields for the five aggregated corn CYPD's of the Brookings County sample was presented in Table 5.10.

Table 5.10 Cumulative Density Function (CDF) Values for MPCI Insurable Yields on CYPD's Aggregated by Historical Mean Yield (μ).*

INSURED YIELD AS A % OF THE μ YIELD	CDF VALUE WHEN μ=83 BU/AC	CDF VALUE WHEN μ=75 BU/AC	CDF VALUE WHEN μ=70 BU/AC	CDF VALUE WHEN μ=65 BU/AC	CDF VALUE WHEN μ=55 BU/AC
75% LEVEL:	0.176	0.173	0.205	0.159	0.206
65% LEVEL:	0.108	0.117	0.135	0.098	0.152
50% LEVEL:	0.041	0.066	0.652	0.048	0.090

* The historical mean yield of each CYPD was assumed equal to the APH yield.

Inconclusive evidence was provided in Table 5.10 for the hypothesis that crop yield risk declined as the mean crop yield rose. There was an uncertain pattern to the CDF values across the rows in Table 5.10. The CDF values for the μ=83 and μ=75 CYPD's were smaller than the CDF values for the μ=70 and μ=55 CYPD's. However, the values for the μ=65 CYPD did not fit the pattern of increasing risk as the mean corn yield decreased. Further research was needed to verify or reject the hypothesis that the chance of insurable yield losses decreased as mean historical yield increased.

Another method used to check if the aggregated CYPD's exhibited decreasing risk with increasing mean yield was to estimate the expected value of the indemnities. The MPCI indemnity to a producer was calculated from the difference between the insured yield and the yield that a producer "salvaged" after a disaster. For example, if a producer had an insured yield of 50 bu/ac and the producer was able to harvest 20 bu/ac, then the indemnity payment would be based on the

(50-20) = 30 bu/ac difference. The expected indemnity payment was estimated with the following formula:

$$\int_0^{\phi(\mu)} [\phi(\mu)-y_d]\cdot f(y_d) = E(\text{Indemnity}) \qquad \text{Equation 5.1}$$

Where:

$\phi(\mu)$ = insured yield level, as a % of the mean yield
y_d = disaster yield, such that $(\phi(\mu) \geq y_d)$
$f(y_d)$ = probability density function value at y_d

The expected indemnity value was determined from the sum of probability density values multiplied by the respective yield "payoffs" to the producer (Equation 5.1). The expected indemnities from the mean-yield aggregated corn CYPD's were calculated and presented in Table 5.11.

Table 5.11 Expected MPCI Indemnities Derived from Corn CYPD's Aggregated by Historical Mean Yield (μ)*.

Insured Yield as a % of the μ yield	Expected Indemnity when μ=83 Bu/Ac	Expected Indemnity when μ=75 Bu/Ac	Expected Indemnity when μ=70 Bu/Ac	Expected Indemnity when μ=65 Bu/Ac	Exp. Indm. when μ=55 Bu/Ac
75% Level:	1.825	2.210	1.928	1.285	1.938
65% Level:	0.996	1.351	1.102	0.778	1.263
50% Level:	0.327	0.603	0.406	0.320	0.547

* The historical mean yield of each CYPD was assumed equal to the APH yield. The expected indemnity was measured in bushels/acre.

Expected indemnities did not consistently decrease as the mean yield increased in Table 5.11. The declining relationship was only apparent if the indemnity values for the μ=75 and μ=65 CYPD's were ignored. The hypothesis that producers with higher mean yields should

receive lower indemnities was not completely supported by these results.

The calculation of the expected indemnities was sensitive to the distribution of the probability mass in the left tail of the CYPD. The aggregated CYPD with μ=75 had a thick tail, which increased the expected indemnity, whereas the CYPD with μ=65 had a thin tail and a lower expected indemnity.

Actual MPCI premium rates were also compared to the expected indemnities derived from the aggregated CYPD's. Expected indemnities were a pure break-even premium rate: the amount of premium charged just offset the expected losses. Actual and CYPD-derived rates were displayed in Table 5.12.

Table 5.12 Actual MPCI Premium Charges and CYPD-Derived Indemnities.*

Insured Yield as a % of the μ Yield	Expected Indemnity μ=83 Bu/Ac	μ=75 Bu/Ac	μ=70 Bu/Ac	μ=65 Bu/Ac	μ=55 Bu/Ac
	CYPD-Derived Expected Indemnity Payment ($/Acre)				
75% Level:	$3.61	$4.38	$3.88	$2.53	$3.88
65% Level:	$1.94	$2.73	$2.18	$1.52	$2.50
50% Level:	$0.58	$1.13	$0.84	$0.59	$1.10
	Actual MPCI Premium Charged ($/Acre)				
75% Level:	$15.81	$15.75	$16.49	$15.31	$17.66
65% Level:	$ 7.44	$ 7.41	$ 7.83	$ 7.27	$ 8.44
50% Level:	$ 4.15	$ 4.13	$ 4.34	$ 4.03	$ 4.68

* The mean yield (μ) of each CYPD was assumed equal to the APH yield. The expected indemnity and actual premium payments assumed a $2.00/bu indemnity price election, and were calculated as:

(% coverage level) · (μ) · ($2/bu) · (% premium rate)

Actual MPCI premium rates were noticeably higher than the CYPD-derived indemnity rates (See Table 5.12). No additional government subsidy was provided for the extra yield coverage between the 65% and 75% coverage level in the actual MPCI rates. The absence of the subsidy was one cause of the dramatic difference between the MPCI and CYPD-derived rates at the 75% level. The above differences between the actual MPCI and perceived break-even premium rates were used to

hypothesize that the producers who purchase MPCI must be risk averse (Arrow 1971).

5.7. Sample-Wide CYPD Aggregation

Aggregation techniques were applied to develop a CYPD based on the elicitations of the entire producer sample. The sample-wide CYPD was constructed for comparison with the CYPD's estimated with SRS county level data in chapter six. If the CYPD's derived from county level data were similar to the sample-wide aggregation of elicited CYPD's, then alternatives to elicitation processes would exist for approximating subjective CYPD's.

The properties of the sample-wide aggregation of elicited corn CYPD's were presented in Table 5.13. The CYPD characteristics for the historical mean yield aggregations were also displayed in Table 5.13.

Table 5.13 Properties of the Sample-Wide-Aggregated CYPD and of the Historical-Mean-Yield-Aggregated CYPD's for Corn in Brookings County, South Dakota.

CYPD Property	Sample-Wide CYPD	CYPD Aggregation by Historical Mean Yield Interval				
		91-101 bu/ac	80-90 bu/ac	69-79 bu/ac	59-68 bu/ac	< 57 bu/ac
μ (Mean)	72.0	82.5	75.2	69.2	65.1	54.8
σ^2 (Variance)	470.9	489.2	460.0	490.4	317.0	314.0
CV (Coeff. of Variation)	0.30	0.27	0.29	0.32	0.27	0.32
α_3 (Skewness)	-0.18	-1.15	-0.71	-0.20	-0.62	-0.67
α_4 (Kurtosis)	-0.04	1.93	0.86	0.22	0.80	0.32

The effects of the Central Limit Theorem (CLT) were the probable cause for differences in the sample-wide CYPD's skewness and kurtosis values as compared to the CYPD's classified by historical mean yield intervals. The CLT was used to predict that the distribution of a set of sample means was normally distributed, regardless of the underlying distribution of the sample means themselves. A purely normal distribution had skewness and kurtosis values both equal to zero.

The skewness and kurtosis values of the sample-wide CYPD were closer to zero than any of the historical mean yield CYPD's. One implication of this finding was that the perceived probability of an insurable crop yield loss would differ among defined sets of producers.

MPCI's AREA Plan offered a single type of insurance policy to all producers within an area of a county. Such a policy design was challenged in this research because an area's average soil productivity was determined to not be a good predictor of producer mean yields. If this research were generalized, and if MPCI were designed as a "one size fits all" product for a group of diverse producers, then some producers would obtain a windfall by purchasing MPCI while others would not buy MPCI. Attempts such as the APH Plan to modify MPCI to be a more individually-oriented insurance product had the potential of attracting producers based on their subjective probabilities of crop yield losses.

5.8. Chapter Summary and Conclusions

The conviction weights elicitation technique was employed to assess producers' subjective CYPD's (Nelson and Harris 1978; Pease 1987). A random sample of Brookings County, South Dakota producers was selected for CYPD elicitation. The elicited CYPD's were initially aggregated by estimated mean soil productivity intervals for the elicited producers' farms.

The null hypothesis that producers' elicited mean corn yields were equal on farms with different mean soil productivity indexes was not rejected in seven out of ten cases. When the same null hypothesis was tested with historical mean corn yields, there was no statistical difference in ten out of ten cases. An alternative hypothesis was offered: the producer's management goals and skills were an important determinant of mean crop yields in Brookings County.

Mean crop yields were used as an alternative criteria for aggregating the CYPD's. There was inconclusive evidence in the mean yield-aggregated CYPD's for the concept that MPCI premium rates should decline as the mean crop yield increases. The mean yield-aggregated CYPD's were used an application of the EUH for analyzing the MPCI purchase decision (see chapter 7).

The elicited corn CYPD's were also aggregated over the entire sample. The resultant sample-wide CYPD was used in comparisons with CYPD's derived from alternative estimation procedures in chapter six.

The historical and elicited mean corn yield results of the CYPD estimations did not support the use of a soils-based MPCI program. The AREA Plan in MPCI was a program which partly depended on soils information to determine coverage levels and premium rats. If average

soil productivity were not a good indicator of a producer's mean crop yield, then a soils-based program would create inequities. Some producers would be able to insure an abnormally high yield compared to their mean production, while others might not be able to purchase enough coverage to justify the premium cost.

The APH program in MPCI was based on an individual producer's historical crop yield average. APH was hypothesized to be a an improvement over the AREA Plan as a method of providing an insurance coverage. A farm manager could insure yields which were more consistent with his historical yield performance and with the yield derived from his subjective CYPD.

Alternative CYPD estimation procedures were tested in chapter six for their potential to approximate subjective CYPD's for an expense which was less than the cost of performing and analyzing elicitations.

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Chapter Six

Alternative Estimations of Subjective CYPD's in Brookings County, South Dakota

Estimations of CYPD's were tested in this chapter for their potential to approximate subjective CYPD's elicited from producers. If there were statistical similarities among the distributions obtained with the alternative procedures, then researchers and FCIC administrators could use the estimated subjective CYPD's to economically model the MPCI purchase decision.

Three estimations of subjective CYPD's were presented: (1) CYPD's were derived from crop yield capacity functions (CYCF's) (Gallagher 1983), (2) CYPD's were derived from frequency distributions of historical county-level crop yield data, and (3) aggregated CYPD's were developed from elicitations of individual subjective CYPD's.

This chapter was organized into three sections. First, CYCF models were specified for corn, soybeans and oats crops in Brookings County, South Dakota. Corrected ordinary least squares (COLS) was selected as the procedure to estimate the CYCF's. Second, the Brookings County CYCF's and their corresponding CYPD's were estimated and the results were analyzed. The CYCF-derived CYPD's were tested for non-random crop yield variability. Finally, the CYCF-derived CYPD's were used in tests to determine if statistical similarities existed among alternatively estimated CYPD's. In particular, three comparisons were performed: (1) CYCF-derived CYPD's were compared to CYPD's aggregated

from individually elicited CYPD's, (2) CYPD's derived from the frequency distribution of historical mean county crop yields were compared to the aggregated-elicited CYPD's, and (3) CYCF-derived CYPD's were compared to CYPD's derived directly from a frequency distribution of historical mean county crop yields.

If one or both of the CYCF-derived and historical-frequency CYPD's were similar to producers' subjective CYPD's, then alternative estimation procedures would be available for the FCIC to assess the perceived value of MPCI to producers.

The assumptions and logic for modeling a CYCF-derived CYPD were developed in the first section of the chapter below.

6.1. Modeling Crop Yield Capacity Functions

The concept of a CYCF was discussed in chapter four (see section 4.6). Stochastic CYCF's were fitted to Brookings County corn, soybeans and oats yields in this study. The stochastic CYCF model had not been applied in published MPCI investigations prior to this study. Stochastic CYCF's were estimated with the COLS procedure. COLS had not previously been applied to model CYCF's.

COLS was originally developed for estimating frontier production function (FPF) models (Olson, Schmidt and Waldman 1980). FPF estimations had been performed with cross-sectional industry data. CYCF's were estimated using time-series data for the dependent and independent variables.

6.1.1. Economic Theory and Model Specification

The CYCF model was specified using microeconomic theory and previous research on crop yield response to economic and technological variables (Gallagher 1983; Hirshleifer 1976; Houck and Gallagher 1976).

Crop yields were specified as the dependent variable in the CYCF model. Economic and technological variables were the independent variables. Crop yield fluctuations associated with environmental factors were modeled as a two-part error term in the stochastic CYCF estimation. The entire error term was treated as a random variable.

The error term derived from the stochastic CYCF was represented as two CYPD's. One CYPD represented the measurement error for estimating the capacity yield. The other CYPD was a set of deviations below the capacity crop yield. The sub-capacity yields were assumed to be generated by changes in environmental crop growth conditions. The capacity yield was assumed to occur when the conditions were ideal for crop production.

The model specification and variable definitions for the CYCF were:

$$YCAP_t = \alpha + \beta(PCROP_{t-1}/PFERT_t) + \delta(PACRES_t) + \Phi(TREND_t) + U_t \qquad \text{(Equation 6.1)}$$

Where: $\alpha,\beta,\Phi > 0$
$\delta < 0$
$U_t = (\Omega_t - \theta_t)$
$U_t \leq 0$
$\theta_t \geq 0$

Variable Definitions:

$YCAP_t$ = capacity crop yield
α = constant term
β,δ,Φ = coefficients of the independent variables
$PCROP_{t-1}$ = lagged crop price
$PFERT_t$ = weighted fertilizer price
$PACRES_t$ = proportion of acres harvested, proxy for Farm Program influence
$TREND_t$ = technological trend variable
U_t = the environmental variable, measured as the total disturbance term beneath the capacity crop yield.
Ω_t = normally-distributed measurement error, centered on the capacity yield.
θ_t = part of the error term representing production below the capacity yield level.

The CYCF model was specified to test the relationship between crop yields and four major classes of independent variables (see Equation 6.1). These four independent variables were outlined and further discussed below:

1. output and input price variables
2. government farm policy variables
3. technological trend variables
4. environmental variables

Output Prices. The dynamic relationship between output prices and crop production was modeled in earlier research (Nerlove and Bachman 1960). Observable lagged output prices were used as a simple approximation of producer expectations in this model. Adaptive and rational expectations models of producer price expectations were not used because the data set was not large enough to test these alternative specifications.

Input Prices. CYCF's were specified with input prices to measure the producer incentive to employ inputs which enhance crop yield growth. Upward trends in U.S. crop yields after World War II were strongly associated with increased inorganic fertilizer usage (Cochrane 1979).

The theory of derived demand was used to specify an inverse relationship between the crop yield and fertilizer price variables. Fertilizer price was modeled as the denominator in a ratio with lagged output price to approximate the net incentive to produce the crop. When a ratio variable was specified, there was an implicit assumption that current fertilizer price and lagged output price were of equal importance in the production decision. Although this

assumption was not completely realistic, the variable was treated as an approximate measure of the role that economic incentives played in determining crop yields.

Farm Programs. The effects of federal farm policies on crop yields and production were documented in previous research (Houck and Ryan 1972). Cropland diversion programs caused producers to idle their less productive lands, and to farm the remaining land in production more intensively. The proportion of crop acreage in production was used as a variable to represent the effects of the farm program (Gallagher 1986).

The farm program variable was included in the CYCF estimations of the Brookings County corn and oats crops, since both of these crops had price support and acreage control programs associated with their production. No farm program variable was tested in the soybean CYCF estimation, since this crop was not traditionally included in the government programs.

Technology. Increased agricultural productivity was frequently modeled as a function of technological change (Griliches 1957; Hayami and Ruttan 1970; Tweeten 1979). Technology was specified as an independent time trend variable in crop yield response models (Houck and Ryan 1972). If the productivity trend was found to be linear, then crop yield could be specified as a linear function of time t, where t={1,2, 3,...} or some other linearly ascending set of numbers (Maddala 1977). A crop yield trend for the CYCF was selected from a variety of linear and curvilinear alternatives using the Box-Cox transformation procedure (Judge, et. al. 1985).

Environment. Environmental impacts on crop yields were investigated in previous research. Temperature, precipitation and soil moisture variables were explicitly modeled in some studies, and implicitly with crop yield indexes in others (Stallings 1961; Doll 1967). The CYCF was specified to implicitly capture environmental impacts in the error term of the estimation (Gallagher 1983).

6.1.2. Error Term Specification

The U_t error term in Equation 6.1 was specified to estimate a stochastic CYCF (see chapter four). The U_t error term was modeled with two probability distributions. One distribution (Ω_t) was symmetrically centered on the capacity yield. The symmetrical distribution represented the effect of statistical "noise" and measurement error when estimating the capacity yield level. The error term's other distribution (θ_t) was a statistical model of deviations below the capacity crop yield. Sub-capacity crop yields were modeled with a truncated normal distribution.

Stochastic frontier production function estimation techniques were developed as a solution to the problem in deterministic models where observed values could be greater than estimated capacity values (Forsund, Lovell and Schmidt 1980). Another method used to improve the modeling of observed crop yields was to adjust CYCF estimations for heteroskedasticity in the error term (Gallagher 1983). No measurable heteroskedasticity was determined to exist in the error terms of the Brookings County crop yield estimations.

An important aspect of any estimation procedure was the use and source of data. Data considerations were discussed below.

6.1.3. Data Requirements

County-level crop yield data were used in the CYCF estimations. Historical series of harvested crop yields for corn, soybeans and oats in Brookings County, South Dakota were the basis for estimating the $YCAP_t$ variable of Equation 6.1 (South Dakota Crop and Livestock Reporting Service [SDCLRS], issued publications, 1957-1987). The time series length used in this study extended from 1957 to 1986. The number of years of crop yield data analyzed was based on the history of South Dakota fertilizer usage.

Inorganic fertilizer use was closely correlated with the adoption of hybrid crop varieties and other yield-enhancing technologies (Cochrane 1979). The properties of empirical and subjective CYPD properties were determined to be sensitive to fertilizer applications in past studies (Day 1965; SriRamaratnam 1987). Fertilizer use in South Dakota began to increase significantly in 1957 (USDA, Agricultural Statistics 1960).

The USDA publication, Agricultural Prices, was the source of South Dakota's annual data on crop and fertilizer prices (PCROP and PFERT in Equation 6.1). A Laspeyres price index for fertilizer was developed by this author. The prices of nitrogen, phosphorus and potash prices were weighted by their respective South Dakota usage rates in 1972 (SDCLRS 1973). The 1972 base year was a transition year in the U.S. between the farm-program-dominated agriculture of the 1960's and

the export-dominated agriculture of the 1970's. Brookings County acreages followed national trends and increased in the latter 1970's.

Planted crop acreage (PACRES) was used as a proxy for farm program influences. Brookings County's principle crop acreages during the 1957-1986 period were obtained from SDCIRS publications. A crop yield acreage index was developed for each crop, using 1972 as a base year. Acreages of Brookings County's principle crops were summed for each year. Then the 1972 principle crop acreage was used to construct a Laspeyres index of crop acreage use. An increase in the crop acreage index was assumed to be associated with a larger proportion of marginal land being allocated to crop production.

The Box-Cox transformation procedure was used to determine whether Brookings County crop yield data displayed linear or one of a variety of curvilinear trends. The crop yield data was modified with a logarithmic function, and then the transformed data was regressed against a trend variable. The trend was varied by making changes in the coefficient of the transformation function. The selected coefficient produced the lowest sum of squared residuals in the regression estimations.

When the Box-Cox procedure was applied to Brookings County corn, soybean and oats yields, the trends for all three crops were determined to be linear. Linear time trends were used in the estimated equations for the CYCF's.

6.1.4. Selection of the CYCF Estimation Technique

There were two primary techniques for estimating CYCF's:

1. corrected ordinary least squares (COLS), and
2. maximum likelihood (ML) estimation methods.

A deterministic or a stochastic CYCF could be estimated with either COLS or ML. Differences in the statistical properties of the estimators derived from COLS and ML were presented in Table 4.6 of chapter four.

If the FCIC were to use CYCF's to help estimate actual and/or perceived crop yield risks, the COLS procedure would be a relatively inexpensive estimation technique. COLS estimations were easily performed with statistical software packages run on microcomputers.

Gallagher (1985) estimated CYCF's with ML techniques which required extensive and expensive calculations on a mainframe computer. The ML algorithm developed by Gallagher for estimating CYCF's was initially applied to Brookings County crop yield data. The algorithm failed to converge on an ML estimator. Considerable computer time and money were needed to refine the ML procedure.

There was not likely to be a large gain in the accuracy of the estimators if the effort was expended to revise the algorithm. ML and COLS estimation procedures were tested using Monte Carlo simulations in previous research, and the ML and COLS results did not differ significantly for sample sizes of 400 or less (Olson, Schmidt and Waldman [OSW] 1980). Time and budget considerations, combined with

the OSW Monte Carlo results, were used as reasons to select COLS techniques for the Brookings County CYCF estimations.

6.1.5. COLS Estimation

Statistical properties of the COLS stochastic CYCF estimators were described by OSW (1980). The parameters of the U_t distribution in the Brookings County CYCF's were specified using the OSW formulation:

$$U_t = (\Omega_t - \theta_t) \quad \text{(total disturbance term)} \qquad \text{Equation 6.2}$$

Where:
$$\sigma^2 = \sigma^2_\theta + \sigma^2_\Omega$$
$$\sigma^2(U_t) = \{[(\pi-2)\cdot\sigma^2_\theta]/\pi\} + \sigma^2_\Omega$$
$$\phi = \sigma\theta/\sigma\Omega$$
$$0 < \phi < \infty$$

Variable Definitions:

σ^2 = variance of the capacity function estimator
$\sigma^2(U_t)$ = variance of the disturbance term
σ^2_θ = variance of the error term representing production below the capacity yield level
σ^2_Ω = variance of the normally-distributed error which is centered on the capacity yield level
ϕ = COLS estimation parameter

When the above parameters were used, COLS could be applied to obtain unbiased estimators for all the coefficients of the explanatory variables, except the constant term (Equation 6.2). The bias of the constant term equalled the mean (μ) of U_t (OSW):

$$\mu = -(\sqrt{[2/\pi]})\cdot\sigma_\theta$$

An ordinary least squares (OLS) estimation of the stochastic CYCF was performed first in the COLS procedure. Then the COLS estimate of the stochastic capacity level was calculated by adjusting the OLS

constant term. The constant term was "corrected" by adding the absolute value of μ to the estimated OLS constant term. The variances of Ω_t and θ_t were also consistently measured by using the second and third moments of the OLS residuals in the formulas below (OSW):

$$\hat{\sigma}^2_\theta = \{\sqrt{[\pi/2]\cdot[\pi/(\pi-4)]\cdot\hat{\mu}_3}\}^{2/3}$$

$$\hat{\sigma}^2_\Omega = \hat{\mu}_2 - [(\pi-2)/\pi]\cdot\hat{\sigma}^2_\theta$$

Where: $\hat{\mu}_2$ = second moment of the OLS residuals

$\hat{\mu}_3$ = third moment of the OLS residuals

The above OSW formulations for μ, $\hat{\sigma}^2_\theta$, and $\hat{\sigma}^2_\Omega$ assumed that Ω_t was normally distributed and θ_t was half-normal. The mode of the half-normal curve for θ_t was located at the capacity level.

The half-normal specification of θ_t was a limitation of the COLS procedure. Under most circumstances, the optimum yield was not expected to be the most frequently occurring yield. A more desirable specification would have been to use a truncated normal distribution with its mode below the capacity level. However, the COLS procedure could not be implemented unless the half-normal assumption was made. The COLS model was estimated and interpreted with the recognition that the error term specification was an approximation and not an attempt to precisely model crop yield growth.

CYCF-derived CYPD's were determined to be negatively skewed below the capacity yield level in previous research (Gallagher 1983, 1985).

The half-normal specification of the θ_t variable in the COLS error term was a proxy measure of the CYPD's expected negative skewness.

The distribution of subcapacity yields was represented by a variable described by Gallagher (1985):

$$DEV_t = (YCAP_t - Y_t) \qquad \text{Equation 6.3}$$

Where: DEV_t = crop yield deviation below capacity at time t
Y_t = observed crop yield at time t
$YCAP_t$ = capacity crop yield level at time t

The DEV_t variable specified by Gallagher corresponded to the θ_t variable in the COLS estimations of the Brookings County stochastic CYCF's (Equation 6.3). If an actual crop yield exceeded the capacity yield in DEV_t, then the deviation was reported as a negative number. If the θ_t variable was described as DEV_t, then the two-part error term of the stochastic CYCF would be depicted with the probability density functions in Figure 6.1.

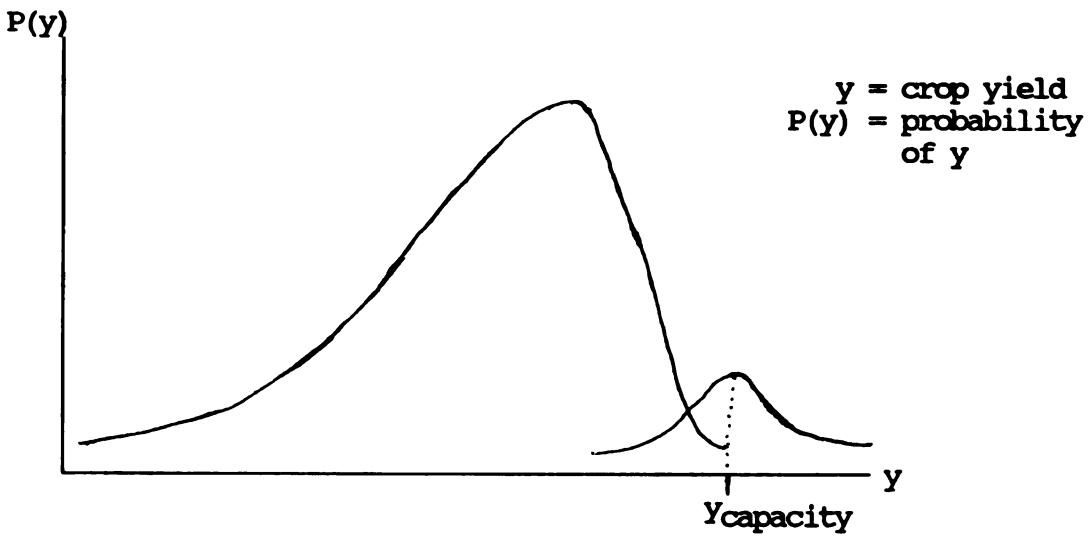

Figure 6.1 Graph of a disturbance term for a stochastic CYCF*.

* The Ω_t variable was specified as $N(0, \sigma_\Omega)$. A half-normal probability density function was used to represent the distribution of θ_t. The θ_t variable was defined as:

$$DEV_t = (YCAP_t - Y_t)$$

The properties of the distributions in Figure 6.1 were derived from the two-part error term of the CYCF model. The two-part error term was determined using the COLS residuals. The COLS-estimated CYPD's and their CYCF parameters were presented and discussed in the next section.

6.2. CYCF Estimation Results and Analysis

Stochastic CYCF's were estimated for Brookings County corn, soybeans and oats crops with the COLS procedure. The corn and oats crop yields were modeled with all the independent variables of

Equation 6.1. The soybean yield equation did not include the proxy variable for the farm program.

When equation 6.1 was fitted to the corn, soybean and oats yield data and initially estimated with OLS, multicollinearity was found to occur among the independent variables. The trend variable for all three crops had the expected positive coefficient ($\Phi > 0$). However, the crop-price-to-fertilizer-price ratio coefficient and the acreage variable coefficient did not have the predicted signs ($\beta < 0$, $\delta > 0$) (see Equation 6.1). The ratio and acreage variables did have the predicted signs when they were modeled as the sole explanatory variables in the CYCF estimations (see Appendix E). A joint F-test was performed to determine which variables statistically explained the variation in crop yield (Pindyck and Rubinfeld 1981). The results of the F-test were presented in Table 6.1.

Table 6.1 Joint F-test of CYCF Regression Coefficients for Equation 6.1.

Crop	Number of Restrictions	Number of Unrestricted variables	Number of Independent observations	Degrees of Freedom	Value of F-test
Corn	2	4	30	2,26	12.67
Soybeans	2	4	30	2,26	1.18
Oats	2	4	30	2,26	0.94

Note: The equation restriction being tested was $\beta=\delta=0$. The null hypothesis that $\beta=\delta=0$ was rejected at the 95% level when the test statistic was greater than ($f_{2,26}=3.37$).

The oats and soybean restricted models were not determined to be statistically different from their respective unrestricted models (see Table 6.1). If a t-test were used to test the single restriction that $\delta=0$, the acreage variable was determined not to be statistically significant in the corn, soybean and oats equations.

The statistical results in Table 6.1 were used as a basis to respecify the CYCF model of the soybean and oats yields as functions of single technology trend variables. A complete discussion of each of the CYCF estimations for corn, soybeans and oats was presented below.

6.2.1. CYCF Estimation of Brookings County Corn Yields

Modeling of the corn yield was problematic. The price ratio variable had a negative coefficient ($\beta < 0$) instead of the positive coefficient specified in Equation 6.1. The portion of corn yield

variability explained by the price-ratio variables was significant at the 0.05 level (see Table 6.1). The trend and price-ratio variables for corn in Equation 6.1 had a simple correlation of 0.82.

Hypotheses were offered to explain the high correlation of the trend and price-ratio variables and the unexpected sign of the price ratio coefficient. One possibility was a positive correlation between fertilizer demand and producer adoption of yield-enhancing technologies. For example, as new high-yielding crop varieties were planted, producers would often increase their inorganic fertilizer applications to try to obtain the full yield potential. The market demand for fertilizer would be affected when producers adopted such technologies in the aggregate. An increase in fertilizer price would be associated with an increase in fertilizer demand; that is, the data reflected a change in demand for fertilizer rather than a change in quantity demanded.

Another hypothesis was the aggregate producer response to output price changes. If a crop were generally perceived to become more profitable, producers as a whole would likely try to expand the resources for that crop. For example, if all producers increased the acreage for their crop enterprises, and if the use of each land unit was accompanied by fertilizer application, then the market demand for fertilizer would rise. Again, changes in the demand for fertilizer were possibly being observed in the data.

One other reason for the price-ratio variable to differ from the expected sign was considered. It was the connection between changes in input demand and the farm program. The price ratio variable could

have absorbed some the crop yield fluctuations that were caused by producer responses to the farm program. For instance, the acreage set-aside program was abandoned in the mid-1970's and was back in use by the mid-1980's. Large movements of land in-and-out of crop production were likely to be associated with demand shifts for other inputs.

The corn CYCF was estimated with both the trend and price-ratio variables, even though the coefficient of the price ratio did not have the predicted sign. The critical role of fertilizer use in producers' decisions to adopt high-yielding corn varieties was a primary consideration for including the price-ratio variable in the estimation.

The acreage proxy for the farm program was not statistically significant, and was left out of the estimation. The farm program remained an important variable, despite the failure of the acreage proxy to represent its impacts. The results of the estimated corn CYCF's were interpreted to account for farm program effects that were not explicitly specified in the model.

The general form of the estimated function for the corn CYCF was:

$$YCAP_t = \alpha + \beta(PCROP_{t-1}/PFERT_t) + \Phi(TREND_t) + U_t \qquad \text{Equation 6.4}$$

Where: $U_t \leq 0$

$U_t = (\Omega_t - \Theta_t)$ (total disturbance term)

$\sigma^2 = \sigma^2_\Theta + \sigma^2_\Omega$

$\sigma^2(U_t) = \{[(\pi-2)\cdot\sigma^2_\Theta]/\pi\} + \sigma^2_\Omega$

$\phi = \sigma_\Theta/\sigma_\Omega$

$0 < \phi < \infty$

The specification of the corn CYCF in equation 6.4 included restrictions placed on the error term (U_t) parameters. These restrictions were derived from the econometric conditions for performing a COLS estimation.

The distributions for Ω_t and θ_t were assumed to be independent. The variance of U_t was therefore equal to the sum of the variances of the error term's two components (see Equation 6.4).

The parameter (ϕ) was a measure of whether the error term's two components had moments which were estimable. The variance of θ could become very large compared to the variance of Ω with some data sets. In those cases, the variance of Ω was set to zero and a deterministic CYCF estimation was performed instead of the stochastic CYCF.

The COLS regression for the corn CYCF specified in Equation 6.4 was run using the data inputs discussed earlier. The results of the estimation were reported in Table 6.2 and discussed below.

Table 6.2 COLS Estimation Results for a Stochastic Corn Yield Capacity Function in Brookings County, South Dakota.

Estimated Parameter	Crop Modeled by CYCF Technique: Brookings County Corn
α Coefficient	84.31 (5.44)*
β Coefficient	-4375.00 (3.22)
Φ Coefficient	1.70 (7.74)
$\bar{R}^2$	0.70
F-Statistic (2, 27)	34.28
Error Term Variance ($\sigma^2(U_t)$)	97.34
Capacity Variance ($\sigma^2 = \sigma^2_\Theta + \sigma^2_\Omega$)	225.32
Ω_t Variance (σ^2_Ω)	24.29
Θ_t Variance (σ^2_Θ)	201.03
Θ_t Standard Deviation (σ_Θ)	14.18
Θ_t Mean ($\mu = (\sqrt{[2/\pi]}) \cdot \sigma_\Theta$)	11.31
ϕ Parameter for COLS Estimation ($\phi = \sigma_\Theta/\sigma_\Omega$)	2.88
U_t Skewness (α_3)	-0.68
U_t Kurtosis (α_4)	0.03

*Numbers in parentheses were t-values. A 90% confidence limit was used. The critical t-value at the 0.10 level was 1.70. The critical F-value at the 0.05 level was 3.35.

The t- and F-values for Equation 6.4 were statistically significant at the 0.10 level (see Table 6.2). The parameter estimates for the CYCF-derived CYPD were used to indicate that the mean (μ) corn yield was 11.3 bu/ac below the capacity level, and that the standard deviation σ_θ of the θ_t distribution was 14.18.

The μ and σ_θ information was used to provide an initial indication of whether the CYCF-derived CYPD was similar to an aggregation of the elicited corn CYPD's in chapter five. For example, the capacity corn yield for Brookings County in 1986 was estimated to be 94.2 bu/ac (Equation 6.4). The mean of the θ_t distribution was 82.9 bu/ac (=94.2-11.3), and its coefficient of variation (CV) was 0.17 (=14.18/82.9). In contrast, the corn CYPD obtained by aggregating the sample of elicited CYPD's had an expected mean of 72 bu/ac, an approximate maximum yield of 135 bu/ac and a CV of 0.31 (see chapter five).

The differences in mean and standard deviation estimates noted above were an indication that the CYCF-derived CYPD was overly "optimistic" as compared to the perceived CYPD. If the CYCF-derived CYPD were used in a model of the MPCI purchase, then the prediction of a "buy decision" would be underestimated as compared to the use of a subjective CYPD obtained by elicitation. A test of the goodness-of-fit for the two CYPDF's was performed in section 6.3 (see also Table 6.7).

One reason for the CYCF's over-estimate of the mean yield was likely the requirement in the COLS procedure to specify the CYCF with the mode of its θ_t distribution at the capacity yield level. Another

hypothesis was the tendency of producers to provide a conservative estimate of their expected mean yield in the elicitations, as compared to their recent historical yields (see Table 5.3 in chapter five). The mean of the underlying CYPD could have increased more quickly than what producers believed was possible.

Another consideration was the multicollinearity problem and unexpected sign of the price-ratio coefficient that occurred in the corn CYCF estimation. The difficulty encountered in the corn CYCF specification likely had some bearing on the properties of the CYCF-derived CYPD as an estimator of the aggregated-elicited CYPD. For example, when the corn CYCF was estimated with technological trend as the only independent variable, a better fit to the aggregated-elicited corn CYCF was obtained (see Table E.3 in Appendix E). The specification of such a CYCF was presented in Equation 6.5 below.

The CYCF-derived corn CYPD estimated with Equation 6.5 had a mean of 76.4 bu/ac, a standard deviation of 18.7 bu/ac and a CV of 0.24. The CYPD results of this "simplified" corn CYCF were a better approximation to the parameters of the aggregated-elicited CYPD for corn. If this result were generalized, then county-level capacity function estimations of farm-level CYPD's could be modeled as equations which primarily contained an adjustment for the trend in mean yields over time.

The above discussion was primarily concerned with the results of the corn CYCF estimation. A more complete discussion of the comparisons between the CYCF-derived CYPD and aggregated-elicited CYPD for corn was presented in section 6.3 of this chapter. The results for

all the corn, soybean and oats CYCF's were summarized in Section 6.3. Alternatively-estimated CYPD's were then examined for their differences and similarities.

The soybean and oats CYCF models were discussed next. The soybean and oats CYCF's were estimated solely as functions of technological change, based on the F-test results in Table 6.1.

6.2.2. CYCF Estimation of Brookings County Soybean and Oats Yields

Technology was hypothesized as the dominant influence on systematic changes in Brookings County soybean and oats yields. CYCF modeling of soybean yields in previous research also used technology trend as the sole explanatory variable (Gallagher 1983). The specified equation to estimate both the soybean and oats CYCF's was:

$$YCAP_t = \alpha + \Phi(TREND_t) + U_t \qquad \text{Equation 6.5}$$

Where: $U_t \leq 0$
$U_t = (\Omega_t - \theta_t)$ (total disturbance term)
$\sigma^2 = \sigma^2_\theta + \sigma^2_\Omega$
$\sigma^2(U_t) = \{[(\pi-2)\cdot\sigma^2_\theta]/\pi\} + \sigma^2_\Omega$
$\phi = \sigma_\theta/\sigma_\Omega$
$0 < \phi < \infty$

The description of the error term variables in Equation 6.5 was the same as in Equation 6.4. The results of the soybean yield estimation were discussed immediately below. The results and interpretation of the oats CYCF followed the soybean CYCF discussion.

Soybean CYCF Estimation. As in the previous corn CYCF estimation, the soybean CYPD characteristics were derived using the COLS parameters and the moments of the OLS residuals. The complete set of

estimated parameters for the stochastic CYCF estimation of Equation 6.5 was summarized in Table 6.3.

Table 6.3 COLS Estimation Results for a Stochastic Soybean Yield Capacity Function in Brookings County, South Dakota.

Estimated Parameter	Crop Modeled by CYCF Technique: Brookings County Soybeans
α Coefficient	16.84 (8.22)*
Φ Coefficient	0.57 (6.50)
$\bar{R}^2$	0.59
F-Statistic (1, 28)	42.18
Error Term Variance ($\sigma^2(U_t)$)	16.47
Capacity Variance ($\sigma^2 = \sigma^2_\Theta + \sigma^2_\Omega$)	44.34
Ω_t Variance (σ^2_Ω)	0.54
Θ_t Variance (σ^2_Θ)	43.84
Θ_t Standard Deviation (σ_Θ)	6.62
Θ_t Mean ($\mu = (\sqrt{[2/\pi]}) \cdot \sigma_\Theta$)	5.28
ϕ Parameter for COLS Estimation ($\phi = \sigma_\Theta/\sigma_\Omega$)	9.00
U_t Skewness (α_3)	-0.99
U_t Kurtosis (α_4)	2.28

*Numbers in parentheses were t-values. A 90% confidence limit was used. The critical t-value at the 0.10 level was 1.70. The critical F-value at the 0.05 level was 3.35.

The t- and F-values for Equation 6.5 were statistically significant at the 0.10 level (see Table 6.3). The parameter estimates for the CYCF-derived CYPD were used to indicate that the mean (μ) soybean yield was 5.28 bu/ac below the capacity level, and that the standard deviation was 6.62 bu/ac. The distribution had negative skewness, which was similar to the results of the corn CYPD estimation. The negative skewness hypothesis for CYPD's discussed by Gallagher (1983) was supported by these results.

There were MPCI implications if producers perceived negative skewness in their subjective CYPD's. If a subjective CYPD were negatively skewed, the perceived chance of an insurable "disaster" yield was reduced when compared to a normally distributed CYPD with the same mean and variance.

Suppose a producer did perceive a negatively skewed CYPD. If such a producer were modeled as an MPCI purchaser who paid a premium based on a normal CYPD, that producer would necessarily be specified as a risk averse decision maker (see chapter three).

Comparisons of skewness and other CYCF estimated soybean parameters with those of the aggregated-elicited soybean CYPD's were delayed until section 6.3 for reasons identified earlier. The estimation results of the oats CYCF were presented next.

Oats CYCF Estimation. The oats yield model was specified as a stochastic CYCF with Equation 6.5. When COLS was applied to the equation, the moments of the function were determined to be estimable. The results of the oats CYCF estimation were presented in Table 6.4.

Table 6.4 COLS Estimation Results for a Stochastic Oats Yield Capacity Function in Brookings County, South Dakota.

Estimated Parameter	Crop Modeled by CYCF Technique: Brookings County Oats
α Coefficient	51.38 (15.06)*
Φ Coefficient	0.62 (3.41)
$\bar{R}^2$	0.27
F-Statistic (1, 28)	11.64
Error Term Variance ($\sigma^2(U_t)$)	68.33
Capacity Variance ($\sigma^2 = \sigma^2_\Theta + \sigma^2_\Omega$)	168.89
Ω_t Variance (σ^2_Ω)	10.92
Θ_t Variance (σ^2_Θ)	157.97
Θ_t Standard Deviation (σ_Θ)	12.59
Θ_t Mean ($\mu = (\sqrt{[2/\pi]}) \cdot \sigma_\Theta$)	10.03
ϕ Parameter for COLS Estimation ($\phi = \sigma_\Theta/\sigma_\Omega$)	3.80
U_t Skewness (α_3)	-0.81
U_t Kurtosis (α_4)	0.40

*Numbers in parentheses were t-values. A 90% confidence limit was used. The critical t-value at the 0.10 level was 1.70. The critical F-value at the 0.05 level was 3.35

The proportion of oats yield variation explained by the trend variable in the CYCF model was 0.27 (see Table 6.4 and Equation 6.5). When a similar model specification was fitted to soybean yields, about 60% of the variability was explained (see Table 6.3).

One difference among the soybean, corn and oats crops was the impact of technological change. Mean crop yields for the first and last five-year intervals in the 1957-1986 data set were used to make some simple comparisons. The mean Brookings County soybean yield increased 105% from the 1957-61 period to the 1982-86 period. Between the same time intervals, the mean corn yield increased 126% and the mean oats yield increased 34%. Given this information on proportional yield increases, a coefficient of determination less than 0.50 for the oats CYCF of Equation 6.5 was more easily interpreted. Technological change was not as important an influence on oats yields as on the corn and soybean crops.

The corn, soybean and oats CYPD's derived from the CYCF estimations were used to approximate the probabilistic nature of crop yield variations associated with environmental crop growth conditions. Two hypotheses about the nature of these crop yield variations were considered because of their implications for an MPCI purchase decision model. First, the randomness of the crop yield variations was tested. Producers' views towards the need for MPCI could be affected by runs or bunchiness in crop yield distributions. Second, the CYPD's were tested for their similarity to a normal distribution. The assumption of normally distributed crop yields was used by the FCIC in some aspects of MPCI premium ratemaking (Botts and Boles

1958). If CYPD's did not have the symmetry or kurtosis properties associated with a normal distribution, then the producer's MPCI purchase decision could be affected.

6.2.3. CYCF-derived CYPD's: Tests of Randomness

Environmental influences on crop yields were determined to be non-random in some previous research (Black and Thompson 1978; Lin, Hildreth and Tefertiller 1963). Day (1965) also stressed the importance of testing the null hypothesis that yields were random. The capacity residuals for the Brookings County corn, soybean and oats crops were subjected to standard statistical tests for randomness.

A 90% confidence limit was selected for all the tests. A level of statistical confidence higher than 90% was not used because the chance of a type II error rose as the confidence limit was increased. A type II error involved accepting the null hypothesis of randomness when it was false. A type II error could be potentially more damaging for a producer than a type I error, since actual runs or bunchiness in crop yields over time could increase the risk of a business failure for a producer who did not purchase MPCI.

The results of the tests of crop yield randomness were summarized in Table 6.5.

Table 6.5 Tests of Randomness for the CYCF-Derived COLS Residuals.

Test of Randomness	Crop Modeled by CYCF Technique		
	Corn	Soybeans	Oats
Moore's Mean Square Successive Difference Test (δ < 1.55 to reject H_o)	Not Reject* (δ = 1.98)	Not Reject (δ = 2.01)	Not Reject (δ = 2.48)
Swed-Eisenhart Run Test (z > 1.65 to reject H_o)	Not Reject (z = 1.11)	Not Reject (z = 1.11)	Reject (z = 2.60)
Wallis-Moore Phase Frequency Test (z > 1.65 to reject H_o)	Not Reject (z = 0.82)	Not Reject (z = 0.52)	Not Reject (z = 0.82)
Cox-Stuart Test for Monotone Trend (z > 1.65 to reject H_o)	Reject (z = 1.89)	Not Reject (z = 0.63)	Not Reject (z = 0.63)

* The numbers in parentheses were the actual values calculated for each test. When the null hypothesis (H_o) was not rejected in these tests, the data were determined to be random. A 90% confidence limit was used to determine the critical value in all the tests. The procedures and tables used to conduct the tests were taken from Sachs (1982).

The tests of the Brookings County CYCF residuals in Table 6.5 were mostly random. There were two exceptions. First, an upward trend in the corn yield residuals was detected with the Cox-Stuart test. The results of the test could be used to hypothesize a positive weather (environmental) trend for corn yield growth. Some evidence of so-called weather trends was also reported in previous research (Haigh 1977). If such a trend were incorporated into the subjective crop yield beliefs of producers, the perceived need for MPCI would likely be diminished.

Second, the Swed-Eisenhart Run Test indicated that the oats yield fluctuated above and below its median yield level "more regularly" than would be expected if the data series were random. The median yield was the 50th percentile yield in the CYPD. The "regular" change in the oats yield COLS residuals was considered somewhat analogous to the non-random oscillation produced by a trigonometric sine function.

If producers perceived that oats yields switched regularly from good to poor and back again, then the MPCI purchase would provide them an opportunity to obtain greater income stability. Not all producers considered income stability as desirable. A producer's risk attitude would play a role in whether he would value income stability enough to consider purchasing MPCI (see chapter three).

Another consideration, not investigated in this study, was whether a producer's creditors would request a producer to purchase MPCI to increase his income stability.

If a producer perceived his CYPD as being generated by a random process, there were additional questions about the properties of the

associated crop yield distribution. Tests of those properties for the CYCF-derived CYPD's were discussed below.

6.2.4. CYCF-derived CYPD's: Tests of Normality

The normal distribution was used by Botts and Boles (1958) to define crop yield variations for crop insurance purposes. Day (1965) and Gallagher (1983) presented evidence that crop yields were not normally distributed. Differences in the symmetry or kurtosis of a CYPD could influence the outcomes of a model of the MPCI purchase decision.

The COLS-estimated CYCF residuals for Brookings corn, soybeans and oats crops were tested for departures of their distributions from the normal curve. The results of those tests were summarized in Table 6.6.

Table 6.6 Tests of Normality for the CYCF-Derived COLS Residuals.

Test of Normality	Crop Modeled by CYCF Technique		
	Corn	Soybeans	Oats
Kolgomorov-Smirnov goodness of fit test ($D > 0.144$ to reject H_o)	Reject* ($D = 0.148$)	Not Reject ($D = 0.089$)	Not Reject ($D = 0.098$)
Run test: randomness of the fit ($z > 1.65$ to reject H_o)	Reject ($z = 2.60$)	Reject ($z = 1.86$)	Reject ($z = 4.09$)
Chi-square goodness of fit test ($X^2 > 2.71$ to reject H_o)	Reject ($X^2 = 2.87$)	Not Reject ($X^2 = 0.83$)	Not Reject ($X^2 = 1.39$)
Pearson's $\sqrt{b_1}$ test of Skewness ($\lvert\sqrt{b_1}\rvert > 0.51$ to reject H_o)	Reject ($\sqrt{b_1} = -0.68$)	Reject ($\sqrt{b_1} = -0.99$)	Reject ($\sqrt{b_1} = -0.81$)
Pearson's b_2 test of Kurtosis ($b_2 > 3.68$ to reject H_o)	Not Reject ($b_2 = 3.03$)	Reject ($b_2 = 5.28$)	Not Reject ($b_2 = 3.40$)

* The numbers in parentheses were the actual values calculated for each test. When the null hypothesis (H_o) was not rejected in these tests, the data were determined to be normally distributed. A 90% confidence limit was used to determine the critical value in all the tests. The expressions $\sqrt{b_1}$ and b_2 respectively measured skewness and kurtosis. The D value of the K-S measured the maximum absolute distance between the normal and capacity cumulative density functions.

The hypothesis that the CYCF-derived CYPD for corn was normally distributed was rejected in four of five statistical tests (see Table 6.4). Only in the kurtosis test was the normality assumption for corn yields not rejected. Given that negative skewness in a CYPD could make a difference in the MPCI purchase decision, the results of these tests were considered to be important. If producers' subjective corn CYPD's were similar to CYCF results, the FCIC would have a fairly strong case for investigating the role of CYPD asymmetry in the marketing of MPCI to producers.

The evidence in the tests of the soybean and oats crops for a normal or non-normal CYPD was not conclusive (see Table 6.6). The Brookings County soybeans and oats capacity-derived CYPD's were determined to not be statistically different from the normal distribution in the Kolgomorov-Smirnov (K-S) test and Chi-Square (C-S) tests.

The K-S and C-S tests were not designed to detect distinct patterns in the underestimation and overestimation of the normal distribution's fit to an empirical distribution (Sachs 1982). If the normal distribution were a good fit to the crop yield data, the differences between the observed and the fitted distributions would randomly fluctuate between positive and negative values. The normal was rejected as the underlying distribution in the randomness of fit run tests for all three crops (see Table 6.6). In addition, the CYCF-derived CYPD's were determined to be statistically different from the normal for all three crops in the skewness tests. The hypothesis that CYPD's were skewed was supported with the run test results. These

tests could be used to further challenge to the practice of assuming a normal CYPD in modeling the MPCI purchase decision.

Kurtosis values were observed to be significantly non-normal for soybeans. Higher kurtosis meant that the likelihood of extremely low yields was greater than what would be predicted by a normal distribution. If extremely low yields were determined to occur more frequently than the normal curve would predict, then break-even MPCI premium rates calculated from a normal curve would underestimate the downside yield risk.

The normal distribution was adjusted to give a higher probability to total crop failures in previous crop insurance research (Skees and Reed 1986; Driscoll 1986). Another related issue was whether kurtosis was perceived in subjective CYPD's. Kurtosis properties of a CYPD had the potential to influence outcome of the MPCI purchase decision.

Various measures were used to test for similarities and differences among capacity-derived, subjective and historical-frequency CYPD's in the next section of this chapter.

6.3. Comparison of Alternative CYPD Estimations

CYCF functions were modeled in this chapter to estimate CYPD's which could approximate producers' subjective CYPD's. Subjective CYPD's were a critical element in the MPCI purchase decision model developed in this study (see chapter three). If CYCF-derived CYPD's were determined to be similar to subjective CYPD's, then the MPCI purchase decision could be modeled by the FCIC in other counties

without the necessity of conducting individual producer interviews to obtain subjective CYPD's.

The CYCF procedure had the potential of being an economical and practical alternative to individual CYPD elicitations in MPCI applications. The CYCF procedure required access to existing SRS data on county crop yields and the use of statistical software available on microcomputers. Producer elicitations required that producers be individually interviewed to voluntarily reveal their subjective CYPD's.

The elicitation process was desirable from the standpoint that subjective CYPD's were obtained directly from the producer. If biases were minimized through the use of an interview protocol, then the elicitation process could be used to obtain farm-level estimates of crop yield variability (see chapter five).

The difficulties of using elicitations in MPCI applications were cost and producer willingness to reveal subjective probabilities. One of the costs was for training interviewers to conduct the elicitations. There was also the cost of time: each interview would require at least an hour to complete. In addition, if a producer believed that his subjective CYPD had some bearing on his crop insurance premium rates, there might be an incentive either to underestimate the risks or to refuse to respond to an elicitation request. The CYCF technique was a possible alternative that could be used to avoid the problems of applying elicitation techniques for MPCI purposes.

6.3.1. CYPD's Derived from Historical Crop Yield Frequencies

In addition to the CYCF technique, one other method for approximating subjective CYPD's was considered. The method was based on the premise that producers' subjective CYPD's were no more sophisticated than a set of historical crop yield frequencies. The CYPD produced by the method was referred to as a historical-frequency CYPD.

For example, if corn yields fell below the 50 bu/ac five times in the last fifteen years, then the perceived cumulative density of a producer's subjective CYPD below that yield level would roughly be 0.30. Such an extrapolation would assume that producers made little or no adjustment in their subjective CYPD's over time for the adoption of new corn varieties that were resistant to different forms of environmental stress.

If a producer conformed to the basic rules of Bayesian probabilities, then his subjective CYPD would not be expected to be similar to a historical-frequency CYPD. A producer would revise his subjective probabilities as new information about the ability of the crop withstand stress was assimilated.

Rejecting the null hypothesis that historical-frequency CYPD's were similar to subjective CYPD's would help to establish at least three basic premises. First, there would be further evidence that elicitation processes were capable of capturing a sophisticated set of producer beliefs; that is, the subjective CYPD reflected probabilities that were revised over time as new information about crop yield potentials and stress-resistance was acquired. Second, the need for more demanding estimation procedures such as the CYCF would become

greater, since a simple frequency distribution of past crop yields would not be representative of a producer's beliefs. Finally, there would be support for the FCIC to design incentive plans to encourage producers to buy MPCI based on their current CYPD beliefs. Such incentive plans could complement the traditional method of relying on the history of insured crop yield losses.

If the null hypothesis that the historical-frequency CYPD's and elicited CYPD's were the same could not be rejected, then a new set of issues would arise. For example, the reliability or accuracy of the elicitation technique or its application could be re-examined. If the elicited subjective CYPD's were representative of actual producer beliefs, then historical-frequency CYPD's would be a more economical approximation to subjective CYPD's than CYCF-derived CYPD's.

The historical-frequency CYPD's were estimated using the same thirty years of data as the CYCF-derived CYPD's. The same data set was applied because a comparison of the historical-frequency CYPD was made with the CYCF-derived CYPD as well as with the subjective CYPD. The comparison with the CYCF-derived CYPD was performed to establish whether the two techniques were different measures of crop yield variability.

The historical-frequency, CYCF-derived and subjective CYPD's were initially compared by examining similarities and differences in their distributional moments. Then goodness-of-fit tests were applied to formally examine whether the alternatively estimated CYPD's were similar.

6.3.2. Comparison of Distributional Moments of the Alternatively Estimated CYPD's

Three pairwise CYPD comparisons were performed to check for similarities in the distributions:

1. CYCF-derived CYPD's were compared with aggregated-subjective CYPD's
2. CYCF-derived CYPD's were compared with CYPD's developed from frequency distributions of historical county crop yield data.
3. Aggregated-subjective CYPD's were compared with CYPD's developed from frequency distributions of historical county crop yield data.

The CYCF-derived CYPD's for the corn, soybean and oats crops were estimated above. The aggregated-subjective CYPD's were derived from individual producer responses (see chapter five). The historical-frequency CYPD's were calculated directly from the county level yield data for the three crops over the 1957-1986 period.

In past studies, farm-level crop yield variances were measured as two to four times larger than the county-level crop yield variances (Eisgruber and Schuman 1963). Higher farm level variances were also found to exist when the aggregated-subjective CYPD's were compared to the capacity-derived CYPD's in Table 6.7 below. Differences also occurred in the skewness and kurtosis measures of the CYCF-derived, aggregated-subjective and historical-frequency CYPD's.

Table 6.7 Comparison of Distributional Characteristics of Alternative CYPD Estimations.

Type of Crop and Distribution	Mean Yield (Bu/Ac)	Coeff. of Variation	Variance	Skewness	Kurtosis
Corn:					
Elicited	72.0	0.30	470.9 (21.7)*	-0.18	-0.43
Capacity	82.9	0.17	201.03 (14.2)	-0.68	0.03
Historical-Freq.	51.3	0.35	329.9 (18.2)	0.42	-0.90
Soybeans:					
Elicited	27.9	0.31	76.2 (8.73)	-0.19	0.08
Capacity	27.5	0.24	43.83 (6.62)	-0.99	2.28
Historical-Freq.	19.5	0.35	46.0 (6.78)	0.05	-1.11
Oats:					
Elicited	64.8	0.32	430.0 (20.7)	-0.18	0.00
Capacity	58.0	0.22	157.97 (12.6)	-0.81	0.40
Historical-Freq.	48.7	0.21	103.2 (10.2)	-0.59	0.02

* Values in parentheses were the crop yield standard deviations measured in bushels per acre.

The CYCF-derived and historical-frequency CYPD's were both based on county-level crop yield data (see Table 6.7). Both were also observed to have shortcomings as proxies for aggregated subjective CYPD's. The differences among the alternatively estimated CYPD's was discussed below on a crop-by-crop basis.

Comparison of Corn CYPD's. The CYCF-derived CYPD for corn had a coefficient of variation (CV) and variance (σ^2) which was about half the respective CV and σ^2 values for the aggregated-elicited distribution (Table 6.7). The corn CYCF also had a mean crop yield which was approximately 11 bu/ac higher than in the aggregated-elicited corn CYPD. The differences in the estimated value of the mean corn yield were attributed to characteristics of the COLS estimation procedure and the tendency of Brookings County producers to discount their yield estimates in the elicitations (see section 6. .).

The inability to completely specify the CYCF for the effects of the farm program also could have inflated the mean of the corn CYPD. When producers participated in set-aside programs, they generally idled the less productive land and farm the better land more intensively. The program's effect on crop yields was possibly absorbed in the error term of the CYCF, since the acreage proxy for farm program effects was not statistically significant and left out of the estimated equation.

The CYCF-derived CYPD for corn was more negatively skewed than the aggregated-elicited CYPD. One reason for this difference was the effect of the aggregation procedure on the observed moments of the elicited CYPD's. The process of aggregation produced a mean or

"average" CYPD for the entire sample. When the CYPD's were alternatively aggregated according to equal sized intervals of mean yields, the producer perception of skewness was much more pronounced (see chapter five). The central limit theorem (CLT) had application to the aggregation of the entire sample's elicited CYPD's: means of non-normal data sets were themselves normally distributed. The implication of the CLT for this analysis was that the skewness in the CYCF-derived CYPD was a relatively good approximation to the asymmetry in the CYPD's perceived by individual producers.

The historical-frequency CYPD for corn had mean yields which were much lower than the elicited means. The mean yield of the historical frequency was reduced because it included yield data from the late 1950's and early 1960's when yield-increasing technologies had not yet been fully adopted in Brookings County. The higher variance in the historical yield data was primarily caused by the large difference in technological influences between the beginning and the end of the 1957-1986 period of analysis.

Comparison of Soybean CYPD's. The mean soybean yields perceived by producers were more closely estimated by the CYCF-derived CYPD's than by the mean yields obtained from the historical-frequency CYPD's. The better approximation to the elicited mean yield provided by the CYCF-derived CYPD largely stemmed from the adjustment for technological change that occurred in the capacity function. The soybean crop was also not as strongly influenced by the farm program as the corn crop was.

Larger skewness and kurtosis values were observed in the CYCF-derived CYPD's for soybeans than what were found in the aggregated subjective CYPD's (Table 6.7). The difference in skewness was likely associated with the effects of the CLT on the aggregated-elicited CYPD's.

The difference in kurtosis between the CYCF-derived and aggregated-elicited CYPD's had possible MPCI implications. If this observation were repeated in other studies, producers would be predicted to perceive the tails of their soybean CYPD's to be "thinner" than the tails of CYPD's derived by other estimation techniques. One hypothesis to explain the difference in kurtosis was the tendency of people to underestimate the frequency of rare and disastrous events (Kunreuther and Slovic 1978).

If the tails of elicited CYPD's underestimated crop yield risks, the elicitation process itself might be partly responsible. However, the questioning procedure developed by Pease for obtaining subjective CYPD's was purposely designed to encourage respondents to give careful thought to the chance of low crop yields. If it were demonstrated that producers did underestimate the chance of a "total wipeout," then an educational opportunity existed for crop insurers, extension agents and others to heighten producer awareness of crop failures, their likelihood and their implications for MPCI and other risk management strategies.

Comparison of Oats CYPD's. The difference between the mean oats yield obtained from the CYCF-derived and aggregated-elicited CYPD's

was the opposite of the corn and soybean results. Producers perceived a higher mean oats yield than what was derived with the CYCF.

One hypothesis for this observed result was excessive producer optimism about the oats yield potential in Brookings County. During the elicitations, Brookings County producers regularly assigned probabilities to oats yields above 100 bu/ac, even though such levels of oats production were attained only specific fields. The elicitations were performed on a "whole-farm" basis. The chance of a whole-farm average oats yield greater than 100 bu/ac was possibly more remote than what producers elicited.

Oats yields did not increase as rapidly as corn and soybean yields during the 1957-1986 period of analysis. Producers could have assigned too much weight to the current technological potentials for oats yields, based on the successes that were experienced with corn and soybeans.

Another factor which might have contributed to producers' beliefs about oats yields was the non-randomness measured in the CYCF-derived CYPD (see Table 6.5). If oats yields were regularly switching between good and poor production on annual basis, producers might find it more difficult to assess oats yield potentials.

The historical-frequency CYPD for oats could not be used to closely approximate the moments of the respective aggregated-elicited CYPD (see Table 6.7). A similar conclusion was also reached for the corn and soybean crops. The CYCF-derived CYPD's appeared to be a somewhat better approximation to the aggregated-elicited CYPD's than the historical-frequency CYPD's. Improvements in CYCF modeling, such

as the improved specification of farm program effects, could be applied to more closely estimate the CYPD's perceived by producers.

The above discussion of the corn, soybean and oats CYPD's was used to compare distributional moments. The CYPD's were compared with goodness-of-fit tests in the section below.

6.3.3. Tests of Differences among the Estimated CYPD's

Statistical tests were employed to determine whether the subjective CYPD's obtained by elicitation techniques could be approximated using the results of CYCF estimations or frequencies of historical yields. If a good "fit" could be obtained with one of the latter two procedures, less costly alternative procedures to estimate subjective CYPD's would be available for modeling and other purposes.

The Kolgomorov-Smirnov (K-S) test was used to test the goodness-of-fit among the historical, capacity and aggregated-subjective CYPD's. The K-S test was distribution-free: no assumption had to be made as to the parameters of the underlying distribution function to perform the test. Distribution-free tests were designed for calculation ease and "conservative" statistical decisions (Sachs 1982).

A conservative statistical test was defined as one where the null hypothesis was more difficult to reject; the test lacked power when testing hypotheses with small samples. The concept of "power" in statistics referred to the tradeoff between Type I and Type II errors in hypothesis testing. A test with "weaker" power had a higher risk of a Type II error (accepting the null hypothesis when it was false)

than other tests which made more use of the information contained in the data.

The null hypothesis in a K-S test was that the distributions being compared were the same. A higher chance of a Type II error meant that there was a greater probability of declaring two distributions as statistically similar, when they were actually different. The 90% confidence limit was selected to try to alleviate the increased risk of a Type II error associated with the use of the K-S test.

The results of the K-S test for the three types of CYPD's were displayed in Table 6.8. Soybeans was the only crop where a similarity was determined to exist among the alternatively estimated CYPD's. The CYCF-derived CYPD for soybeans was not statistically different from the aggregated-elicited CYPD. The CYCF-derived CYPD's for corn and oats were determined to be different from their respective aggregated-elicited CYPD's.

Table 6.8 Goodness-of-Fit Tests of Alternative CYPD Estimations*.

Distributions Tested for Goodness-of-Fit	CYPD's Compared Using the Kolgomorov-Smirnov Test		
	Corn	Soybeans	Oats
Elicited CYPD Compared to Capacity-derived CYPD	Reject (D=0.39)	Not Reject (D=0.17)	Reject (D=0.37)
Elicited CYPD Compared to Historical-Freq. CYPD	Reject (D=0.42)	Reject (D=.40)	Reject (D=0.49)
Capacity Derived CYPD Compared to Historical-Freq. CYPD	Reject (D=0.63)	Reject (D=0.53)	Reject (D=0.40)

* When the null hypothesis was not rejected in these tests, the CYPD's were determined to be similar. A 90% confidence limit was used to determine the critical value in all the tests. The D value of the K-S measured the maximum absolute distance between the normal and capacity CDF's.

The CYCF-derived CYPD's for corn and oats were poor approximations to the elicited CYPD's primarily because the CYCF-derived CYPD had insufficient accumulation of probability density at low yield levels (see Table 6.8). Producers were able to assign probabilities to low yields, such as the chance of a 0 to 10 bu/ac yield. The SRS data were at an aggregation level where very low yield levels could not usually be observed.

The soybean CYCF-derived provided a better approximation of the aggregated-elicited CYPD because there were observations in the SRS county soybean data that allowed for estimation of probabilities at low yield levels. For example, the Brookings County average soybean yield during the 1976 drought year was 8 bu/ac.

Estimation of the soybean CYCF was not as complicated as was the corn CYCF. The farm program did not have as great a potential to influence the mean yield. The mean CYCF-derived soybean yield was a relatively close approximation of the aggregated-elicited mean soybean yield (see Table 6.7).

The potential for CYCF-derived CYPD's to serve as an approximation to subjective CYPD's was determined to be limited, based on the above results. The CYCF model did show some promise, but considerable adjustment was needed. For example, the probability of "disaster" yields was not well-estimated because of data aggregation problems. One solution to this problem was to use simulation techniques to derive probabilities for a range of crop yields which was wider than what had been derived from the CYCF error term. Another consideration

was to develop better proxies for CYCF explanatory variables such as the farm program.

The historical-frequency CYPD was found to be dissimilar from both the capacity and elicited CYPD's for all three crops. If the test results in Table 6.6 were representative, then the use of CYPD's derived from raw historical crop yield data was not a suitable proxy for aggregated-subjective CYPD's, nor were they similar to the CYPD's derived from a more advanced procedures which included adjustments for technological and environmental factors.

The limitations of county-level crop yield data for measurement of CYPD dispersion were highlighted by a visual comparison of the capacity-derived CYPD's to the aggregated-subjective CYPD's (see Figures F.1 through F.9, Appendix F).

The capacity functions, even with their shortcomings, provided a better fit to the elicited distributions than the historical frequency CYPD's. An estimation of a subjective CYPD's skewness and kurtosis were also gained by the use of CYCF-derived CYPD's.

6.4. Summary and Implications of the Analysis

Crop yield capacity functions were specified in this chapter to derive CYPD's for corn, soybean and oats yields in Brookings County, South Dakota. CYPD's were also derived from a frequency distribution of historical county level crop yields. The CYCF-derived CYPD's and the historical-frequency CYPD's were compared to aggregations of subjective CYPD's elicited from producers. Alternative methods for

CYPD estimation had the potential of providing economical means for analyzing producers' MPCI purchase decisions.

COLS was applied for the first time in stochastic CYCF estimation. The capacity yield was modeled as a stochastic variable, and the error term of the stochastic CYCF was composed of two distributions.

The usefulness of a CYCF-derived CYPD as an approximation to a subjective CYPD was limited by problems of data aggregation and model specification. One difficulty with CYCF-derived CYPD's was the inability to obtain estimates of very low yields with aggregated data. A possible solution to the aggregation problem was to use the estimated moments of the CYCF-derived CYPD as the basis for additional modeling with simulation techniques.

An advantage of the COLS technique was its ease of use. A drawback of the procedure was the requirement that the CYCF-derived CYPD be specified to have its mode at the capacity level. That specification had the effect of increasing the CYCF estimation of the CYPD's mean yield. However, the specification also had the advantage of being an approximation to negative skewness in the CYPD.

As in previous research, negative skewness was determined to be an important characteristic of CYCF-derived CYPD's (Gallagher 1983). Negative skewness was also a property of the subjective CYPD's obtained by elicitation methods. The combined results of the CYCF modeling and the elicitation results were used to identify CYPD asymmetry as a consideration in analyzing the MPCI purchase decisions of producers.

Historical-frequency CYPD's were a poor estimator of subjective CYPD's. The dissimilar nature of the two distributions was used to additionally support the notion that producers' crop yield perceptions were sophisticated. More advanced estimation methods, such as CYCF's, were needed to approximate producers' personal crop yield probabilities.

The lack of similarity of the historical-frequency CYPD's and subjective CYPD's had MPCI implications. Past crop yield history might not be sufficient information for designing an MPCI product capable of attracting many new producers to the program. The FCIC might need to consider using approximations of producer's subjective CYPD's in addition to past crop yield history to devise incentive plans to sucessfully encourage MPCI purchases.

CYCF estimation with COLS had some promise as a technique for approximating subjective CYPD's for MPCI research, if the aggregation and model specification problems were resolved. Direct elicitation of subjective CYPD's had the advantage of providing estimates of low yield events that were of particular concern in MPCI modeling. Aggregated-elicited CYPD's discussed in this chapter (and derived in chapter five) were subsequently used in the next chapter to simulate the MPCI purchase decision with an application of the expected utility hypothesis.

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CHAPTER SEVEN

An MPCI Purchase Decision Analysis of the APH and AREA Coverage Plans

A theoretical model based on the Expected Utility Hypothesis (EUH) was applied to predict a producer's MPCI purchase decision in this chapter. Producers' potential MPCI purchases were determined under two alternative coverage plans: (1) the Actual Production History Plan (APH Plan) and (2) the AREA Coverage Plan (AREA Plan). Producers' net gains or losses associated with MPCI purchases under the alternative coverage plans were measured with a ratio of indifference premium to break-even premium. Welfare implications of the change in coverage plans were analyzed. Overall conclusions determined from this EUH application were discussed.

7.1. Methods Used to Construct the MPCI Purchase Decision Model

The MPCI purchase was modeled in this study as a decision made under the business risk of crop yield loss. A producer was predicted to buy or not buy MPCI based on which alternative created a larger increase in his expected utility.

A producer's expected utility, and his MPCI selection, were modeled to include the effects of three primary factors: (1) a theoretical expected utility function which embodied a producer's risk attitudes, (2) a producer's net cash flow distribution derived from both the MPCI decision and an aggregated subjective crop yield probability

distribution (CYPD), and (3) a producer's initial net wealth level measured by the proportion of his net equity associated with the potentially-insured crop enterprise. The three factors were sequentially discussed below.

7.1.1. Expected Utility as a Model Component

A producer's theoretical expected utility level was specified as a function of a probability distribution of "ending net wealth" derived from a crop enterprise. Ending net wealth was the sum of the crop enterprise's net cash flow and its assumed initial net wealth level.

A simulation algorithm was adopted to integrate the expected utility function and the ending net wealth calculation into an overall MPCI purchase decision model. The complete model was referred to in this chapter as "the algorithm."

The MPCI decision was predicted with the algorithm by analyzing the problem as a sequence of simpler subproblems. The algorithm for the Brookings County, South Dakota MPCI purchase analysis was an extension of a program written for MPCI analysis in Banner County, Nebraska (Black 1988). The algorithm was executed with the Turbo-Pascal version of the Pascal computer programming language on a microcomputer. The code for the entire algorithm was placed on pages 387 - 410 of Appendix G.

CES and natural log utility functions were alternatively substituted into the algorithm for theoretical analyses of the MPCI purchase. Both utility functions possessed the decreasing absolute risk aversion (DARA) property, and the CES function was specified to be

globally more risk averse than the natural log function at all the possible ending net wealth (ENW) levels in the model (see chapter three).

The estimation procedures for calculating the model's ENW levels were described below. The method used to determine the crop enterprise's net cash flow was outlined first. The determination of the initial net wealth was subsequently explained.

7.1.2. Net Cash Flow Probability Distribution as a Model Component

An enterprise budget was used to determine the net cash flow (NCF) associated with a given crop yield and MPCI purchase decision. Crop yield was modeled as a random variable based on the elicited subjective crop yield probability distributions (CYPD's) of Brookings County producers (see chapter five). Net cash flow was a random variable derived from a producer's subjective CYPD, an MPCI decision and an enterprise budget of crop costs and revenues.

Described in this chapter section were the methods used to arrive at NCF values. A farm model for a Brookings County producer was constructed. Producers' underlying subjective CYPD's used to derive NCF's were discussed. Input and output price assumptions were identified. Costs of production under alternative crop yields were outlined. The effect of the MPCI decision on the NCF as crop yield varied was discussed. Finally, the use of a random number generator to determine net cash flow outcomes from the NCF distribution was explained.

Farm Model for the Brookings County Producer. Characteristics of the farm model used in this analysis were obtained from the Ag Census and consultations with the Economics Department staff at South Dakota State University.

A typical Brookings County producer raised crops on approximately 600 tillable acres (Toland and Pflueger 1987). A Brookings County producer often allocated 40% of the cropland to corn, 40% to soybeans and 20% to other crops.

Corn was studied as a single crop enterprise with the MPCI decision model. A producer was assumed to produce corn on 250 (= 40% x 600) tillable acres. MPCI coverage for the corn enterprise was analyzed using 1987 MPCI premium rates and price elections published by the FCIC for Brookings County. The CYPD elicitations and other data collection efforts for the study were conducted in 1987.

Most Brookings County producers were participants in the farm program during 1987 (USDA, ASCS 1987). Corn's monthly market prices were below the farm program's loan rate throughout most of that year (South Dakota Crop and Livestock Reporting Service 1988). The loan rate was modeled as a deterministic "market price" for corn producers in the MPCI decision algorithm.

A producer was also modeled in the algorithm as a participant in the 1987 farm program's "set-aside" plan. Participation in the set-aside plan meant that a producer incurred the expenses of idling part of his cropland to qualify for a deficiency payment. The deficiency payment was a supplement to the revenue side of the producer's net cash flow.

Brookings County producers generally set aside 20% of their corn acreage base to qualify for the 1987 program (ASCS 1987). Twenty-percent (or 48 acres) of the 250 corn acres were kept out of production in the model.

An enterprise budget was constructed for estimating the costs associated with acres idled under the set-aside plan. A producer was expected to control weeds, pay real estate taxes and incur other overhead expenses on set-aside acres. The sum of set-aside costs was included in the calculation of the producer's net cash flow for the corn enterprise. The enterprise budget for set-aside expenses was presented in Table B.1 on page 348 of Appendix B.

No adjustment was made for a producer's tendency to idle marginal lands under the set-aside plan, because of the study's time and budget constraints. If such an adjustment had been built into the model, then the hypothesis was that a producer's incentive to purchase MPCI decreased. That hypothesis was based on the assumption that a producer left the best land in production, and that the best land was less risky to farm.

Subjective CYPD's Selected for the Analysis. Aggregated subjective CYPD's (see chapter five) were derived for sampled producers whose mean yields fell within certain crop yield intervals. The intervals were determined by dividing the sample into producer groups with relatively homogeneous CYPD's.

The most frequently elicited CYPD in the Brookings County producer sample was corn. Corn was also the dominant row crop in Brookings County as measured by acreage planted and revenue received (USDC,

Agricultural Census 1982). The NCF simulation was performed with the subjective corn CYPD's because of the economic importance of the crop in the county.

The MPCI decision was analyzed for three aggregated subjective corn CYPD's in Brookings County: (1) producers in the elicited sample who were classified in the high historical mean corn yield interval (91-101 bu/ac), (2) producers in the medium historical mean corn yield interval (69-79 bu/ac), and (3) producers in the low historical mean yield interval (39-57 bu/ac).

Historical mean crop yield was considered to be an indicator of a producer's management goals and skills in this research. A farm's average soil productivity was not a statistically significant explanatory variable for mean crop yield in the producer sample (see chapter five).

CYPD's for the three mean corn yield intervals were selected to analyze the MPCI purchase decision over a wide spectrum of the county's management skill levels for corn production.

The MPCI premium scale under the APH Plan was another reason to study the purchase decision for producers with different historical mean yields. The FCIC's per acre premium rates decreased as a producer's historical mean yield increased. If the sliding premium scale made a difference in MPCI's attractiveness, then a producer would be predicted to buy MPCI with increased frequency as his mean yield rose.

Price Assumptions for the Analysis. Input and output prices were assumed to be deterministic in the model. The analysis was designed

to isolate MPCI's role in moderating crop yield risk. The aspect of price risk was important, but beyond the study's scope.

The data for input prices in Brookings County were taken from the publication, "Costs of Production and Net Returns for Alternative Farming Systems in Northeastern South Dakota: 1986 and Normalized Situations" (Dobbs, Weiss and Leddy 1987). The MPCI insurance premium and coverage rates were obtained from "Actuarial Documents for Brookings County, South Dakota" (FCIC, USDA 1986).

Market prices were not used in the model. Instead, revenues were determined using the deficiency payment and loan rate levels of the 1987 farm program. The set-aside expenses which a producer incurred to qualify for a deficiency payment were included as part of the corn crop's production costs.

The producer's deficiency payment ($1.82/bushel) was multiplied by the farm's ASCS yield as part of the revenue calculation. The ASCS yield was assumed equal to the producer's expected mean yield in the model. Revenues from the deficiency payment were consequently not affected by the predicted yield variations of a given CYPD. Assuming that a producer's ASCS revenues increased the stability of a producer's net cash flow, there was a decreased need for the modeled producer to buy MPCI.

The farm program's loan rate ($1.61/bu) was multiplied by the producer's actual yield. Variability in a producer's revenue associated with the CYPD was generated with this element of the model.

The MPCI purchase decision was analyzed at each of the three possible insured yield levels, which were 75%, 65% or 50% of the

historical APH yield. Producers were also assumed to select only one of three available MPCI indemnity price levels. The selected indemnity price was the one most similar to the loan rate ($1.61/bu), which was serving as the crop's market price in the model. The assumption behind the MPCI price election was that a producer would not over-insure or under-insure the crop's value. The three 1987 MPCI indemnity price elections for corn were $1.25/bu, $1.50/bu, and $2.00/bu. The $1.50/bu indemnity price level was selected as the closest approximation to the market value of the crop.

Costs of Production for Alternative Mean Corn Yields. Variable and fixed production costs were specified for the corn enterprise budgets.

Fertilizer and seed costs were treated as pre-harvest variable costs which increased as the expected mean yield of a CYPD increased. Guidelines for determining fertilizer and seed costs were adopted from suggested application rates in published crop budgets (Dobbs, Weiss and Leddy 1987; Nott, et. al. 1988).

Variable costs associated with crop harvesting were determined to be directly dependent on the actual yield produced. Storage, hauling and drying were the activities which generated post-harvest costs in the model.

Fixed costs were assumed to include categories such as interest and insurance on land and machinery, real estate taxes and general overhead. Land control costs, such as rental rates, were determined to be positively related to the CYPD's mean expected crop yield.

Set-aside expenses were modeled as part of the total costs of operating the crop enterprise. An estimated $11.42 cost per set-aside acre was multiplied by the 48 idled acres, and the result was added to the cost of production in the corn enterprise budget.

The overall corn enterprise budgets, and an itemization of set-aside costs, were placed in Tables B.1 through B.3 in Appendix B.

The average cost of production was designed to decrease as the expected mean yield of the corn CYPD increased in the model. The implication of this specification was that a producer who managed a crop enterprise to obtain an increased mean yield earned an increase in mean net cash flow, ceteris paribus.

Net Cash Flow and the MPCI Purchase Decision. The net cash flow for a theoretical producer who did not buy MPCI was determined by subtracting budgeted production costs from the sum of cash revenues plus a deficiency payment. The 1987 corn loan rate multiplied by a randomly selected yield from a CYPD was the source of cash revenues. The deficiency payment was equal to the $1.82/bu rate for 1987 Brookings County corn multiplied by a producer's ASCS yield.

The budgeted production costs were the sum of variable, fixed and set-aside costs described above. Production costs were specified to fluctuate in response to a change in a producer's crop yield and/or a producer's theoretical MPCI indifference premium.

The MPCI indifference premium was the maximum amount a producer would pay to remain indifferent between not-insuring and purchasing a given level of MPCI coverage. The indifference MPCI premium was determined for a producer with a theoretical risk aversion coefficient

and an ending net wealth level. A producer was predicted to purchase MPCI only if the indifference MPCI premium was larger than the actual MPCI premium that appeared in the published FCIC actuarial tables.

When a producer's MPCI purchase was being evaluated in the decision making model, the impact of indemnities on the producer's net cash flow was necessarily evaluated. If the actual crop yield fell below the insured crop yield level, then the producer's revenues were supplemented by the MPCI indemnity payment. The MPCI indemnity payment was equal to the MPCI indemnity price election ($1.50/bu) times the positive difference between the insured and actual crop yield levels. Crop yield levels were randomly selected from a producer's CYPD to determine if an MPCI indemnity payment became part of the revenues in the enterprise budget.

Randomly-Generated Net Cash Flows in the Model. An NCF probability distribution was derived as part of the simulation algorithm. Random draws were taken from a selected aggregated-subjective CYPD. The randomly-drawn crop yield was then used to determine an NCF with and without a particular level of MPCI coverage (50%, 65% or 75%). The value of the randomly-generated NCF was then added to the initial wealth level to determine ending net wealth. One thousand draws were taken in each of ten simulations to develop the ending net wealth distribution and predict the MPCI purchase decision.

A procedure in the algorithm modeled the producer's MPCI choice. The expected utility level associated with a non-purchase of MPCI was initially determined. Then the algorithm was designed to search for the indifference MPCI premium. The algorithm converged when the

purchase decision produced the same expected utility level as the non-purchase decision (Black 1988).

The premium derived from the algorithm's search procedure was an estimate of the indifference MPCI premium. A mean indifference MPCI premium was determined from the ten "one-thousand draw" simulations that were run for each yield coverage combination. The mean indifference MPCI premium for the ten simulations was then compared to the actual MPCI premium to predict the MPCI purchase decision.

7.1.3. Initial and Ending Net Wealth Components in the Model

Wealth impacts on risk attitudes and MPCI purchase decisions were theoretically, rather than empirically, analyzed in this study. A producer's net equity position before the addition of the randomly-drawn NCF was assumed to be the measure of initial net wealth.

Estimation of the Initial Net Wealth Level. Initial net wealth in the MPCI decision model was derived from a producer's net equity position. More precisely, the initial net wealth in the model was the proportion of a producer's net equity associated with his corn enterprise. A procedure was developed to estimate what the initial net wealth level would be for the corn enterprise of a typical Brookings County producer.

The publication, Economic Indicators of the Farm Sector: State Financial Summary, 1986 (USDA, ERS 1988), was used to provide an estimate of a producer's whole-farm net equity. A five-year average of a South Dakota farm's net equity was calculated over the 1982-1986 period (Table 7.1). A five-year average was developed because of

differential trends in the financial condition of producers' balance sheets across the state of South Dakota. Net equity values declined in all areas over the 1982-1986 period. But producers' financial conditions deteriorated more rapidly in the state's production areas west of the Missouri River (Schmiesing and Swinson 1986).

Brookings County was located along the South Dakota's eastern border. Statewide figures probably overstated the decline in net equity for the county. If a low net equity value were used in the MPCI decision model, then MPCI purchase predictions would be overly optimistic. The five-year average of net equity was selected as a method to approximate the net equity position of a Brookings County farm.

Table 7.1 Estimation of Net Equity per Farm in South Dakota, Years 1982-1986.

	Balance Sheet Category			
Year	Assets per Farm	Debt per Farm	Net Equity per Farm	Debt-to-Asset Ratio
1982	$447,154.9	$123,312.5	$323,842.4	0.276
1983	$446,434.9	$129,377.2	$317,057.8	0.290
1984	$376,960.8	$130,178.4	$246,836.4	0.345
1985	$334,238.9	$119,161.2	$215,077.8	0.357
1986	$296,526.7	$104,381.3	$192,145.4	0.352
5-Year Average	$380,263.2	$121,282.1	$258,981.1	0.320

Source: EIFS, State Financial Summary, 1986.

The 1986 State Financial Summary (USDA, ERS 1988) was also used to estimate a 5-year average of South Dakota gross crop revenues as a percent of gross farm income (Table 7.2). The crop revenue percentage was used as an approximation of the proportion of net equity that could be attributed to all crop enterprises.

Ideally, the proportion of net equity assigned to an enterprise should have been associated with its net revenues. Estimates of net revenues for South Dakota farm enterprises were unavailable. An assumption was made that similar rates of return to farm enterprises were determined by competitive conditions in agricultural markets. The fraction of whole farm net equity attributed to the relative size of crop enterprise gross revenues was based on the competitive market assumption.

Table 7.2 Estimation of Crop Revenue as Percent of Gross Farm Income (GFI) in South Dakota, Years 1982-1986.

	Source of Cash Receipts as a % of GFI in SD		
Year	Crops	Livestock	Other
1982	0.30	0.53	0.17
1983	0.30	0.56	0.14
1984	0.30	0.52	0.18
1985	0.36	0.59	0.05
1986	0.31	0.50	0.19
5-Year Average	0.31	0.54	0.15

Source: EIFS, State Financial Summary, 1986.

The 1982 Agricultural Census was used to estimate the corn crop's proportion of total crop revenues in Brookings County. The corn crop's proportion was then multiplied by the net equity figure associated with revenues of all Brookings County crops. This latter calculation was used to estimate the mean net equity value specifically for the corn enterprise (Table 7.3).

Table 7.3 Estimation of Net Equity Associated with a Corn Enterprise in Brookings County, SD for Years 1982-1986.

Step One: Calculation of Net Equity Associated with All Crop Enterprises

5-Year Average Net Equity per S.D. Farm, 1982-1986 (Table 7.1)	= $258,981.00 = NE
5-Year Average Percent of GFI Obtained from Crop Enterprises (Table 7.2)	= 0.31 = Pr_{crop}
Estimate of Mean Net Equity Associated with all Crop Enterprises (NEall)	= NE x Pr_{crop} = $80,688.00

Step Two: Corn Crop's Estimated Percent of Total Crop Receipts in Brookings County, SD (Ag Census 1982)

$$\frac{\text{1982 Revenues, Corn, Brookings Co.}}{\text{1982 Revenues, All Crops, Brookings Co.}} = 0.67 = (Pr_{corn})$$

Step Three: Estimated Mean Net Equity Associated with Corn Enterprise

$$(NEall) \times (Pr_{corn}) = \$54,187.00$$

The variance of net equity values about the mean net equity value for the corn enterprise was additionally estimated. The publication, Regional Farm Financial and Operating Characteristics by Sales Class and Farm Type, January 1985 (Salassi and Gatton 1987), was used to obtain an estimate of the coefficient of variation (CV's) for the net equity value.

The modal and mean farm size, by volume of sales, in Brookings County was in the interval of $40,000 to $99,999 per year (USDC, Agricultural Census 1982). Salassi and Gatton (1987) published CV's for Northern Plains farm debts and assets in 1984 by farm sales intervals. No CV's were published by Salassi and Gatton for net equity.

The CV for net equity in the $40,000-$99,999 sales class was estimated as the weighted average of the farm debt and asset CV's in that class. The CV's were weighted by the respective dollar amounts in the farm debt and asset categories.

The estimated net equity CV estimate was used to determine the net equity values which were three standard deviations on either side of the corn enterprise's mean net equity value. Theoretically, 99% of all Brookings County producers' net equity values associated with corn enterprises were included by utilizing the plus/minus three standard deviation calculation (Table 7.4).

Table 7.4 Estimation of Three Alternative Initial Wealth Levels for Modeling the MPCI Purchase in Brookings, SD.

Mean Net Equity Associated with the Corn Enterprise (NE_{corn}), on a Brookings County Farm (Table 7.3)	= $54,187.00
Coefficient of Variation (CV) for Net Equity of a Northern Plains Farm with Total Gross Sales between $40,000 and 99,999 per Year (Salassi and Gatton 1987)	= 0.097
Estimated Standard Deviation of NE_{corn}, based on Northern Plains CV estimate	= $5,279.00

Three Initial Net Equity Levels Estimated for Simulation of MPCI Purchase Decision

Mean Net Equity Minus Three Standard Deviations	Mean Net Equity of NEcorn	Mean Net Equity Plus Three Standard Deviations
$38,350.00	$54,187.00	$70,024.00

Ending Net Wealth Estimation. The end results of the net equity estimations were three initial net wealth levels which could each be analyzed in the simulation algorithm model of the MPCI purchase. Randomly-drawn NCF's were added to the estimated initial wealth levels to determine the ending net wealth levels. The ending net wealth levels were evaluated with the expected utility function, and the MPCI choice was predicted based on the relationship between the utility function's indifference MPCI premium and the FCIC's actual MPCI premium.

7.2. MPCI Decision Analysis Results for Elicited Corn CYPD's in Brookings County, South Dakota

MPCI purchases were analyzed under both the APH and AREA Plans. Basic characteristics of the three corn CYPD's and their corresponding MPCI purchase options under the two coverage plans were summarized in Table 7.5. The complete premium rate tables for the APH and AREA Plans in Brookings County were presented in Tables J.1 through J.4 of Appendix J.

Table 7.5 Corn CYPD's and their Associated MPCI Coverage and Premium Rates in Brookings County, SD under the APH and AREA Plans.

Mean Yield bu/ac	Yield Standard Deviation bu/ac	MPCI Coverage (%)	Insured Yield bu/ac	Actual MPCI Premium @ $1.50/bu Price Election $/acre
		Self Insurance		
83	23	None	None	$0.00
70	22	None	None	$0.00
55	18	None	None	$0.00
		MPCI Under the APH Plan		
83	23	75%	61.5	$11.87
83	23	65%	53.3	$5.58
83	23	50%	41.5	$3.12
70	22	75%	52.5	$12.36
70	22	65%	45.5	$5.87
70	22	50%	35.0	$3.26
55	18	75%	41.3	$13.25
55	18	65%	35.8	$6.33
55	18	50%	27.5	$3.51
AREA Plan's Insurable Yield (bu/ac)		MPCI Under the AREA 1 Plan		
49	N/A	75%	36.8	$7.67
49	N/A	65%	31.9	$4.92
49	N/A	50%	24.5	$3.12
		MPCI Under the AREA 2 Plan		
49	N/A	75%	36.8	$12.13
49	N/A	65%	31.9	$7.22
49	N/A	50%	24.5	$4.52

The effects of MPCI premium subsidies and premium-rate scaling under the APH Plan could be observed in Table 7.5. The full 30% government subsidy was in effect for the 65% and 50% coverage levels, whereas the extra coverage between the 65% and 75% levels was unsubsidized. A large jump in the producer's premium was noticeable at the 75% coverage level for all three mean corn yields in Table 7.5.

The impact of scaling the premium rates to decrease as mean yield increased was also demonstrated in Table 7.5 under the APH Plan. Producers with a mean corn yield of 83 bu/ac would pay a lower premium per acre than those with a 55 bu/ac mean corn yield for a similar percent coverage level.

The AREA Plan's coverages and premiums were separated into two separate sub-plans (Table 7.5). The two sub-plans corresponded to the insurable production regions in Brookings County under the AREA Plan. Brookings' AREA One was classified as less risky than AREA Two. AREA Two lay within the immediate flood plain of the Big Sioux River. The MPCI premium rates in AREA Two were higher, reflecting the higher risk of crop loss caused by flooding.

The MPCI coverages and premium costs under the alternative coverage plans were inputted to the algorithm to model the MPCI purchase decision. Additional information needed for the simulation included the utility function, NCF enterprise budget and initial net wealth level.

The number of times the simulation algorithm was run under each of the APH and AREA Plans to predict the MPCI purchase was determined by varying four factors: (1) the underlying CYPD (and its corresponding

enterprise budget), (2) the utility function, (3) the initial net wealth level, and (4) the MPCI coverage level. All the possible combinations of three CYPD's, two utility functions, three initial wealth levels and three coverage levels were analyzed for each coverage plan. As a result, fifty-four runs of the algorithm were conducted for evaluating the each of the APH and AREA Plans in Brookings County (a total of 108 runs).

7.2.1. Results of the MPCI Purchase Analysis Under the APH Plan

The MPCI purchase decision of a Brookings County corn producer with a high, medium or low mean CYPD was analyzed under the APH Plan with the simulation model. The utility function and the set of ending net wealth distributions generated from each CYPD were determining factors in the prediction of an MPCI purchase or non-purchase.

The simulations were conducted by changing the three initial wealth positions and three percent coverage levels for each combination of a producer's subjective CYPD and theoretical utility function. The simulation results for MPCI decisions under the APH Plan were first examined with the CES utility function, and then with the logarithmic utility function.

MPCI Purchase Decisions with the CES Utility Function. The results in Table 7.6 below were developed for Brookings County producers who: (1) were considering an MPCI purchase under the APH Plan, (2) had a CYPD with a high mean corn yield, and (3) could be modeled with the CES utility function developed for this analysis. The "buy" or "not buy" decisions in the table's last column were determined by

Table 7.6 Predicted MPCI Purchase Decision under the APH Plan for Brookings County Producers with a High Mean Corn Yield and CES Utility Function.

Expected Mean Yield = APH yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$11.87	$6.22	NOT BUY
65%	53.3	$5.58	$3.84	NOT BUY
50%	41.5	$3.12	$1.90	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$11.87	$7.08	NOT BUY
65%	53.3	$5.58	$4.50	NOT BUY
50%	41.5	$3.12	$2.23	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$11.87	$8.96	NOT BUY
65%	53.3	$5.58	$6.01	BUY
50%	41.5	$3.11	$3.38	BUY

comparing the indifference premium to the FCIC's published premium in the Brookings County Actuarial Table. A buy decision was predicted when the indifference premium was greater than the actual; otherwise a not buy decision was the result. The MPCI decisions for the three coverage levels were predicted under each of the three assumed initial wealth positions.

The indifference MPCI premium rates generated by the simulation under the $70,000 and $54,200 initial wealth assumptions were less than the actual premiums by as much as $5.65/acre (Table 7.6). The results were an indication that a producer would not buy MPCI, if his ending net wealth distribution and utility function were similar to those modeled under the $70,000 and 54,200 initial net wealth positions in Table 7.6.

A primary factor which determined the indifference premium was the global Pratt-Arrow Absolute Risk Aversion Coefficient (PARAC) derived from the ending net wealth probability distribution and the assumed utility function. A calculation of the global PARAC was not performed because of the increased time and expense required to numerically estimate an inverse functional form of the utility function (see chapter three). An approximation of the producer's global PARAC was the local PARAC at the initial wealth level.

The local PARAC had a value of 0.000071 at the $54,200 initial wealth level, assuming the CES utility function was used to evaluate the CYPD with the 83 bu/ac mean corn yield. No MPCI purchase was predicted (Table 7.6) when the PARAC value was at or below the 0.000071 figure. For example, the indifference MPCI premiums for

yield coverages at the 0.000053 PARAC value were less than those for the 0.000071 PARAC value by as much as $0.86/acre for comparable coverage levels.

If producers' empirical PARAC values were related to initial net wealth levels as they were modeled in the CES utility function, then Brookings County producers with an average or above-average net equity position would be predicted to self-insure rather than buy MPCI.

The risk attitudes associated with PARAC values were classified by interval estimates in previous research (Raskin and Cochran 1986; Thomas 1987). A summary of those risk behavior categories was presented in Table 3.1 of chapter three. The "risk neutral" classification was assigned to the PARAC interval between the values -0.0001 and 0.00014. The local PARAC values at the initial wealth levels in Table 7.6 all fell within the so-called risk neutral interval.

The predictions of "not buy" decisions were not completely unexpected in Table 7.6, assuming that producers with the selected utility function and wealth levels had PARAC values which were risk neutral. A purely risk-neutral decision maker was theoretically determined to make choices among risky distributions by selecting those distributions which had the highest expected value. Decision makers who were close to being risk neutral were predicted to derive greater utility from increasing the expected value of the distribution than from decreasing the occasional losses caused by variance in the distribution.

When MPCI was purchased in the Brookings County simulations, there was a decrease in the expected value and the variance of the ending net wealth distribution (see Figures I.1 and I.2, Appendix I). A theoretical utility function with a globally more risk-averse set of PARAC values would have been required before MPCI purchases were predicted more frequently for producers described by the CYPD parameters in Table 7.6.

When the low end of the initial wealth assumption ($38,400) was placed into the decision making model, MPCI purchases were predicted at the 65% and 50% coverage levels (Table 7.6). The local PARAC value for the CES utility function at this low initial net wealth level was 0.000111. This PARAC value approximated the upper boundary of the interval that had been defined as risk neutral. If the risk neutral interval's boundaries were meaningful, then the decision maker with a 0.000111 PARAC value was on the border line between being risk-neutral and risk-averse.

A producer with a PARAC on the boundary line between risk neutrality and risk aversion could be labeled as a "marginal MPCI customer". At the margin, these were the type of producers who were most likely to sensitive to the effects of government premium subsidization at the 65% and 50% coverage levels on the decision to buy MPCI. The "not buy" decision at the 75% coverage level was probably related to the lack of any additional subsidy on the extra premium charged between the 65% and 75% coverage levels.

If producers' risk attitudes were described by the CES utility function of Table 7.6, then at least three implications followed.

First, the DARA property of the utility function caused the PARAC value to rise as the initial net wealth level decreased. If such a relationship existed in the real world, then only producers with a below-average net equity would be considered potential MPCI buyers.

Second, producers with low net equity levels were more likely to be considered "financially-stressed" by their creditors. Such producers would have less unrestricted collateral to cover a major income loss caused by a crop failure. MPCI might be viewed by creditors as a tool to increase the business survival chances of financially-stressed producers (Pflueger and Barry 1986). The relationships among risk attitudes, farm financial-stress and MPCI's potential risk management role were likely to be a valuable area for future empirical research.

Finally, these results were premised on crop yield variability being the only source of risk. Future MPCI research should be used to explore the sensitivity of MPCI decisions to other sources of risk (e.g. price and financial), and to the correlations between the other risks and the crop yield variations.

The predicted MPCI decisions under the APH Plan for Brookings County producers with the medium mean corn yield were presented in Table 7.7. The outcomes in Table 7.7 differed from those in Table 7.6 in that a "not buy" MPCI decision was predicted at all coverage and net wealth levels. One reason for this outcome was the increase in MPCI's actual per bushel premium rates as the mean yield decreased.

If a producer had the low initial net wealth level ($38,400) in Table 7.7, then the indifference premiums were almost equal to the

Table 7.7 Predicted MPCI Purchase Decision under the APH Plan for Brookings County Producers with a Medium Mean Corn Yield and CES Utility Function.

Expected Mean Yield = APH yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	52.5	$12.36	$6.15	NOT BUY
65%	45.5	$5.87	$3.93	NOT BUY
50%	35.0	$3.26	$2.03	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	52.5	$12.36	$6.92	NOT BUY
65%	45.5	$5.87	$4.51	NOT BUY
50%	35.0	$3.26	$2.44	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$12.36	$8.56	NOT BUY
65%	53.3	$5.87	$5.83	NOT BUY
50%	41.5	$3.26	$3.17	NOT BUY

actual MPCI premiums. For example, at the $38,400 initial wealth position, the spread between the actual and indifference premiums for the 65% level was only $0.04/acre. If the utility function had been specified to be slightly more risk averse at this net wealth level, a "buy" decision would have been predicted.

The results of Tables 7.6 and 7.7 together were used to identify some additional implications. The measurement of empirical risk attitudes of producers appeared to be a critical determination in assessing the potential to market MPCI under the APH Plan in Brookings County. Producers in the model above were predicted to buy MPCI if their PARAC values were marginally risk averse. If a large portion of producers were globally more risk averse than what was represented in the CES utility used above, then an increased potential would exist to market MPCI to producers under the current structure of subsidized premiums and coverage levels, particularly for low net equity (financially-stressed) producers.

If producers' risk attitudes were similar to or less risk averse than what was modeled in the theoretical CES utility function, then attaining the goal of increased participation probably meant an increase in direct subsidies for MPCI premiums would be needed. For example, if a Brookings County producer had an APH yield and expected corn yield equal to 70 bu/ac, an initial net wealth of $54,200 associated with the corn enterprise, and a 0.000071 PARAC, then the actual MPCI premium at the 65% coverage level would have to be reduced by more than 23% before the producer was predicted to buy MPCI (Table 7.7).

The current 30% government share of MPCI premium costs at the 50% and 65% coverage levels was predicted to make only a marginal impact on producers' MPCI purchases, if producers were generally less risk averse than the risk attitude levels modeled in this study.

One additional observation for Tables 7.6 and 7.7 was the role that the 75% coverage level had in the MPCI program. If one of the goals of the FCIC was to discourage the MPCI purchase at the 75% level, then the model was used to predict that the FCIC had accomplished its objective. The spread between the indifference and actual premium rates was often quite large at the 75% level, which meant that a strong case could be built for the model's "not buy" prediction.

One hypothesis, which was not tested in this study, was that producers exhibited an increased potential for moral hazard at the 75% coverage level. Moral hazard was an "undesirable" clientele behavioral pattern, from the perspective of the FCIC as the insuring organization (FCIC 1984). The FCIC's premium structure was a disincentive for producers to purchase MPCI at the highest coverage level, and possibly a technique to limit the impact of moral hazard on the balance between the FCIC's indemnity payments and premium collections.

The MPCI results for the producers represented by the CYPD with the 55 bu/ac mean expected corn yield CYPD were presented in Table 7.8. These producers were classified as the low-yield group, because the expected mean corn yield for the entire Brookings County sample was 71.4 bu/ac (chapter five).

The results in Table 7.8 were similar to those in Table 7.6 for the high-yield producers. "Not buy" decisions were predicted at the average and above-average initial net wealth levels, whereas a "buy" decision was predicted at the 65% and 50% coverages when the model was applied at an assumed $38,400 initial wealth level.

The buy decisions were predicted in Table 7.8 even though an increase in actual MPCI premium was associated with the decrease in mean corn yield. A visual inspection of the low-yield CYPD revealed a relatively "thick tail" on the left end of the probability distribution (see Figure D.5, Appendix D). Producers represented by this CYPD apparently perceived an increased chance of "disaster" type crop yields, especially when compared with the CYPD's of producers with the 70 bu/ac and 83 bu/ac mean corn yields.

Table 7.8 Predicted MPCI Purchase Decision under the APH Plan for Brookings County Producers with a Low Mean Corn Yield and CES Utility Function.

Expected Mean Yield = APH yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	41.3	$13.25	$6.23	NOT BUY
65%	35.8	$6.33	$4.37	NOT BUY
50%	27.5	$3.51	$2.66	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	41.3	$12.36	$6.98	NOT BUY
65%	35.8	$5.87	$5.00	NOT BUY
50%	27.5	$3.26	$2.92	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	41.3	$12.36	$9.38	NOT BUY
65%	35.8	$5.87	$6.74	BUY
50%	27.5	$3.26	$3.82	BUY

One implication of the modeling results for the 55 bu/ac mean corn yield CYPD was that MPCI under APH could attract the producers with mean crop yields below the county mean. If the results of Table 7.8 were examined jointly with those of Tables 7.6 and 7.7, then MPCI participation under the APH Plan would be more attractive for producers at the extremes of the distribution of mean corn yields in Brookings County.

The scaling and subsidization of MPCI premiums contributed to the predicted MPCI purchases by low net equity producers with an 83 bu/ac expected mean corn yield. The increased risk of disaster yields perceived by the low net equity producers in the 55 bu/ac was a major factor in their predicted purchase decision.

The so-called "average mean corn yield producers" in Brookings County were not predicted to buy MPCI at net wealth and risk attitude levels similar to those of the producers with yields above and below the expected county mean. If this outcome were replicated elsewhere, then MPCI participation would be predicted to suffer because of the inability to attract producers from the group of "average" producers. Average producers were typically those who accounted for the largest proportion of possible MPCI users within a county.

MPCI Purchase Decisions with the Logarithmic Utility Function. The PARAC values for the logarithmic utility function were globally less risk averse at the initial net wealth levels modeled in this MPCI purchase analysis. If producers' preferences and net wealth levels were similar to those modeled in Tables 7.9, 7.10 and 7.11 below, then MPCI would simply not be purchased at current premium levels in

Brookings County. Levels of premium subsidization had to increase by as much as 53% of the current premium level before producers would consider buying MPCI at the 65% and 50% coverage levels, and by even more at the 75% coverage level (Table 7.9).

Table 7.9 Predicted MPCI Purchase Decision under the APH Plan for Brookings County Producers with High Mean Corn Yield and Logarithmic Utility Function.

Expected Mean Yield = APH yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000014

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$11.87	$4.72	NOT BUY
65%	53.3	$5.58	$2.77	NOT BUY
50%	41.5	$3.12	$1.10	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000018

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$11.87	$4.62	NOT BUY
65%	53.3	$5.58	$2.93	NOT BUY
50%	41.5	$3.12	$1.19	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000026

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	61.5	$11.87	$5.07	NOT BUY
65%	53.3	$5.58	$3.18	NOT BUY
50%	41.5	$3.11	$1.34	NOT BUY

Table 7.10 Predicted MPCI Purchase Decision under the APH Plan for Brookings County Producers with a Medium Mean Corn Yield and Logarithmic Utility Function.

Expected Mean Yield = APH yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000014

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	52.5	$12.36	$4.80	NOT BUY
65%	45.5	$5.87	$2.77	NOT BUY
50%	35.0	$3.26	$1.30	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000018

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	52.5	$12.36	$5.13	NOT BUY
65%	45.5	$5.87	$2.99	NOT BUY
50%	35.0	$3.26	$1.33	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000026

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	52.5	$12.36	$5.32	NOT BUY
65%	45.5	$5.87	$3.11	NOT BUY
50%	35.0	$3.26	$1.46	NOT BUY

Table 7.11 Predicted MPCI Purchase Decision under the APH Plan for Brookings County Producers with a Low Mean Corn Yield and Logarithmic Utility Function.

Expected Mean Yield = APH yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000014

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	41.3	$13.25	$4.98	NOT BUY
65%	35.8	$6.33	$3.41	NOT BUY
50%	27.5	$3.51	$1.76	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000018

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	41.3	$12.36	$5.05	NOT BUY
65%	35.8	$5.87	$3.30	NOT BUY
50%	27.5	$3.26	$1.76	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000026

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under APH Plan
75%	41.3	$12.36	$5.62	NOT BUY
65%	35.8	$5.87	$3.67	NOT BUY
50%	27.5	$3.26	$1.95	NOT BUY

The results in Tables 7.6 through 7.11 were used to estimate the sensitivity of the indifference premium to the local PARAC value at the initial wealth position for a given coverage level. The indifference MPCI premiums were taken from Tables 7.6 - 7.11 at the 65% coverage level for each of the three CYPD's that were simulated. The association between the local PARAC value and indifference premium at the 65% level was summarized in Table 7.12 and the corresponding Figure 7.1.

Table 7.12 Sensitivity of the Simulated Indifference MPCI Premium to the Local PARAC Value at the 65% Coverage Level

PARAC Value	Indifference Premium at the 65% Coverage Level Measured in Dollars Per Acre: CYPD with 83 bu/ac Mean	CYPD with 70 bu/ac Mean	CYPD with 55 bu/ac Mean
0.000111	6.01	5.83	6.74
0.000071	4.50	4.51	5.00
0.000053	3.84	3.93	4.37
0.000026	3.18	3.11	3.67
0.000018	2.93	2.99	3.30
0.000014	2.77	2.77	3.41

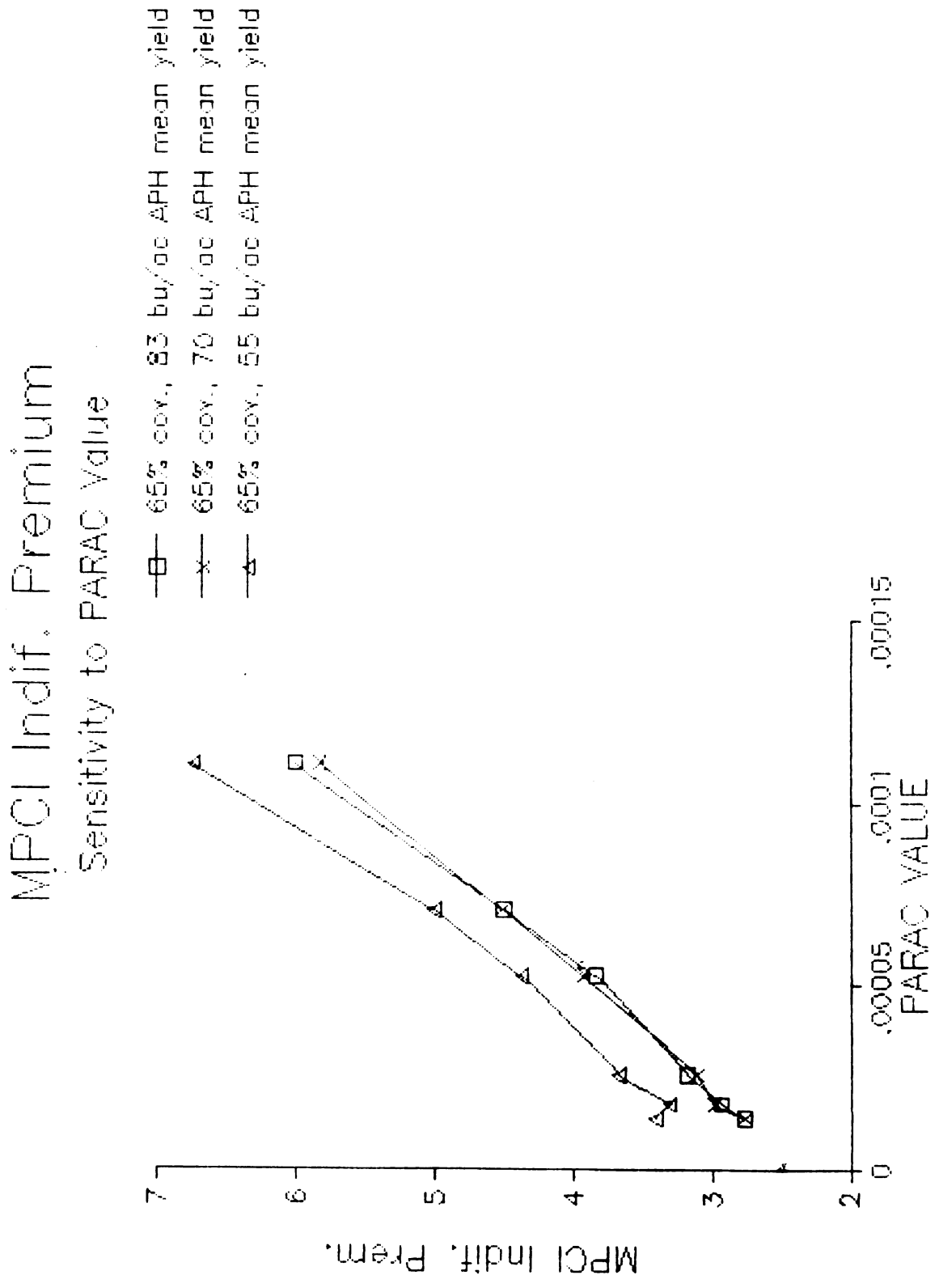

Figure 7.1 MPCI Indifference Premium: Sensitivity to PARAC Value.

The indifference MPCI premium was positively related to the local PARAC value in the simulation model, as demonstrated in Table 7.12 and Figure 7.1. The graphical presentation in Figure 7.1 was also used to identify some implications for the APH Plan in Brookings County. Producers with the 70 bu/ac and 83 bu/ac mean corn yields had indifference MPCI premiums which were almost identical at similar net wealth and PARAC levels (see Figure 7.1). Producers with these average to above-average mean corn yields apparently perceived similar crop yield risks. By comparison, the FCIC's actual MPCI premium rates facing producers in the 70 bu/ac mean yield category were higher than the rates charged to those in the 83 bu/ac mean yield category.

Producers represented by the CYPD with the 70 bu/ac corn CYPD were the modal group of the sample in this research. If the purchase of MPCI were to become an attractive alternative to a larger proportion of Brookings County producers, then some changes in MPCI's structure would be needed to encourage the modal group producers to participate. For example, the scaling of the MPCI premiums might be designed to decline more rapidly as the producer's mean yield approached the county average. The premium rates could also be designed to increase more rapidly as the producer's yield decreased below the county mean. Such a design would discourage participation by the county's below-average producers, but could also result in greater use of the product by the county's average to above-average producers. The losses for below-average producers created by the design might be offset by increasing the availability and/or accessibility of other farm programs which help a producer boost his productivity.

Brookings County corn producers represented by the CYPD with the 55 bu/ac mean yield had a set of indifference premiums which were consistently above the values for the other two sets of producers (see Figure 7.1). If the CES utility function, 65% coverage level and $38,400 initial wealth level were assumed, the actual MPCI premium for the 55 bu/ac mean corn yield producer could have been increased by $0.86 per acre and a buy decision would still have been predicted in the model (see Table 7.8). The concept of charging increased MPCI rates for producers with low mean yields was consistent with this modeling result. If rates were increased further for below-average producers, then some flexibility would exist to reduce the rates for the modal producers, and possibly create an overall increase in the use of MPCI under the APH Plan.

7.2.2. Results of the MPCI Purchase Analysis Under the AREA Plan

The set of simulation techniques used in analyzing the APH Plan above were also applied to predict MPCI decisions under the AREA Plan.

The insurable yield for the Brookings County MPCI AREA Plan was equal to 49 bu/ac for the entire county. Percent coverages were determined based on the 49 bu/ac base yield figure.

The county was divided into two areas for MPCI purposes. The MPCI premium rates in the floodplain (AREA 2) were higher than those in AREA 1 at all coverage levels.

If a producer was predicted to "not buy" MPCI in AREA 1 in the model, he also did not buy in AREA 2. Separate tables were not

constructed in this chapter to report the AREA 2 simulation results primarily because the modeling outcomes in both areas were very similar.

The simulation results were first summarized under the assumption of the CES utility function in Tables 7.13 through 7.15. Producers in both the 83 bu/ac and 70 bu/ac mean yield CYPD's were not predicted to buy MPCI under the AREA Plan for any of the initial net wealth and coverage level combinations. The indifference MPCI premiums were approximately $2.00/acre less than the actual MPCI premiums at the 65% and 50% coverage levels, and an even larger spread existed at the 75% coverage level (Tables 7.13 and 7.14).

Table 7.13 Predicted MPCI Purchase Decision under the AREA 1 Plan for Brookings County Producers with High Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$1.18	NOT BUY
65%	31.9	$4.92	$0.93	NOT BUY
50%	24.5	$3.12	$0.57	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$1.97	NOT BUY
65%	31.9	$4.92	$1.19	NOT BUY
50%	24.5	$3.12	$0.67	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$2.53	NOT BUY
65%	31.9	$4.92	$2.17	NOT BUY
50%	24.5	$3.12	$1.00	NOT BUY

Table 7.14 Predicted MPCI Purchase Decision under the AREA 1 Plan for Brookings County Producers with a Medium Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$2.39	NOT BUY
65%	31.9	$4.92	$1.48	NOT BUY
50%	24.5	$3.12	$0.92	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$2.84	NOT BUY
65%	31.9	$4.92	$1.90	NOT BUY
50%	24.5	$3.12	$0.98	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$3.59	NOT BUY
65%	31.9	$4.92	$2.70	NOT BUY
50%	24.5	$3.12	$1.46	NOT BUY

Table 7.15 Predicted MPCI Purchase Decision under the AREA 1 Plan for Brookings County Producers with a Low Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$4.71	NOT BUY
65%	31.9	$4.92	$3.52	NOT BUY
50%	24.5	$3.12	$1.90	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$5.62	NOT BUY
65%	31.9	$4.92	$4.06	NOT BUY
50%	24.5	$3.12	$2.30	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 1 Plan
75%	36.8	$7.67	$7.24	NOT BUY
65%	31.9	$4.12	$5.59	BUY
50%	24.5	$3.12	$3.25	BUY

Producers included in the 55 bu/ac mean yield CYPD were predicted to buy MPCI under the AREA 1 Plan at the 65% and 50% coverage levels if the initial net wealth was $38,400 (Table 7.15). These were the only conditions under which a buy decision for the AREA Plan was predicted in the model. No purchases of MPCI were predicted in AREA 2 under any of the net wealth, coverage and utility function combinations.

The adverse selection problem associated with the AREA Plan in previous research was also determined to exist in this study. The producer group in the 55 bu/ac corn CYPD were below-average relative to the county's mean corn yield. The predicted purchase of MPCI under the AREA Plan occurred when their net wealth level was low enough to create a PARAC level that was classified as "marginally risk averse" using intervals of PARAC estimates. The narrowly defined group of producers who purchased MPCI under the AREA Plan in the model might be described as "financially-stressed, risk-averse and low-mean-yield producers."

The prospect for increased MPCI participation under the current structure of the AREA Plan was very limited. If the insurable yield (49 bu/ac) were increased, or if higher premium subsidies were used, then the likelihood of producer participation could be re-examined. However, if the insurable yield were increased, producers with below-average mean yields would obtain the opportunity to insure their crop yields at levels greater than what they might normally expect to produce. The adverse selection problem could worsen if the incentives

for the below-average producers to buy MPCI under the AREA Plan were increased more rapidly than those for the remaining producers.

The results of the MPCI purchase under the AREA Plan with the logarithmic utility function were summarized in Tables H.1 through H.3 on pages 411-414 of Appendix H. Since the logarithmic function was globally less risk averse than the CES function, the not buy prediction was practically "automatic" for all combinations of wealth and coverage levels.

The level of participation in MPCI under the pre-1985 AREA Plan was low, but perhaps not as low as the logarithmic utility function would have predicted. The actual market performance of MPCI under the AREA Plan might be used to cast doubt on the prospect that producers behave as if they had a logarithmic utility function with primarily risk neutral attitudes.

7.3. Measuring Gains and Losses Associated With MPCI Purchases

The switch from the AREA Plan to the APH Plan within MPCI was costly for the FCIC. The FCIC's objective for the conversion to the APH Plan was to enhance the economic attractiveness of an MPCI purchase for an increased number of producers. One method to measure what difference the APH Plan made for potential MPCI users was to estimate a producer's net gains and/or losses associated with an MPCI purchase under the alternative coverage plans.

A producer's perceived break-even and indifference MPCI premium rates, along with the FCIC's actual MPCI premium rates, were used to

estimate net gains and losses for an MPCI purchase (see chapter three).

The break-even premium rate derived from a subjective CYPD for a given coverage level was equal to the expected value of the MPCI indemnities for that crop yield coverage. The indifference MPCI premium was the maximum premium a producer would be willing and able to pay to obtain a given level of yield coverage, and remain indifferent with the option of not buying MPCI (self-insuring). If the actual MPCI premium exceeded a producer's indifference premium, then the producer preferred to self-insure.

The ratio of the indifference premium to the break-even premium was a measure of how much a producer would pay above the break-even rate to reduce variability in his ending net wealth probability distribution. The ratio was referred to as the "indifference premium ratio." The ratio of the indifference premium to the break-even premium was expected to be greater than one for producers with a PARAC greater than zero. A producer was predicted to increase his indifference premium as his PARAC value increased in the model.

A ratio of the FCIC's actual MPCI premium rate to the perceived break-even rate was also calculated. This latter ratio was compared with the indifference premium ratio to estimate the net gain or loss associated with an MPCI purchase. The actual and indifference ratios were only comparable when the percent coverage (and the insured yield) were the same.

7.3.1. Producer Gains and Losses Produced by an MPCI Purchase Under the APH Plan

Actual and indifference premium ratios under the APH Plan for the low, medium and high mean corn yield producers with an assumed CES utility function were presented in Tables 7.16 to 7.18. Simulation results for the logarithmic utility function were placed in Tables H.7 through H.12 on pages 418 - 423 of Appendix H.

Actual MPCI premiums for the high-yield producers were approximately five times larger than the perceived break-even premiums at the 75% and 50% coverage levels (Table 7.16). The actual premium ratio at the 65% coverage level was roughly equivalent to a value of four. Other factors held constant, a producer would purchase MPCI more frequently at the 65% level than at the other yield coverages.

The increased value of the actual premium ratio at the 75% level was likely caused by the FCIC's removal of the MPCI premium subsidy for additional coverage beyond the 65% level.

The value of the actual premium ratio at the 50% coverage level was partly associated with the probabilities that producers assigned

Table 7.16 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the APH Plan for Producers with a High Mean Corn Yield and CES Utility Function.

Expected Mean Yield = APH yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.56	$6.22	$11.87	2.43	4.64
65%	$1.44	$3.84	$5.58	2.67	3.88
50%	$0.61	$1.90	$3.12	3.11	5.11

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.56	$7.08	$11.87	2.77	4.64
65%	$1.44	$4.50	$5.58	3.13	3.88
50%	$0.57	$2.23	$3.12	3.91	5.47

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.56	$8.96	$11.87	3.50	4.64
65%	$1.44	$6.01	$5.58	4.17	3.88
50%	$0.60	$3.38	$3.12	5.63	5.20

Table 7.17 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the APH Plan for Producers with a Medium Mean Corn Yield and CES Utility Function.

Expected Mean Yield = APH yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.68	$6.15	$12.36	2.29	4.61
65%	$1.58	$3.93	$5.87	2.49	3.72
50%	$0.72	$2.03	$1.47	2.82	4.53

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.68	$6.92	$12.36	2.58	4.61
65%	$1.58	$4.51	$5.87	2.85	3.72
50%	$0.72	$2.44	$3.26	3.39	4.53

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.68	$8.56	$12.36	3.19	4.61
65%	$1.58	$5.83	$5.87	3.69	3.72
50%	$0.67	$3.17	$3.26	4.73	4.87

Table 7.18 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the APH Plan for Producers with a Low Mean Corn Yield and CES Utility Function.

Expected Mean Yield = APH yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.81	$6.23	$13.25	2.22	4.72
65%	$1.86	$4.37	$6.33	2.35	3.40
50%	$1.02	$2.66	$3.51	2.61	3.44

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.81	$6.98	$13.25	2.48	4.72
65%	$1.86	$5.00	$6.33	2.69	3.40
50%	$0.96	$2.92	$3.51	3.04	3.66

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.98	$9.38	$13.25	3.15	4.45
65%	$1.96	$6.74	$6.33	3.44	3.23
50%	$0.93	$3.82	$3.51	4.11	3.77

to large yield reductions. Producers with the high and medium mean yield CYPD's perceived lower break-even premium rates and higher actual premium ratios at the 50% level (Tables 7.16 and 7.17) than the producers represented by the low mean yield CYPD (Table 7.18).

The subjectively-perceived left tails of the high and medium mean yield producers' CYPD's were relatively "thinner" than the left tail of the low mean yield CYPD (see Figures D.1, D.3 and D.5 in Appendix D). The decreased probability attached to the extremely low yields by the medium and high mean yield producers meant that their perceived break-even premiums for the 50% coverage level were reduced.

The break-even premium was the denominator of the actual premium ratio. Reductions in the break-even premium caused the actual premium ratio to rise and the likelihood of an MPCI purchase at this coverage level to decline.

A reason for the numerator of the actual premium ratio to increase at the 50% level was the likelihood that crop yield reductions for individual producers were not always independent events. A regional drought would be one example where many producers would simultaneously experience extreme yield losses. Such a phenomenon was classified in MPCI as a catastrophic yield event. The FCIC increased MPCI premium rates by "load factors" to account for the costs of catastrophic yield reductions. The individual producer, using only his own subjective CYPD to evaluate MPCI's attractiveness, would generally not have a private incentive to adjust his break-even premium rate for catastrophic events. The 30% premium subsidies at the 50%

and the 65% coverage levels were one method to offset the adverse impact of load factors on MPCI's potential marketability.

Indifference premium ratios decreased as the level of coverage increased at a given wealth level (see Table 7.16). For example, the indifference premium ratio was 3.11 at the 50% coverage level, 2.67 at the 65% level, and 2.43 at the 75% level, when the $70,000 initial wealth level was assumed in Table 7.16. The pattern in the indifference premium ratio was the result of the decreasing relative risk aversion (DRRA) property of the CES utility function. The coefficient of relative risk aversion for the CES function decreased as ending net wealth increased (see chapter three).

The interpretation of the DRRA property was a diminishing marginal utility for additional "units" of risk reduction, assuming a given initial wealth level. An example of a unit of risk reduction would be a one standard deviation decrease in ending net wealth variability.

The earlier-mentioned disincentive to purchase MPCI at the 75% coverage level was reinforced by the DRRA property. If producers actually possessed the DRRA property, then the 75% coverage level would rarely be considered by producers as an MPCI purchase option, and the coverage alternatives might be "effectively" reduced to a choice between the 50% and 65% yield levels.

The losses predicted under the assumption of the logarithmic utility function were used to predict that producers would not buy MPCI. The actual premium ratios were much higher than the indifference premium ratios at all combinations of coverages and wealth levels. If producers behaved as if they possessed a log utility

function, then the APH Plan would not have much potential to create a measurable increase in MPCI participation.

7.3.2. Producer Gains and Losses Produced by an MPCI Purchase Under the AREA Plan

Indifference and actual premium ratios were determined under the AREA Plan, and the results under the assumption of the CES utility function were reported in Tables 7.19 to 7.21.

Table 7.19 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the AREA 1 Plan for Producers with a High Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$0.35	$1.18	$7.67	3.37	21.91
65%	$0.26	$0.93	$4.92	3.58	18.92
50%	$0.14	$0.57	$3.12	4.07	22.29

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$0.47	$1.97	$7.67	4.19	16.32
65%	$0.26	$1.19	$4.92	4.58	18.92
50%	$0.13	$0.67	$3.12	5.15	24.00

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$0.40	$2.53	$7.67	6.33	19.18
65%	$0.30	$2.17	$4.92	7.23	16.40
50%	$0.11	$1.00	$3.12	9.09	28.36

Table 7.20 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the AREA 1 Plan for Producers with a Medium Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$0.86	$2.39	$7.67	2.78	8.92
65%	$0.49	$1.48	$4.92	3.02	10.04
50%	$0.29	$0.92	$3.12	3.17	10.76

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$0.87	$2.84	$7.67	3.26	8.82
65%	$0.54	$1.90	$4.92	3.52	9.11
50%	$0.24	$0.98	$3.12	4.08	13.00

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$0.81	$3.59	$7.67	4.43	9.47
65%	$0.53	$2.70	$4.92	5.09	9.28
50%	$0.24	$1.46	$3.12	6.08	13.00

Table 7.21 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the AREA 1 Plan for Producers with a Low Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.02	$4.71	$7.67	2.33	3.80
65%	$1.43	$3.52	$4.92	2.46	3.44
50%	$0.71	$1.90	$3.12	2.68	4.39

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.11	$5.62	$7.67	2.66	3.63
65%	$1.43	$4.06	$4.92	2.84	3.44
50%	$0.73	$2.30	$3.12	3.15	4.27

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.14	$7.24	$7.67	3.38	3.58
65%	$1.50	$5.59	$4.92	3.73	3.28
50%	$0.74	$3.25	$3.12	4.39	4.22

Actual premium ratios under the AREA Plan varied considerably at comparable percent coverage levels for the high, medium and low mean yield producers. The actual premium ratios were relatively small for the low mean yield producers, as contrasted to the values for the other two producer groups (Tables 7.19 - 7.21). One reason for the disparity of the ratios was that the AREA Plan's insurable 49 bu/ac corn yield was similar to 55 bu/ac expected corn yield of the low mean yield producers, but was much less than the expected mean yields of the other two producer groups.

The actual premium ratios for the high yield producers under the AREA Plan were larger than the corresponding indifference premium ratios by as much as a factor of six (Table 7.19). The actual premium ratios exceeded the indifference premium ratios by at least a factor of 1.8 for the medium yield producers (Table 7.20). The only producers who would be predicted to consider an MPCI purchase with the modeling results were the low mean yield producers. The hypothesis that adverse selection occurred under the AREA Plan was supported in Tables 7.19 through 7.21.

7.4. Producers' Net Gains and Losses for MPCI Purchases Under the APH and AREA Plans

Measurement of the net gains or losses associated with an MPCI purchase under the APH and AREA Plans were presented in Tables 7.22 to 7.24. The net value was determined by subtracting the actual premium ratios from the indifference premium ratios presented in Tables 7.16 through 7.21.

Table 7.22 Comparison of Brookings County Corn Producers' Net Benefits of Using MPCI under the APH and AREA 1 Plans, Assuming a High Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 83 bu/ac = APH Yield
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]*	
	APH Plan:	AREA 1 Plan:
75%	-2.21	-18.54
65%	-1.21	-15.35
50%	-2.00	-18.21

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]	
	APH Plan:	AREA 1 Plan:
75%	-1.87	-12.13
65%	-0.75	-14.35
50%	-1.56	-18.85

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]	
	APH Plan:	AREA 1 Plan:
75%	-1.14	-12.85
65%	0.30	-9.17
50%	0.43	-19.27

*Ind_Pr/BE_Pr = Ratio of Indifference MPCI Premium to Break-Even Premium.
Act_Pr/BE_Pr = Ratio of Actual MPCI Premium to Break-Even Premium.

Table 7.23 Comparison of Brookings County Corn Producers' Net Benefits of Using MPCI under the APH and AREA 1 Plans, Assuming a Medium Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 70 bu/ac = APH Yield
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]*	
	APH Plan:	AREA 1 Plan:
75%	-2.32	-6.14
65%	-1.23	-7.02
50%	-1.71	-7.59

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]	
	APH Plan:	AREA 1 Plan:
75%	-2.03	-5.55
65%	-0.86	-5.59
50%	-1.14	-8.92

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]	
	APH Plan:	AREA 1 Plan:
75%	-1.42	-5.04
65%	-0.03	-4.19
50%	-0.13	-6.92

*Ind_Pr/BE_Pr = Ratio of Indifference MPCI Premium to Break-Even Premium.
Act_Pr/BE_Pr = Ratio of Actual MPCI Premium to Break-Even Premium.

Table 7.24 Comparison of Brookings County Corn Producers' Net Benefits of Using MPCI under the APH and AREA 1 Plans, Assuming a Low Mean Corn Yield and CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 55 bu/ac = APH Yield
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]*	
	APH Plan:	AREA 1 Plan:
75%	-2.50	-1.47
65%	-1.05	-0.98
50%	-0.83	-1.72

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]	
	APH Plan:	AREA 1 Plan:
75%	-2.23	-0.97
65%	-0.72	-0.60
50%	-0.61	-1.12

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

% MPCI Coverage	Producer's Relative Net Gain or Loss by Purchasing MPCI, Measured by the Expression: [Ind_Pr/BE_Pr - Act_Pr/BE_Pr]	
	APH Plan:	AREA 1 Plan:
75%	-1.30	-0.20
65%	0.21	0.45
50%	0.33	0.18

*Ind_Pr/BE_Pr = Ratio of Indifference MPCI Premium to Break-Even Premium.
Act_Pr/BE_Pr = Ratio of Actual MPCI Premium to Break-Even Premium.

Both the APH and AREA Plans predominantly generated net losses with an MPCI purchase for producers in the high, medium and low mean yield categories (Tables 7.22 - 7.24). The net losses associated with an MPCI purchase consistently decreased for the medium and high mean yield producers under the APH Plan as compared to the AREA Plan. The likelihood of a producer purchase by these average to above-average producers appeared to improve with the APH Plan. However, the net losses predicted for the MPCI purchase under APH were an indication that the FCIC had not changed MPCI's structure enough with APH to cause producers to choose MPCI over the alternative of self-insurance under a variety of assumed net wealth and risk aversion combinations.

At the 50% yield coverage, for the $70,000 and $54,200 initial net wealth levels, the low mean yield producers had lower the net losses under the APH Plan than under the AREA Plan (Table 7.24). Under these circumstances, producers in the low mean yield category would theoretically prefer the MPCI purchase under the APH Plan as compared to the AREA Plan.

At the percent coverage levels above 50%, the net losses for the low mean yield producers were less under the AREA Plan as opposed to the APH Plan. The FCIC's decision to changeover MPCI to the APH Plan did create welfare losses for low mean yield producers in the model, but not under all circumstances.

The results in Table 7.24 could not be used to support the notion that the switch to the APH Plan would either reduce or expand MPCI participation by low mean yield producers. The indeterminate impacts in Table 7.24, combined with the results in Tables 7.22 and 7.23,

could be used to hypothesize that the APH Plan had "improved" MPCI's net welfare position for the average to above-average producers without a definite reduction in the potential participation of below-average producers. The "improvement" in MPCI's appeal to the average to above-average producers did not cause producers with a local PARAC value less than 0.000111 to perceive the MPCI purchase to create positive net benefits.

7.5. Welfare Implications of the Analysis

An evaluation of the desirability of alternative states of the economy was identified as an objective in welfare economics (Henderson and Quandt 1971; Quirk and Saposnik 1968). When welfare economics was applied in this study, the "alternative states" were MPCI's AREA and APH Plans, and the impacts of those coverage plans on producers.

The net losses and gains calculated with the premium ratios in Tables 7.22 to 7.24 were one measure of the producer impacts of implementing the APH Plan. As might be expected in real world policy-making, the change to a new "economic state" under the APH Plan was Pareto-nonoptimal. Some producers were predicted to be better-off after the change, while others were made worse-off.

A Pareto-optimal change would have improved the welfare of at least one producer without harming another. When the results in Tables 7.22 to 7.24 were examined in detail, it was determined that the APH Plan, as compared to the AREA Plan, would reduce the perceived losses associated with an MPCI purchase for the medium and high mean corn yield producers. A "reduction of losses" theoretically

meant that those producers were predicted to be better-off under the APH Plan. But the improvement with the APH Plan was not large enough under most wealth and coverage combinations in the model to change the actual purchase decision that was predicted under the AREA Plan. As stated earlier, only those producers who operated under financial stress or who possessed a risk averse PARAC were predicted to buy MPCI under the APH Plan. However, even those producers identified as financially-stressed and risk-averse were not predicted to buy under the AREA Plan, unless they were also a low mean yield producer.

The low mean corn yield producers were better-off with an MPCI purchase under the AREA Plan, assuming the 65% and 75% coverage levels were selected. It was interesting to note, however, that some low mean corn yield producers were better off under the APH Plan, if it was assumed that the 50% coverage level was selected.

One type of welfare evaluation which was considered in this analysis was to establish whether the winners (beneficiaries of the plan) could "potentially" compensate the losers to encourage them to accept the change in policy. One such basis for welfare analysis was known as the Kaldor criterion. The Kaldor criterion was used to state that a new policy was preferable to its predecessor if the gainers could bribe the losers, and the gainers would still be in a better position than under the old policy.

If the Kaldor criterion were employed in this analysis, the APH Plan was predicted to be socially desirable in the sense that the gainers (medium and high mean corn yield producers) had the potential to submit bids to the losers (low mean corn yield producers). Those

bids would theoretically entice the low mean yield producers to accept the APH Plan as a new policy, while leaving the medium and high yield producers better-off than under the AREA Plan (see premium ratios in Tables 7.22 to 7.24).

The Kaldor criterion had application because of the relationships between the premium ratios under the alternative coverage plans. As the switch was made from the AREA to the APH Plan, the gains in the premium ratios for the medium and high yield producers under the APH Plan were generally much greater than the losses in the premium ratios indicated for the low mean yield producers under APH.

The main drawback to the Kaldor criterion was that compensation of the APH Plan's losers by its gainers would likely remain a potential, and not a real, possibility. To that extent, the application of the Kaldor welfare concept was an interesting theoretical exercise which would not be useful in determining actual welfare changes.

A discussion of the welfare implications of the APH Plan was made more complete when the overall cost to society of implementing APH was considered. The APH Plan was more difficult and expensive for the FCIC to administer than the AREA Plan. The APH Plan had increased data collection and analysis requirements associated with monitoring individualized crop yield data as opposed to the resources needed to manage the county-level crop yield data base for the AREA Plan.

The APH Plan was associated with the purchase of MPCI by financially stressed and risk averse producers in this study. The AREA Plan's participation was even more restrictive, being confined to those risk averse producers with low mean yields. If a larger

societal perspective were employed in a welfare analysis, then the APH Plan was judged to be a marginal improvement in the MPCI program. That improvement was gained at considerable public expense.

Who were the gainers and losers from the MPCI program under the APH Plan when the societal welfare view was emphasized? One response would be that taxpayers were the losers, and that some of MPCI's users were the gainers. However, such a response was considered an over-simplification of the welfare issues involved.

The federal government had several objectives with respect to the assistance that should be received by producers adversely affected by natural hazards (CBO 1978). Among these federal objectives were: (1) to help to producers to adjust to uncertainty and income instability, and (2) to treat all producers equitably (CBO 1978). If the assumption was made that the goals of the federal government reflected the desires of various citizen interest groups and taxpayers, then it could be argued that the MPCI program was one policy instrument which served to promote the welfare of those groups whose interests were represented in the federal goals.

To the extent that public support existed for programs that assist agricultural producers, the welfare question for MPCI might be better addressed by investigating issues such as the program's ability to serve all producers equitably.

The analysis performed in this chapter was used to determine that the AREA Plan primarily served the interests of low mean yield producers. The APH Plan was predicted to be a modest step towards a

more equitable MPCI program, in the sense that MPCI had become a more attractive choice for a somewhat larger set of producers.

The APH Plan also seemed to have greater "unfulfilled" potential than the AREA Plan to serve an increased number of producers and their risk management needs. The APH Plan was determined in the analysis to be most appealing to low and high mean yield producers, under certain net wealth and risk attitude assumptions. If the APH Plan were further modified to provide additional inducements to "medium mean yield" producers, then an important segment of producers could become better served by the availability of MPCI crop yield coverage. Such a change could be viewed as a welfare gain from the perspective of a program that served an increased number of producers in an equitable manner.

7.6. Summary and Implications

When risk preferences of producers were represented by the CES function that possessed the DARA property, MPCI was predicted to be purchased more frequently under the APH plan than under the AREA Plan. No producers were predicted to purchase MPCI under either the APH Plan or the AREA Plan when the logarithmic utility function was assumed. The only class of producers determined to prefer MPCI under the AREA Plan were those with low mean crop yields, a low initial net wealth level and a CES utility function.

MPCI under the APH plan was predicted to be purchased by producers who had a PARAC of 0.000111 or higher. One of the goals of MPCI's APH Plan was to increase participation among a wider range of producers.

If interval estimates of PARAC estimates were used to classify producers, a PARAC value of 0.000140 or higher was considered risk-averse. MPCI's attractiveness under the APH plan was increased for producers in the model whose risk attitude varied between being marginally risk neutral to risk averse.

MPCI was not predicted to be purchased under either the APH plan or the AREA plan if a producer with an assumed CES utility function had an initial net wealth was much above a "financially stressed" level. If this result were repeated in future studies, then MPCI was a risk management tool which would be primarily used by producers who did not have the financial strength to survive a crop yield disaster by using self-insurance techniques.

The attractiveness of MPCI under the APH Plan in Brookings County was somewhat limited by the current premium and coverage structure. Modeling results were used to indicate that overall participation could be increased by further decreasing premium rates for medium to high mean yield producers while increasing premium rates for low yield producers.

There were few net gains associated with an MPCI purchase under the APH plan for the low, medium and high mean yield producer groups. Net gains occurred only under the assumption of the model's highest local PARAC value (0.000111), lowest initial net wealth position ($38,400), and MPCI coverage at the 65% and 50% levels.

Net welfare losses for an MPCI purchase occurred at all modeled coverage and wealth combinations for medium to high mean yield producers under the AREA plan. The only time a net welfare gain was

predicted with the AREA Plan was for producers in the low mean yield category. The model results were used to support the notion that MPCI had greater adverse selection problems under the AREA plan than it did under the APH plan.

If the AREA Plan were used in Brookings County as a basis for determining coverages in MPCI, and if the FCIC wanted to increase participation in the program, then the insurable yield would have to be increased to attract a larger proportion of the medium to high yield producers. However, an increased insurable yield would also further encourage adverse selection by low mean yield producers who could obtain coverage beyond what their own yields would justify.

Producers were predicted to purchase MPCI only at the 65% and 50% coverage levels which receive the maximum 30% government subsidy. If the premium subsidy had been removed, then no MPCI purchases would have been predicted with the model. Federal MPCI subsidies appeared to be an important element in the overall plan to increase producer participation.

The analysis of the MPCI purchase was considered in the model as an isolated aspect of managing risks on a farm. If a producer used other risk-reducing strategies, then the producer's need for MPCI to decrease variability in ending net wealth would be diminished. However, the importance of MPCI for financially-stressed farms appeared to be potential area in need of further research.

Other researchable questions for future studies were the impacts on MPCI participation of the distribution of risk attitudes, and the relationship between risk attitudes and net wealth. Exploration of

the topic of MPCI purchases, wealth and risk attitude was performed in a theoretical manner in the model. There was still much to be learned about the empirical relationships that would determine MPCI participation rates.

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Chapter Eight

Summary, Conclusions and Implications

Two alternative crop yield coverage plans for the MPCI program, and the impacts of those plans on a producer's MPCI purchase decision, were investigated in this dissertation. The study's background, procedures and results were summarized in this chapter. The limitations of the research were explained. The policy implications and future research opportunities were addressed.

8.1. Policy Background for the Study

MPCI was a program with low producer participation before 1980. Congress passed the Federal Crop Insurance Act (FCI Act) of 1980 to establish MPCI as the primary crop disaster program for agricultural producers. A major goal of the FCIC under the FCI Act was to improve MPCI and increase producer use of the program.

The FCIC initially used its broadened FCI Act powers to expand MPCI's availability to new crops and production regions under the AREA Coverage Plan (AREA Plan). The AREA Plan had been developed prior to the FCI Act as a method for determining insurable crops yields. The FCIC utilized soil maps, SRS county average yield data and other county-level information in MPCI's AREA Plan to set crop yield coverage levels.

A relatively stable relationship between premiums and indemnities in the MPCI program was established with the AREA Plan by the late

1970's (FCIC, USDA 1980). But the AREA Plan was also linked to adverse selection and low participation problems in MPCI (GAO 1977; CBO 1978).

The FCIC replaced MPCI's AREA Plan in 1985 with the APH Plan. The producer's insured yield under the APH Plan was based on a ten-year average of his own historical crop yield records. The APH Plan was introduced to counter the adverse selection problem and increase producers' MPCI participation.

8.2. Summary of Procedures

Crop yield estimation procedures and an MPCI purchase decision model were applied to better understand the factors that affected a producer's MPCI participation under the AREA and APH coverage plans.

Crop yield probability distributions (CYPD's) were estimated with elicitation and econometric techniques. CYPD's were used to represent uncontrollable variations in producers' crop yields. Three types of CYPD's were estimated: aggregated-subjective, capacity-derived and historical-frequency (see chapter six). The three CYPD's were statistically compared to test the null hypothesis that the capacity-derived and/or the historical-frequency distributions were good approximations for the aggregated-subjective CYPD's. If alternative estimation procedures for subjective CYPD's were available, then the FCIC could select the least expensive method to aid in the design of future MPCI programs.

An aggregated-subjective CYPD was used to derive a probability distribution of "ending net wealth". The ending net wealth (ENW)

variable was the sum of an assumed initial net wealth level plus a net cash flow calculated from a crop enterprise budget and an MPCI purchase decision. The relationship between a producer's risk attitude and ENW level in the MPCI decision model were theoretically analyzed with CES and logarithmic utility functions.

A producer's ENW distribution, assumed utility function and MPCI decision were incorporated into a model based on the expected utility hypothesis (EUH). The model was used to simulate a producer's MPCI purchase decision.

In the model, a producer's expected utility for an ENW distribution was initially calculated under the assumption that no MPCI was purchased. Then the model was designed to search for an MPCI premium level that would cause him to be indifferent between purchasing and not purchasing MPCI. If the indifference MPCI premium rate were greater than the FCIC's actuarial MPCI premium rate, then the producer was predicted to buy MPCI; otherwise, the producer was not predicted buy MPCI.

A measure of a producer's gain or loss associated with an MPCI purchase was developed. The indifference MPCI premium rate was divided by the break-even premium rate. A ratio of the FCIC's actual premium rate to the break-even premium rate was also determined. Gains (or losses) accruing to producers who purchased MPCI under the APH and AREA plans were estimated by subtracting their actual premium ratios from their indifference premium ratios. The welfare implications of a producer's gains and/or losses associated with an MPCI purchase under the two coverage plans were discussed.

8.3. Summary of Results

The study's results were divided into two primary areas: (1) alternative CYPD estimations, and (2) predicted MPCI purchase decisions under the alternative coverage plans. Similarities and differences among the aggregated-subjective, historical-frequency and capacity-derived CYPD's were observed and tested. The impacts of a producer's subjective CYPD, net wealth position, and risk attitude on the MPCI purchase were analyzed with a simulation algorithm.

CYPD Estimation Results. The major results of the CYPD estimations were:

1. A weighted-average soil productivity index of an elicited producer's farm was the initial criteria used to aggregate the subjective CYPD's. The null hypothesis that the elicited mean crop yields in the different soil productivity intervals were equal was not rejected in seven of ten statistical tests at the 95% level. The null hypothesis that historical mean crop yields in different soil productivity levels were equal was not rejected in ten of ten statistical tests at the 95% level.

2. Mean crop yield intervals were selected as the alternative criteria for aggregating CYPD's. Aggregation by mean crop yield was compatible with the approach in the FCIC's APH Plan where a producer's MPCI premium rate was determined as a function of his historical mean yield.

The actual premium rate decreased as the producer's average crop yield increased in the APH Plan. There was inconclusive evidence that the perceived probability of corn yield losses in Brookings County

decreased as the mean yields of the aggregated-subjective corn CYPD's increased.

3. Capacity-derived and historical-frequency CYPD's both had shortcomings as alternative estimators of aggregated-subjective CYPD's. The mean yields of capacity-derived CYPD's for corn and soybeans were close approximations to their respective aggregated-subjective CYPD's mean yields. But the variances of the aggregated-subjective CYPD's were larger than the capacity-derived CYPD variances by a factor of two to three. Both the capacity-derived and the aggregated-subjective CYPD's exhibited the property of negative skewness.

The capacity-derived oats CYPD was statistically different from the aggregated-subjective oats CYPD. The results of the oats CYPD estimations consistently did not produce the same patterns and relationships as the corn and soybean CYPD estimations.

The historical-frequency CYPD's for corn, oats or soybeans did not provide good approximations to any of their respective subjective CYPD's properties. Producer crop yield probability perceptions were apparently more sophisticated than a simple extrapolation of crop yield history.

An adjustment for technology was made in capacity function estimation before the CYPD obtained from that procedure was derived. The hypothesis that Brookings County producers adjusted their perceived crop yield risks for technological impacts was consistent with the results of the comparisons of the capacity-derived and aggregated-subjective CYPD's.

The null hypothesis that capacity-derived CYPD's were the same as the CYPD's of historical-frequency crop yield data was also rejected.

Results of the MPCI Purchase Analysis. Corn was selected as the crop enterprise for the MPCI purchase decision analysis, because of the crop's economic importance in Brookings County. Three subjective corn CYPD's, aggregated by historical mean yield intervals, were selected:

a.) 91 - 101 bu/ac, the "high" mean yield producers

b.) 69 - 79 bu/ac, the "medium" mean yield producers

c.) 39 - 57 bu/ac, the "low" mean yield producers

The three corn CYPD's were used to derive ENW distributions under different sets of alternative assumptions. The combinations of conditions for the MPCI purchase decision analysis were determined from the following variables: APH v. AREA coverage plan, CES v. logarithmic utility function, three alternative initial net wealth positions, and three MPCI yield coverage levels. Each coverage plan was consequently analyzed under 54 different combinations of CYPD, utility function, net wealth position and yield coverage.

Primary results of the MPCI purchase analysis were:

1. MPCI under the APH Plan was predicted to be purchased by both the high and the low mean corn yield producer groups only when the CES utility function, the $38,400 (low) initial net wealth position, and the 65% and 50% coverage levels were assumed. MPCI was not predicted to be purchased under the APH Plan by the medium mean yield producers under any of the utility function, net wealth and coverage level combinations. No MPCI purchase was predicted under either

coverage plan for any of the three mean yield producer groups when the logarithmic utility function was assumed. The logarithmic utility function was specified to be globally less risk averse than the CES utility function.

MPCI under the AREA Plan was purchased by the low mean yield corn producers only under the assumption of the CES utility function, $38,400 initial net wealth position, and 65% and 50% coverage levels. Producers with the medium and high mean corn yield CYPD's were not predicted to purchase MPCI with the AREA Plan under any of the modeled variable combinations.

2. Net losses were predicted for a producer who purchased MPCI under a majority of the conditions modeled for the high, medium and low mean yield producers in either coverage plan. The size of the net losses was consistently lower under the APH Plan for the high and medium yield producers than under the AREA Plan.

The overall impact of the APH Plan on the low mean yield producer was indeterminate. The net losses associated with an MPCI purchase under the APH Plan were less negative than the AREA Plan's impacts when the 50% coverage level was assumed; otherwise, the predicted effect of an MPCI purchase under AREA Plan created a lower net loss for the modeled low mean yield producer than did the APH Plan.

8.4. Summary of the Study's Conclusions

The research conclusions, based on the research results, were summarized as follows:

1. The concept of designing an MPCI program based on soils and county crop yield data, such as the AREA Plan, was challenged by the research results. Producers' management skills could be just as important as the soil resource in determining his insurable yield. The APH Plan, in comparison to the AREA plan, was designed to include the impact of a producer's management skill level on insurable yield coverage because the APH Plan depended on producers' actual yield experience.

2. The similarities of the capacity-derived corn and soybean CYPD's to their subjective counterparts were important. Both the capacity-derived and the aggregated-subjective CYPD's were negatively skewed. These results were consistent with past research outcomes (Gallagher 1983). The negative skewness of the underlying CYPD perceived by producers had the effect of reducing the premium they would be willing and able to pay to obtain MPCI, compared to the assumption of a symmetrical CYPD with a similar mean and variance.

The expected mean yields of the capacity-derived CYPD's for corn and soybeans were reasonably good estimates of the respective mean yields perceived in the aggregated-subjective CYPD's. Capacity-derived CYPD information could be useful in determining whether a producer would perceive the available yield coverages under MPCI's APH or AREA Plans were sufficiently large to encourage his participation in MPCI.

The Corrected Ordinary Least Squares (COLS) technique for estimating capacity functions was relatively inexpensive to use, and was a definite improvement over the use of raw historical data for estimating the properties of producer's subjective CYPD's within a given area. The major limitation to the use of capacity functions in MPCI and other applications was data aggregation. The capacity-derived CYPD's standard deviations were one-half to one-third as large as the yield standard deviations perceived by individual producers.

If an adjustment was made for the variance-reducing effects of county-level crop yield data aggregation, capacity functions could possibly be used to estimate producer's current perceptions of their CYPD's at a lower expense than was required to conduct individual producer CYPD elicitations.

The oats CYPD estimation results differed from those for corn and soybeans, and the discrepancy merited some attention. Schmiesing (1987), in a recent South Dakota crop production study, indicated that yield-enhancing technologies did not have as great an impact oats yields as on corn and soybean yields. In addition, the elicited Brookings County producers consistently estimated their mean oats yields to be higher than their crop yield history would tend to support. A possible explanation for the difference between the elicited and capacity-derived CYPD's was that Brookings County producers were overly optimistic about their oats yields.

3. MPCI was determined to be purchased under the APH Plan by Brookings County corn producers with high mean yields and with low mean yields, if both producer groups were modeled with the CES

utility function and below-average initial net wealth level. The low net wealth level was additionally associated with a local risk aversion coefficient (0.000111) which was on the margin between being categorized as risk neutral or risk averse.

Producers with medium yields did not buy MPCI under the APH Plan under any of the conditions tested in the model. Only those producers modeled with low mean yield CYPD's were predicted to buy MPCI under the AREA Plan.

One conclusion obtained from the modeling results was that the APH Plan had only marginally improved the attractiveness of MPCI for a broader set of producers. The APH changes did not appear to be large enough to alter the "not buy" to a "buy" decision for producers whose risk attitude was relatively risk-neutral (PARAC < 0.000111) or when their net initial net wealth was classified as average to above-average.

Another observation was that if the FCIC intended to increase overall MPCI participation with the APH Plan, then the group of medium yield producers would need additional incentive to decide to participate. One possible policy change, which was noted in chapter seven, was for the FCIC to accelerate the decrease in MPCI premium rates as a producer's APH yield increased to lure more medium yield producers in to the program. The model was also used to suggest that premium rates for low yield producers could be further increased without causing a "not buy" decision to occur. The trade-off would therefore place a larger premium burden on the low mean yield producer to allow the FCIC to encourage greater participation by the

medium to high mean yield producers. As the premium rates for low yield producers were increased by larger amounts, the FCIC could promote programs in cooperation with other USDA agencies to help producers to boost their productivity, and have them ultimately become eligible for lower MPCI premium rates as their mean yield improved.

4. Producers at all mean yield levels were not predicted to buy MPCI under either the APH or AREA Plan if their initial net equity position was medium to high. This result was used to imply that MPCI had the potential to primarily attract producers who were in a weak financial position.

One interpretation of this conclusion was that financially-stressed producers could possibly benefit from MPCI because of its stabilizing effects on a producer's ENW distribution. Based on this analysis, MPCI could play a larger role in discussions about policies and strategies concerned with the survival and growth of farm operations.

5. When net gains and losses were measured with premium ratios, the reduction in net losses created by an MPCI purchase under the APH Plan were used to predict only a marginal increase in MPCI producer participation under most conditions in the model. On the other hand, the FCIC experienced a sizable increase in the cost of administering the MPCI program with the APH Plan. If that cost were not to become a sunk cost which yielded no benefits for producers, additional changes in MPCI would likely be necessary.

For example, the switch to the APH Plan was primarily a change in MPCI's coverage levels and not in the overall premium structure. The APH Plan's improvement in MPCI was an expansion in the coverage alternatives available for producers who had different expected mean yields. In contrast, the basis for calculating MPCI's premium rates was still developed using a moving-average of the indemnity losses of MPCI participants who had been in the program before the APH Plan was implemented. If the pre-APH clientele in MPCI had been adversely selected, and if their indemnity collection rates necessitated increased premiums, then the APH Plan would likely be characterized by premium rates which would discourage MPCI purchases by a broader spectrum of producers.

Continued or increased subsidization of the MPCI program might eventually allow the premium rates under the APH Plan to become based on a broader based set of producers. Once the program had stabilized, then the subsidies could gradually be removed, given that the premiums would be based on a set of producers who were not subject as much to the problem of adverse selection.

8.5. The Study's Limitations

Risk attitudes were assumed, rather than measured, in this research. The predictions of MPCI purchases or non-purchases depended heavily on how the hypothetical utility functions were specified. The utility functions used in this research both had the characteristic of decreasing absolute risk aversion (DARA). The empirical evidence of DARA was mixed. The implications of the analysis in this research

were based on the assumption that producers behave as if their decision to buy or not buy MPCI was founded on the expected utility hypothesis functions under the DARA assumption.

In addition to the business risk of crop loss, there were price and credit risks which producers must consider in risk management. Pflueger and Barry (1986) demonstrated that credit risks were an important factor which make the purchase of MPCI more attractive to a broader set of producers. However, price risk could moderate the need for MPCI, especially if yields and prices were negatively correlated. Crop yield risk was the primary source of uncertainty for the MPCI purchase decision examined in this study.

Another consideration not fully addressed in the study was the impact of the other farm programs on the incentive for a producer to participate in MPCI. If a producer were in the set-aside program, he received a deficiency payment that did not fluctuate with his individual yield. He also likely idled his marginal land, and kept his best land in production. If his expected mean yield increased when the marginal lands were idled, then a producer might demand a higher coverage level before he would consider purchasing MPCI. The best land left in production might also be less risky to farm, so the farmer's perceived need for MPCI might decrease as the producer perceived less probability of a disaster yield covered under MPCI.

8.6. Policy Implications

The impacts of the crop yield risks, behavior towards risk, and the producer's wealth position on the MPCI purchase decision under

the APH Plan and the AREA Plan were analyzed in the study. The results and conclusions of the analysis had important policy implications for MPCI.

A fundamental principle underlying the administration of MPCI under the AREA Plan was that producers' insurable mean yields could reasonably be estimated using county-level crop yield data and soils information. One of the major results of this research was the inability to reject the null hypothesis that producers with different whole-farm average soil productivity ratings had similar expected mean crop yields and similar historical mean yields.

The implications of these results were significant with respect to the problem of adverse selection in MPCI. The research results were used to identify plausible scenarios where MPCI clientele under the AREA Plan would predominantly be producers who had actual mean yields which were less than the insurable county-level mean yields. For example, a producer with an above-average management skill level and medium whole-farm soil productivity rating conceivably could produce a larger mean crop yield than a less skilled producer-manager on a farm with a relatively higher average soil productivity rating. If such situations were to arise frequently in MPCI under the AREA Plan, the producers who did participate in the program had a higher likelihood of being less-skilled managers who could insure their crop yield at a level which was higher than what the producer would normally expect to gain.

If the anticipated positive relationship between average soil productivity and mean crop yield were rejected in other studies, then

MPCI's AREA Plan was likely to be characterized by efficiency and equity problems in its operation. Inefficiency could occur if a producer's crop yield were overinsured. The soil productivity rating could allow a producer to cover a yield level which was higher than his operation's regular output. Consequently, the premium a producer paid would underestimate the costs of insuring that producer.

From an equity standpoint, the producer who had developed himself into a superior manager would find that MPCI's AREA Plan could not provide him with a level of crop yield protection that was appropriate to the type of production risk that he encountered. Inferior producers could make use of MPCI to occasionally overinsure their yields. Such a system did not seem to provide an equitable means of disaster protection for all producers.

The AREA Plan was not without its benefits. MPCI was easier and less expensive to administer for the FCIC. The adverse selection problems associated with the AREA Plan in this research would likely have to be viewed in light of these administrative concerns, as well as with respect to the overall goals of the MPCI program itself.

In addition to the questions raised by this study's soil productivity-mean crop yield results, there were also the predictions of MPCI purchases with the EUH model applied in chapter seven. MPCI was only predicted to be purchased under the AREA Plan by the producers with a low mean yield and low initial net wealth position. The hypothesis that the AREA Plan was very limited in its ability to appeal to the majority of producers was supported by these results.

All of the "buy" decisions predicted under MPCI's APH Plan applied to the insured yield levels (65% and 50%) that had a 30% federal subsidy on the premium rate charged to the producer. Removal of those subsidies would probably change the buy to a not buy decision under most circumstances in the model. The research results could be used to imply that MPCI required continued subsidization if it were to remain a service which producers would be willing and able to purchase.

The research results were also used to demonstrate that significant problems and questions remained with MPCI operating under the APH Plan. Producers with medium yields were not predicted to purchase MPCI under the risk attitude and net wealth positions in the model. This outcome was used to suggest that the modal producers had not been provided with sufficient incentive to participate in MPCI, particularly compared with the producers at the extremes of the distribution of mean yields.

An important question associated with the research results was the impact of the producer's wealth position and risk behavior on the MPCI purchase. If DARA were determined to exist among most producers, then MPCI would be predicted to be purchased more often by producers whose net equity position was low. Producers with a low net equity position often represented a financial risk to agricultural lenders. MPCI under this scenario could encounter another form of adverse selection: attracting financially-stressed producers.

If the financially-troubled producer were the primary MPCI beneficiary, then MPCI could play a larger role as a risk management tool

used to protect the producer's income and credit-worthiness from destabilizing natural events (droughts, etc.). The entire farm sector encountered financial problems in the 1980's, some of which were caused by forces beyond individual producers' knowledge or control. If MPCI had important impacts on the survivability of the financially-stressed farms, then issues such as MPCI participation rates, premium subsidization had broader farm policy implications. MPCI could become a more important program for income stabilization in the farm sector.

8.7. Future Research Implications

This dissertation was conducted to understand some of the implications of the FCIC's decision to substitute the APH Plan for the AREA Plan on a producer MPCI purchase decision. More work was needed to examine the impacts of: (1) the overall environment of business and financial risks, (2) the distribution of risk attitudes among producers and (3) the empirical relationship between the risk attitude and a producer's wealth position on the producer's decision to purchase MPCI.

Correlations of price, credit and crop yield risk, and the influence of other government programs on the MPCI purchase decision were important aspects of business and financial risks which offered future research opportunities. In addition, researchers in future investigations could more intensively question the contribution of producer's management skills relative to his farm's soil productivity potentials for determining the producer's mean crop yield.

The capacity function estimation technique employed in this study could have application in other research areas. The COLS procedure represented a relatively inexpensive procedure for applied research and extension programs focused on local and regional crop yield potentials. COLS could be performed on microcomputer software that was easy to use and disseminate. Capacity-derived CYPD's were better estimates of the producer's perceived crop yield risks than historical yield averages.

Finally, future research efforts could be directed towards the determining the potential impacts of MPCI use on the overall organization and growth of the farm firm. Producers who used MPCI as part of a comprehensive approach to agricultural risk management would benefit from such research.

8.8. References Cited

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APPENDIX A

Analytical Derivation of an MPCI Indifference Premium

Appendix A

Analytical Derivation of an Indifference MPCI Premium (Robison and Barry 1987).

1. A Negative Exponential (NE) Utility Function for a Producer was Assumed:

$$U(w) = -e^{-\alpha w} \qquad \text{Equation A.1}$$

Where: w = ending net wealth (ENW) = W0 + Z
W_0 = initial net wealth
Z = net cash flow defined as a random variable with a differentiable probability density function.
α = Pratt-Arrow absolute risk aversion coefficient (PARAC)

Note: α was a constant value in the above utility function, and was therefore a global measure of risk aversion (Robison and Barry 1987):

$$R(w) = \frac{-U''(w)}{U'(w)} = \text{PARAC}$$

$$U'(w) = \alpha e^{-\alpha w}$$

$$U''(w) = -\alpha^2 e^{-\alpha w}$$

$$R(w) = \frac{-\alpha^2 e^{-\alpha w}}{-\alpha e^{-\alpha w}} = \alpha \qquad \text{Equation A.2}$$

2. A Global Certainty Equivalent (CE_{gl}) Was Derived from the NE Utility Function and from an Assumed Normal Probability Distribution of ENW.

a. An approximation of the global CE was determined by setting the distribution's global CE equal to the expected utility of the distribution:

$$U[CE_{gl}(w)] = \Sigma\,[U(w) \cdot p(w)] \qquad \text{Equation A.3}$$

b. Robison and Barry (1987), Freund(1956) and Hildreth (1954) derived a $CE_{gl}(w)$ from the Equation A.3, assuming a NE utility function and a normal ENW distribution:

$$CE_{gl}(w) = E(w) - \frac{\alpha \cdot \sigma^2(w)}{2} \qquad \text{Equation A.4}$$

Where:

$CE_{gl}(w)$ = global certainty equivalent
$E[\cdot]$ = expected value
w = ending net wealth (ENW) = $W_0 + Z$ (see Equation A.1)
$\alpha = R(w)$ = PARAC

3. The $CE_{gl}(w)$ in this study was determined for a producer operating a single crop enterprise under two different assumptions: a crop enterprise insured with MPCI, and a non-insured crop enterprise.

a. The $CE_{gl}(w)$ was first derived for the producer who purchased MPCI. Two variables values were defined for Equation A.4:

1.) $E(w_I)$ = expected value of the insured ENW distribution

2.) $\sigma^2(w_I)$ = Variance of the insured ENW distribution

b. The purchase of MPCI was analyzed with the use of an insurance policy which had a "deductible" before indemnification took place. The deductible in MPCI was the percentage of a producer's "insured mean yield" which was not covered under the selected MPCI policy. For example, a 35% deductible meant that a producer had covered 65% of the insured mean yield. The term "yield coverage" referred to the fraction (75%, 65% or 50%) of the insured mean yield which was indemnifiable.

Under the APH Plan, the producer's insured mean yield was the mean crop yield calculated from a ten year production history on his farm. Under the AREA Plan, the mean insured yield was determined as a mean yield for an area within a county, based on SRS county crop yield data, soils information and other technical criteria.

The demand for MPCI could be analyzed under the AREA and APH Plans. MPCI demand was studied by determining the MPCI premium a producer would pay for the insured ENW distributions that resulted from the alternative yield coverages available under each coverage plan.

(continued)

The expected value of the insured ENW distribution had two components. The first component was the expected value below the yield coverage (i.e., a loss greater than the deductible). This first component included the indemnity's impact on the ENW level.

The second component was the upper part of the ENW distribution that remained "uninsured" (a crop yield greater than or equal to the coverage level).

An expression used to represent the expected value of ENW distribution with MPCI was:

$$E(w_I) = \int_{w(y=0)}^{w(y=y_{cov})} [w(y) + (y_{cov}-y)\phi - \pi] \cdot p[w(y) + (y_{cov}-y)\phi - \pi] \cdot dw$$

$$+$$

$$\int_{w(y=y_{cov})}^{w(y=y_{max})} [w(y) - \pi] \cdot p[w(y) - \pi] \cdot dw$$

Equation A.5

Where:

$w[y]$ = ending net wealth (ENW) associated with crop yield level y (see Equation A.1)
$w(y=y_{max})$ = ENW at maximum possible crop yield, assuming ideal weather and efficient production
$w(y=y_{cov})$ = ENW at insured crop yield coverage level
$w(y=0)$ = ENW when crop yield equals zero (lowest possible yield)
$(y_{cov}-y)$ = bushel basis for insurance indemnity payment (yield coverage level minus actual yield)
ϕ = predetermined MPCI price election for converting bushel indemnity into a cash amount
π = MPCI premium at insured crop yield level
$p[\cdot]$ = probability function
y = crop yield defined as a random variable with a differentiable probability density function

c. The following notation was introduced to reduce the amount of "clutter" in the mathematical expressions:

1. Notation for cumulative probabilities:

P_{ind} = cumulative probability of an indemnifiable loss

$$P_{ind} = \int_{w(y=0)}^{w(y=y_{cov})} p[w(y)] \cdot dw \qquad \textbf{Equation A.6}$$

$(1 - P_{ind})$ = cumulative probability above the yield coverage level

$$1 - P_{ind} = \int_{w(y=y_{cov})}^{w(y=y_{max})} p[w(y)] \cdot dw \qquad \textbf{Equation A.7}$$

2. Notation for indemnity's impact on net wealth:

$$w_{ind}(y) = w(y) + (y_{cov}-y)\phi \qquad \textbf{Equation A.8}$$

Where:

$w_{ind}(y)$ = ending net wealth (ENW), including the amount of the indemnity payment, when the actual yield fell below the yield coverage level
$w(y)$ = ENW with no indemnity payment
$(y_{cov}-y)\phi$ = value of the indemnity payment

3. Notation used for describing the ENW distribution where NO MPCI was purchased. For purposes of comparison with the distribution with MPCI purchased, the expected value of the NO MPCI distribution was described with two integrals (Robison and Barry 1987):

$$E(w_N I) = \int_{w(y=0)}^{w(y=y_{cov})} w(y) \cdot p[w(y)] \cdot dw + \int_{w(y=y_{cov})}^{w(y=y_{max})} w(y) \cdot p[w(y)] \cdot dw$$

$$E(w_{NI}) = w_1 + w_2 \qquad \textbf{Equation A.9}$$

4. Notation for the expected value of the variable $w_I(y)$ was:

$$E[w_I(y)] = \{w_{ind}(y) \cdot P_{ind}\} + w_2 - \pi \qquad \text{Equation A.10}$$

5. The notation for the variance $[\sigma^2(w_{NI})]$ of the NO MPCI distribution was:

$$\sigma^2(w_{NI}) = \int_{w(y=0)}^{w(y=y_{cov})} \{[w(y)]^2 \cdot p[w(y)]\} \cdot dw - P_{ind} \cdot [E(w_{NI})]^2$$

$$+$$

$$\int_{w(y=y_{cov})}^{w(y=y_{max})} \{[w(y)]^2 \cdot p[w(y)] \cdot dw - (1 - P_{ind}) \cdot [E(w_{NI})]^2$$

$$\sigma^2(w_{NI}) = \sigma^2{}_1 + \sigma^2{}_2 \qquad \text{Equation A.11}$$

d. The value of $\sigma^2(w_I)$ was determined from the ENW distribution generated when a producer purchased MPCI. The value of the MPCI premium π was treated as a constant. Constant values have a zero variance, and therefore could be ignored. Consequently, the insured ENW distribution was represented by the cumulative density function of the variable Γ:

$$\Gamma(y) = \begin{bmatrix} w_{ind}(y) & \text{with probability } P_{ind} \text{ for } (y \leq y_{cov}) \\ w(y) & \text{with probability } (1-P_{ind}) \text{ for } (y > y_{cov}) \end{bmatrix}$$

e. The expected value of the $\Gamma(y)$ distribution, using the definition of w_2 in Equation A.8, was:

$$E[\Gamma(y)] = w_{ind}(y) \cdot P_{ind} + w_2 \qquad \text{Equation A.12}$$

f. The variance $[\sigma^2(\Gamma)]$ of the Γ distribution was:

$$\sigma^2(\Gamma) = [w_{ind}(y)]^2 \cdot P_{ind} + \int_{w(y=y_{cov})}^{w(y=y_{max})} [w(y)]^2 \cdot p[w(y)] \cdot dw - \{E[\Gamma(y)]\}^2 \qquad \textbf{Equation A.13}$$

g. A substitution from Equation A.11 was made for the integral in the Equation A.13. That substitution was:

$$\int_{w(y=y_{cov})}^{w(y=y_{max})} [w(y)]^2 \cdot p[w(y)] \cdot dw = \sigma^2{}_2 + (1 - P_{ind}) \cdot [E(w_{NI})]^2 \qquad \textbf{Equation A.14}$$

h. The value of $\sigma^2(\Gamma)$, using substitutions from Equations A.12 and A.14, was expressed as:

$$\sigma^2(\Gamma) = \sigma^2{}_2 + (1 - P_{ind}) \cdot [E(w_{NI})]^2 + [w_{ind}(y)]^2 \cdot P_{ind} - \{ [w_{ind}(y)] \cdot P_{ind} + w_2 \}^2 \qquad \textbf{Equation A.15}$$

The value of $\sigma^2(\Gamma)$ in Equation A.15 was the variance of the ENW distribution with MPCI purchased.

i. A global certainty equivalent (CE_{gl}) was calculated for the insured ENW distribution, using the CE_{gl} formulation in Equation A.4, the expected value of $w_I(y)$ in Equation A.10, and the variance determined in Equation A.15. The resulting CE value was:

$$CE_{gl}[w_I(y)] = E(w) - \frac{\alpha \cdot \sigma^2(\Gamma)}{2}$$

(continued)

$$CE_{gl}[w_I(Y)] = \{w_{ind}(Y) \cdot P_{ind} + w_2 - \pi\} - \frac{\alpha}{2} \cdot \Big[\sigma^2_2 + (1 - P_{ind}) \cdot [E(w_{NI})]^2 + [w_{ind}(Y)]^2 \cdot P_{ind} - \{ [w_{ind}(Y)] \cdot P_{ind} + w_2 \}^2 \Big]$$

Equation A.16

j. A global CE was also derived for the NO MPCI ENW distribution, using the CE formulation in Equation A.4, the expected value of $w_{NI}(Y)$ in Equation A.9, and the variance determined in Equation A.11. The resulting CE value was:

$$CE_{gl}(w_{NI}) = E(w_{NI}) - \frac{\alpha \cdot \sigma^2(w_{NI})}{2}$$

$$CE_{gl}(w_{NI}) = (w_1 + w_2) - \frac{\alpha}{2} \cdot \Big[\sigma^2_1 + \sigma^2_2\Big] \qquad \textbf{Equation A.17}$$

k. By setting the $CE_{gl}[w_I(Y)]$ value in Equation A.16 equal to the $CE_{gl}(w_{NI})$ value in Equation A.17, and solving for π, an MPCI premium rate would be determined where a producer would be indifferent between insuring and not insuring.

In the expression below, the notation π_{indif} was substituted for π, and the equation was used to define π_{indif}:

$$CE_{gl}(w_{NI}) = CE_{gl}[w_I(Y)]$$

$$(w_1 + w_2) - \frac{\alpha}{2} \cdot \left[\sigma^2_1 + \sigma^2_2\right] = \{w_{ind}(Y) \cdot P_{ind} + w_2 - \pi_{indif}\} -$$

$$\frac{\alpha}{2} \cdot \Big[\sigma^2_2 + (1-P_{ind}) \cdot [E(w_{NI})]^2$$

$$+ \; [w_{ind}(Y)]^2 \cdot P_{ind}$$

$$- \{[w_{ind}(Y)] \cdot P_{ind} + w_2\}^2 \Big]$$

(Above equation was solved for π_{indif}, and presented on the next page.)

$$\pi_{indif} = w_{ind}(Y) \cdot P_{ind} - w_1 - \frac{\alpha}{2} \cdot \left[\sigma^2(\Gamma) - \sigma^2(w_{NI}) \right]$$

$$\pi_{indif} = w_{ind}(Y) \cdot P_{ind} - w_1 - \frac{\alpha}{2} \cdot \left[-\sigma^2{}_1 + (1-P_{ind}) \cdot [w_1 + w_2]^2 \right.$$

$$+ \; [w_{ind}(Y)]^2 \cdot P_{ind}$$

$$\left. - \{[w_{ind}(Y)] \cdot P_{ind} + w_2\}^2 \right]$$

Equation A.18

Where:

π_{indif} = indifference MPCI Premium Rate.

$w_{ind}(Y) = w(Y) + (Y_{cov}-Y)\phi$ (ending net wealth, supplemented by the indemnity payment).

P_{ind} = cumulative probability of an indemnifiable loss.

w_1 = expected value of the ENW distribution without MPCI, below the crop yield that could have been insured.

w_2 = expected value of the ENW distribution above the crop yield level that could be insured. The "uninsured" portion of the distribution where indemnities are not collected.

$\sigma^2{}_1$ = variance of the ENW distribution without MPCI, below the the crop yield that could have been insured.

α = Pratt-Arrow Coefficient of Absolute Risk Aversion (PARAC) for the negative exponential (NE) utility function.

4. A number of relationships were defined for Equation A.18:

   a. The variance of the insured ENW distribution, $\sigma^2(\Gamma)$, was less than the NO MPCI distribution's variance [$\sigma^2(w_{NI})$]. Consequently, the bracketed expression [$\sigma^2(\Gamma) - \sigma^2(w_{NI})$] was negative.

b. The $[w_{ind}(y) \cdot P_{ind}]$ portion of the insured distribution, where a producer would receive an indemnity payment, had a larger value than the same part of the uninsured distribution (w_1). The expression, $[\ w_{ind}(y) \cdot P_{ind} - w_1\ ]$, was positive.

c. Given the relationships discussed in 4a and 4b directly above, the value of π_{indif} was positive as long as α was greater than or equal to 0. When $\alpha = 0$, a producer was considered risk neutral. When $\alpha > 0$, a producer was classified as risk averse. Such a relationship would indicate that only risk averse producers would be willing and able to pay a positive premium to obtain MPCI protection.

d. If α were set equal to zero, then Equation A.18 was reduced to a calculation of a break-even MPCI premium rate. The break-even rate was a premium that would just equal the expected value of the indemnity payment for a given crop yield coverage level. A risk neutral producer would be indifferent between paying the break-even rate and not insuring. A risk averse producer ($\alpha > 0$) would pay more than the break-even rate to obtain the MPCI coverage.

5. The demand for MPCI was analyzed with Equation A.18:

a. The major change in MPCI made with the APH Plan, as compared to the AREA Plan, was to alter the yield coverage determination technique. As the yield coverage was varied, the value of $w_{ind}(y)$ in Equation A.18 would change. The derivative of π_{indif} with respect to $w_{ind}(y)$ was determined from Equation A.18 as:

$$\frac{d[\pi_{indif}]}{d[w_{ind}(y)]} = P_{ind} - \frac{\alpha}{2} \cdot \Big[2 \cdot P_{ind} \cdot w_{ind}(y) - 2 \cdot [P_{ind}]^2 \cdot w_{ind}(y) - 2 \cdot P_{ind} \cdot w_2 \Big]$$

$$\frac{d[\pi_{indif}]}{d[w_{ind}(y)]} = P_{ind} \cdot \Big[1 + \alpha \cdot [\ w_2 + w_{ind}(y) \cdot (P_{ind}^{-1})\ ] \Big]$$

Equation A.19

Note: The value of w_2 was greater than $[w_{ind}(y) \cdot (P_{ind}^{-1})]$. Therefore, the expression $[w_2 + w_{ind}(y) \cdot (P_{ind}^{-1})]$ was positive.

(continued)

b. The change in the indifference premium rate associated with a change in the indemnified portion of the insured ENW distribution (see Equation A.19) was:

$$\frac{d[\pi_{indif}]}{d[w_{ind}(y)]} > 0 \qquad \text{Equation A.20}$$

The positive value of the derivative in Equation A.20 was used to demonstrate an expected relationship: an increase in MPCI indemnity would cause a rise in the indifference premium rate.

The derivative in Equation A.19 would remain positive if the value of the risk aversion coefficient (α) were modeled as a function of the insured part of the ENW distribution [$w_{ind}(y)$]. The derivative of α with respect to [$w_{ind}(y)$] was positive, when determined from Equation A.18.

When $d(\alpha)/d[w_{ind}(y)] > 0$, then an increase in yield coverage was associated with an increase in risk aversion. Such a relationship could be used to predict that more risk averse producers would seek higher levels of coverage (lower insurance deductibles).

An increase in MPCI indemnity, creating a larger value for $w_{ind}(y)$, would occur if a producer could raise his crop yield coverage level. The impacts of MPCI's APH and AREA coverage plans on a producer's insurable yield, and his willingness to pay for MPCI, could be formally analyzed with Equations A.19 and A.20.

For example, the risk aversion coefficient (α) was positively related to the derivative in Equation A.19. According to this relationship, the more risk averse a producer was, the greater the increase in the indifference premium rate would be for a given increase in coverage level. The derivative of the indifference premium rate with respect to $w_{ind}(y)$ was also predicted to be higher as the cumulative probability of collecting an indemnity increased.

c. Robison and Barry (1987) demonstrated that insurance demand could be further analyzed. Equation A.18 was used to derive the following relationships:

1. The indifference premium rate was determined to be positively related to the risk aversion coefficient. A more risk averse producer was expected to pay a larger indifference premium rate.

$$\frac{d[\pi_{indif}]}{d[\alpha]} = \frac{1}{2} \cdot \left[\sigma^2(w_{NI}) - \sigma^2(\Gamma) \right]$$

$$\frac{d[\pi_{indif}]}{d[\alpha]} > 0 \qquad \text{Equation A.21}$$

2. If the variance of the (w_1) portion of the NO MPCI distribution were increased in value, holding its expected value constant, then the indifference premium rate increased:

$$\frac{d[\pi_{indif}]}{d[\sigma^2{}_1]} = \frac{\alpha}{2} > 0 \qquad \text{Equation A.22}$$

3. If the expected value of the (w_1) of the NO MPCI distribution were increased in value, then a producer was expected to have a higher certainty equivalent for that part of the distribution. Consequently, he also had a lower indifference MPCI premium.

$$\frac{d[\pi_{indif}]}{d[w_1]} = -\left[1 + \alpha \cdot E(w_{NI}) \cdot (1-p) \right] < 0$$

Equation A.23

The value of the derivative in equation A.23 was negative. This impact was the substitution effect in the demand function under the condition of risk. The substitution effect was the change in quantity demanded which resulted from a change in a characteristic of the probability distribution, after the producer was compensated with a change in risk-free income (Robison and Barry 1987). In other words, the substitution effect was measured while holding the PARAC value constant.

(continued)

There also was an income effect for a demand function analyzed under the condition of risk. This income effect depended on the assumption made about the PARAC's relationship to changes in wealth. If the PARAC for a utility function possessed the characteristic of constant absolute risk aversion, then the income effect was zero and therefore did not influence the demand derived from the substitution effect.

If the PARAC was assumed to have the property of decreasing absolute risk aversion (DARA), then the income effect could reinforce or weaken the substitution effect's impact on demand. The utility functions used in chapter seven of this study were modeled with the DARA property.

The income effect under the DARA assumption reinforced the value of the derivative in Equation A.23, as demonstrated in Equation A.24 below:

$$\frac{d[\pi_{indif}]}{d[w_1]} = \frac{\delta(\alpha)}{\delta(w_1)} \cdot \left[-(1/2) \cdot [\sigma^2(\Gamma) - \sigma^2(w_{NI})] \right] < 0$$

Equation A.23

Where:

$$\frac{\delta(\alpha)}{\delta(w_1)} < 0 \quad \text{(the DARA assumption)}$$

$[\sigma^2(\Gamma) - \sigma^2(w_{NI})] < 0$ (variance of the insured ENW distribution is less than the variance of the NO MPCI ENW distribution)

4. The (w_2) portion of the distribution was "uninsured"; the losses did not exceed the deductible, and an indemnity was not collected. An increase in w_2 would not change the amount of a producer's potential indemnity.

   An increase in w_2 would increase the resources available to purchase insurance. Therefore, the substitution effect for the derivative of π_{indif} with respect to w_2 was positive, as demonstrated in Equation A.24 below:

$$\frac{d[\pi_{indif}]}{d[w_2]} = -\alpha \cdot \left[(w_1 - p_{ind} \cdot w_{ind}) - p_{ind} \cdot E(w_{NI}) \right] > 0$$

Equation A.24

Where:

$(w_1 - p_{ind} \cdot w_{ind}) < 0$ (the expected value of the NO MPCI distribution below the yield coverage level was less than expected value of the same portion of the insured distribution)

An income effect for the derivative of π_{indif} with respect to w_2 was also determined. The income effect under the DARA assumption weakened the impact of the substitution effect in this case. The income effect could be economically explained as an increase in wealth which would increase the firm's capacity to self-insure (not buy MPCI). See Equation A.25 below for a derivation of the income effect:

$$\frac{d[\pi_{indif}]}{d[w_2]} = \frac{\delta(\alpha)}{\delta(w_2)} \cdot \left[-(1/2) \cdot [\sigma^2(\Gamma) - \sigma^2(w_{NI})] \right] < 0$$

Equation A.25

Where:

$\frac{\delta(\alpha)}{\delta(w_2)} < 0$ (the DARA assumption)

The overall impact of a change in w2, when both the substitution and income effects were taken into account, was indeterminate. The outcome would depend on the relative strengths of the effects in the MPCI purchase decision at a given wealth level.

APPENDIX B

Enterprise Budgets for Alternative Levels of Mean Corn Yields in Brookings County, South Dakota

APPENDIX B

Enterprise Budgets for Alternative Levels of Mean Corn Yields in Brookings County, South Dakota

Table B.1 Enterprise Budget for Brookings County Corn Producers with a Mean Corn Yield of 83 Bu/Ac.

CORN FOR GRAIN, DRYLAND
1987 ENTERPRISE BUDGET OF YIELD, PRICE, COST, AND PROFIT ESTIMATES
BUDGET ASSUMES FULL PARTICIPATION IN FARM PROGRAM
OF ACRES IN PRODUCTION = 192.00

	OPTIMISTIC	EXPECTED	PESSIMISTIC
CROP YIELD	110.00 BU/AC	83.00 BU/AC	53.00 BU/AC
1987 MKT. PRICE	$1.55/BU	$1.35/BU	$1.18/BU

FARM PROGRAM ANALYSIS: 1987
(PRICES ASSUMED CONSTANT)

*TARGET PRICE	$3.03/BU
*PROJECTED DEFICIENCY PAYMENT	$1.21/BU
*LOAN RATE (Est. for Brookings)	$1.61/BU
*ESTABLISHED ASCS CROP YIELD	83.00 BU/AC
* % ACREAGE IN SET ASIDE	20.00%

ITEM OF EXPENSE	UNIT OF MEASURE	# UNITS PER ACRE	COST PER UNIT	COST PER ACRE
"NORMALIZED" PRE-HARVEST VARIABLE COSTS				
SEED	MVK	19.00	$.75	$14.25
FERTILIZER				
NITROGEN (NH3)	LB	115.00	$.18	$20.70
PHOSPHATE (P2 05)	LB	30.00	$.18	$5.40
POTASH (K20)	LB	.00	$.09	$.00
HERBICIDES				
LASSO II 15G (BANDED)	LB	7.00	$.85	$5.95
INSECT CONTROL				
THIMET	QUARTS	3.35	$1.80	$6.03
CROP INSURANCE	ACRE	.00	$14.00	$.00
FUEL (& LUBRICANTS)	ACRE	1.00	$3.70	$3.70
REPAIRS AND MAINT.	ACRE	1.00	$7.53	$7.53
LABOR	HOUR	4.50	$6.00	$27.00
TOTAL PRE-HARVEST VARIABLE COSTS				$90.56

Table B.1 (cont'd.)

"NORMALIZED" POST-HARVEST VARIABLE COSTS				
STORAGE	BUSHEL	83.00	$.11	$9.21
DRYING	BUSHEL	83.00	$.15	$12.45
HAULING	BUSHEL	83.00	$.01	$.64
CUSTOM COMBINING	ACRE	.00	$20.00	$.00
TOTAL POST-HARVEST VARIABLE COSTS				$22.31
INTEREST ON OPERATING CAPITAL	DOL	112.87	12.00% @6 months	$6.77
TOTAL VARIABLE COSTS PER ACRE IN PRODUCTION				$119.64
FIXED COSTS				
7% INT. ON MACHINERY	ACRE	1.00	$12.74	$12.74
MACH. - DEPRE. & INSUR.	ACRE	1.00	$14.97	$14.97
GENERAL OVERHEAD	DOL	119.64	$.05	$5.98
MANAGEMENT	DOL	119.64	$.05	$5.98
REAL ESTATE TAXES	ACRE	1.00	$5.25	$5.25
LAND CONTROL COST	ACRE	1.00	$29.00	$29.00
TOTAL FIXED COSTS PER ACRE IN PRODUCTION				$73.92
TOTAL BUDGETED COSTS PER ACRE IN PRODUCTION				$193.56
SET ASIDE EXPENSES				
HERBICIDES				
2,4-D AMINE	PINTS	.62	$1.47	$.92
ROUNDUP 3L	PINTS	.31	$10.36	$3.23
MACHINERY REPAIR	ACRE	1.00	$1.00	$1.00
FUEL AND LUBRIC.	GAL	1.40	$.80	$1.12
OVERHEAD	ACRE	1.00	$2.50	$2.50
INTEREST ON NON-LABOR VARIABLE COSTS	ACRE	8.77	12.00% @6 months	$.53
LABOR	HOURS	.35	$6.00	$2.12
TOTAL VARIABLE COST PER SET ASIDE ACRE				$11.42

Table B.1 (cont'd.)

ITEM OF COST	COST PER ACRE	TOTAL ACRES		TOTAL COST
CORN				
ENTERPRISE				
VARIABLE COST	119.638	192.00		22970.5
FIXED COST	73.9238	240.00		17741.7
SET ASIDE				
VARIABLE COST	11.4202	48.00		$548.17
TOTAL COST				41260.4
AVERAGE TOTAL COST PER ACRE				$171.92
AVERAGE TOTAL COST PER BUSHEL				$2.07

ITEM OF REVENUE	PRICE PER BUSHEL	BUSHELS PER ACRE	ACRES	TOTAL REVENUE
DEFICIENCY PAYMENT	$1.82	83.00	192.00	29003.5
LOAN RATE	$1.21	83.00	192.00	19282.6
GROSS REVENUE				48286.1
AVERAGE GROSS REVENUE PER ACRE				$201.19
AVERAGE GROSS REVENUE PER BUSHEL				$2.42
TOTAL NET REVENUE				7025.65
TOTAL NET REVENUE PER ACRE				$29.27
TOTAL NET REVENUE PER BUSHEL				$.35

Table B.2 Enterprise Budget for Brookings County Corn Producers with a Mean Corn Yield of 70 Bu/Ac.

CORN FOR GRAIN, DRYLAND
1987 ENTERPRISE BUDGET OF YIELD, PRICE, COST, AND PROFIT ESTIMATES
BUDGET ASSUMES FULL PARTICIPATION IN FARM PROGRAM
OF ACRES IN PRODUCTION = 192.00

	OPTIMISTIC	EXPECTED	PESSIMISTIC
CROP YIELD	110.00 BU/AC	70.00 BU/AC	53.00 BU/AC
1987 MKT. PRICE	$1.55/BU	$1.35/BU	$1.18/BU

FARM PROGRAM ANALYSIS: 1987
(PRICES ASSUMED CONSTANT)

#TARGET PRICE	$3.03/BU
#PROJECTED DEFICIENCY PAYMENT	$1.21/BU
#LOAN RATE (Est. for Brookings)	$1.61/BU
#ESTABLISHED ASCS CROP YIELD	70.00 BU/AC
# % ACREAGE IN SET ASIDE	20.00%

ITEM OF EXPENSE	UNIT OF MEASURE	# UNITS PER ACRE	COST PER UNIT	COST PER ACRE
"NORMALIZED" PRE-HARVEST VARIABLE COSTS				
SEED	MVK	17.00	$.75	$12.75
FERTILIZER				
NITROGEN (NH3)	LB	80.00	$.18	$14.40
PHOSPHATE (P2 05)	LB	20.00	$.18	$3.60
POTASH (K20)	LB	.00	$.09	$.00
HERBICIDES				
LASSO II 15G (BANDED)	LB	7.00	$.85	$5.95
INSECT CONTROL				
THIMET	QUARTS	3.35	$1.80	$6.03
CROP INSURANCE	ACRE	.00	$14.00	$.00
FUEL (& LUBRICANTS)	ACRE	1.00	$3.70	$3.70
REPAIRS AND MAINT.	ACRE	1.00	$7.53	$7.53
LABOR	HOUR	4.50	$6.00	$27.00
TOTAL PRE-HARVEST VARIABLE COSTS				$80.96

Table B.2 (cont'd.)

"NORMALIZED" POST-HARVEST VARIABLE COSTS				
STORAGE	BUSHEL	70.00	$.11	$7.77
DRYING	BUSHEL	70.00	$.15	$10.50
HAULING	BUSHEL	70.00	$.01	$.54
CUSTOM COMBINING	ACRE	.00	$20.00	$.00
TOTAL POST-HARVEST VARIABLE COSTS				$18.81
INTEREST ON OPERATING CAPITAL	DOL	99.77	12.00% @6 months	$5.99
TOTAL VARIABLE COSTS PER ACRE IN PRODUCTION				$105.76
FIXED COSTS				
7% INT. ON MACHINERY	ACRE	1.00	$12.74	$12.74
MACH. - DEPRE. & INSUR.	ACRE	1.00	$14.97	$14.97
GENERAL OVERHEAD	DOL	105.76	$.05	$5.29
MANAGEMENT	DOL	105.76	$.05	$5.29
REAL ESTATE TAXES	ACRE	1.00	$5.25	$5.25
LAND CONTROL COST	ACRE	1.00	$21.00	$21.00
TOTAL FIXED COSTS PER ACRE IN PRODUCTION				$64.54
TOTAL BUDGETED COSTS PER ACRE IN PRODUCTION				$170.29
SET ASIDE EXPENSES				
HERBICIDES				
2,4-D AMINE	PINTS	.62	$1.47	$.92
ROUNDUP 3L	PINTS	.31	$10.36	$3.23
MACHINERY REPAIR	ACRE	1.00	$1.00	$1.00
FUEL AND LUBRIC.	GAL	1.40	$.80	$1.12
OVERHEAD	ACRE	1.00	$2.50	$2.50
INTEREST ON NON-LABOR VARIABLE COSTS	ACRE	8.77	12.00% @6 months	$.53
LABOR	HOURS	.35	$6.00	$2.12
TOTAL VARIABLE COST PER SET ASIDE ACRE				$11.42

Table B.2 (cont'd.)

ITEM OF COST	COST PER ACRE	TOTAL ACRES		TOTAL COST
CORN				
ENTERPRISE				
VARIABLE COST	105.759	192.00		20305.7
FIXED COST	64.5359	240.00		15488.6
SET ASIDE				
VARIABLE COST	11.4202	48.00		$548.17
TOTAL COST----------				36342.5
AVERAGE TOTAL COST PER ACRE----------				$151.43
AVERAGE TOTAL COST PER BUSHEL----------				$2.16
ITEM OF REVENUE	PRICE PER BUSHEL	BUSHELS PER ACRE	ACRES	TOTAL REVENUE
DEFICIENCY				
PAYMENT	$1.82	70.00	192.00	24460.8
LOAN				
RATE	$1.21	70.00	192.00	16262.4
GROSS				
REVENUE----------				40723.2
AVERAGE GROSS REVENUE PER ACRE----------				$169.68
AVERAGE GROSS REVENUE PER BUSHEL----------				$2.42
TOTAL NET REVENUE----------				4380.72
TOTAL NET REVENUE PER ACRE----------				$18.25
TOTAL NET REVENUE PER BUSHEL----------				$.26

Table B.3 Enterprise Budget for Brookings County Corn Producers with a Mean Corn Yield of 55 Bu/Ac.

CORN FOR GRAIN, DRYLAND
1987 ENTERPRISE BUDGET OF YIELD, PRICE, COST, AND PROFIT ESTIMATES
BUDGET ASSUMES FULL PARTICIPATION IN FARM PROGRAM
OF ACRES IN PRODUCTION = 192.00

	OPTIMISTIC	EXPECTED	PESSIMISTIC
CROP YIELD	110.00 BU/AC	55.00 BU/AC	53.00 BU/AC
1987 MKT. PRICE	$1.55/BU	$1.35/BU	$1.18/BU

FARM PROGRAM ANALYSIS: 1987
(PRICES ASSUMED CONSTANT)

#TARGET PRICE	$3.03/BU
#PROJECTED DEFICIENCY PAYMENT	$1.21/BU
#LOAN RATE (Est. for Brookings)	$1.61/BU
#ESTABLISHED ASCS CROP YIELD	55.00 BU/AC
# % ACREAGE IN SET ASIDE	20.00%

ITEM OF EXPENSE	UNIT OF MEASURE	# UNITS PER ACRE	COST PER UNIT	COST PER ACRE
"NORMALIZED" PRE-HARVEST VARIABLE COSTS				
SEED	MVK	16.00	$.75	$12.00
FERTILIZER				
NITROGEN (NH3)	LB	60.00	$.18	$10.80
PHOSPHATE (P2 05)	LB	.00	$.18	$.00
POTASH (K20)	LB	.00	$.09	$.00
HERBICIDES				
LASSO II 15G (BANDED)	LB	7.00	$.85	$5.95
INSECT CONTROL				
THIMET	QUARTS	3.35	$1.80	$6.03
CROP INSURANCE	ACRE	.00	$14.00	$.00
FUEL (& LUBRICANTS)	ACRE	1.00	$3.70	$3.70
REPAIRS AND MAINT.	ACRE	1.00	$7.53	$7.53
LABOR	HOUR	4.50	$6.00	$27.00
TOTAL PRE-HARVEST VARIABLE COSTS				$73.01

Table B.3 (cont'd.)

"NORMALIZED" POST-HARVEST VARIABLE COSTS				
STORAGE	BUSHEL	55.00	$.11	$6.11
DRYING	BUSHEL	55.00	$.15	$8.25
HAULING	BUSHEL	55.00	$.01	$.43
CUSTOM COMBINING	ACRE	.00	$20.00	$.00
TOTAL POST-HARVEST VARIABLE COSTS				$14.78
INTEREST ON OPERATING CAPITAL	DOL	87.79	12.00% @6 months	$5.27
TOTAL VARIABLE COSTS PER ACRE IN PRODUCTION				$93.06
FIXED COSTS				
7% INT. ON MACHINERY	ACRE	1.00	$12.74	$12.74
MACH. - DEPRE. & INSUR.	ACRE	1.00	$14.97	$14.97
GENERAL OVERHEAD	DOL	93.06	$.05	$4.65
MANAGEMENT	DOL	93.06	$.05	$4.65
REAL ESTATE TAXES	ACRE	1.00	$5.25	$5.25
LAND CONTROL COST	ACRE	1.00	$12.00	$12.00
TOTAL FIXED COSTS PER ACRE IN PRODUCTION				$54.27
TOTAL BUDGETED COSTS PER ACRE IN PRODUCTION				$147.32
SET ASIDE EXPENSES				
HERBICIDES				
2,4-D AMINE	PINTS	.62	$1.47	$.92
ROUNDUP 3L	PINTS	.31	$10.36	$3.23
MACHINERY REPAIR	ACRE	1.00	$1.00	$1.00
FUEL AND LUBRIC.	GAL	1.40	$.80	$1.12
OVERHEAD	ACRE	1.00	$2.50	$2.50
INTEREST ON NON-LABOR VARIABLE COSTS	ACRE	8.77	12.00% @6 months	$.53
LABOR	HOURS	.35	$6.00	$2.12
TOTAL VARIABLE COST PER SET ASIDE ACRE				$11.42

Table B.3 (cont'd.)

ITEM OF COST	COST PER ACRE	TOTAL ACRES		TOTAL COST
CORN				
ENTERPRISE				
VARIABLE COST	93.0587	192.00		17867.3
FIXED COST	54.2659	240.00		13023.8
SET ASIDE				
VARIABLE COST	11.4202	48.00		$548.17
TOTAL COST				31439.3
AVERAGE TOTAL COST PER ACRE				$131.00
AVERAGE TOTAL COST PER BUSHEL				$2.38

ITEM OF REVENUE	PRICE PER BUSHEL	BUSHELS PER ACRE	ACRES	TOTAL REVENUE
DEFICIENCY PAYMENT	$1.82	55.00	192.00	19219.2
LOAN RATE	$1.21	55.00	192.00	12777.6
GROSS REVENUE				31996.8
AVERAGE GROSS REVENUE PER ACRE				$133.32
AVERAGE GROSS REVENUE PER BUSHEL				$2.42
TOTAL NET REVENUE				557.544
TOTAL NET REVENUE PER ACRE				$2.32
TOTAL NET REVENUE PER BUSHEL				$.04

APPENDIX C

Soil Productivity Ratings for Brookings County and Sampled Bookings County Producers

APPENDIX C

Soil Productivity Ratings for Brookings County and Sampled Bookings County Producers

Table C.1 Productivity Ratings of Soils in Brookings County, South Dakota.

Soil Symbol	Crop Rating	AUM Pasture Rating	Acreage of Soil	% of Acreage in County	Subtotals of % Acres	Name of Soil Type
Md	100	.68	2537	.50	.50	Moody Silt Loam, Nearly Level
Ac	96	1.20	2664	.53	1.03	Athelwold Silty Clay Loam, Nearly Level
Me	94	.63	1469	.29	1.32	Moody Silt Loam, Gently Sloping
Oa	93	.68	1956	.39	1.71	Oak Lake Silt Loam, Nearly Level
Ob	93	.68	2835	.56	2.27	Oak Lake Silty Clay Loam, Drainageways
Ba	92	1.13	9796	1.94	4.20	Brookings Silty Clay Loam, Nearly Level
Bb	92	1.13	9787	1.94	6.14	Brookings Silty Clay Loam, Drainageways
Wa	91	.68	1496	.30	6.44	Waubay Silty Clay Loam, Nearly Level
Wb	91	.68	14085	2.79	9.22	Waubay Silty Clay Loam, Drainageways
Lc	89	1.13	6296	1.25	10.47	Lismore Silty Clay Loam, Nearly Level
Ld	89	1.13	11063	2.19	12.66	Lismore Silty Clay Loam, Drainageways
Fa	84	.68	1211	.24	12.90	Flandreau Loam, Deep, Nearly Level
Fc	84	.68	750	.15	13.04	Flandreau Loam, Deep over Till, Nearly Level
Fg	84	.68	903	.18	13.22	Flandreau Silt Loam, Nearly Level
Fk	84	.61	858	.17	13.39	Flandreau Silt Loam, Deep, Nearly Level
Sa	83	.68	2762	.55	13.94	Sinai Silty Clay Loam, Nearly Level
Va	83	.68	23614	4.67	18.61	Vienna Loam, Nearly Level
Aa	81	.59	986	.20	18.80	Ahnberg-Poinsett Complex, Gently Undulating
Ee	81	.68	22335	4.42	23.22	Estelline Silt Loam, Nearly Level
Pd	81	.59	39167	7.75	30.97	Poinsett Silt Loam, Gently Undulating
Kb	80	.63	390	.08	31.05	Kranzburg Loam, Gently Sloping
Kd	80	.54	15997	3.16	34.21	Kranzburg Silt Loam, Gently Sloping
Sd	78	.63	6255	1.24	35.45	Singsaas Loam, Gently Undulating
Vb	78	.63	25312	5.01	40.45	Vienna Loam, Gently Sloping
Eg	77	.63	1261	.25	40.70	Estelline Silt Loam, Gently Sloping
Ek	77	.63	950	.19	40.89	Estelline Silt Loam, Moderately Shallow, Gently Sloping
Sb	77	.64	5120	1.01	41.90	Sinai Silty Clay Loam, Gently Sloping
Ka	76	.54	1695	.34	42.24	Kranzburg Loam, Nearly Level
Kc	76	.60	21261	4.21	46.45	Kranzburg Silt Loam, Nearly Level
Pc	76	.54	5111	1.01	47.46	Poinsett Silt Loam, Nearly Level
Fb	75	.63	210	.04	47.50	Flandreau Loam, Deep, Gently Undulating
Fd	75	.68	1511	.30	47.80	Flandreau Loam, Deep Over Till, Gently Sloping
Fh	75	.63	656	.13	47.93	Flandreau Silt Loam, Gently Sloping
Pg	74	.59	736	.15	48.07	Poinsett-Buse-Pierce Soils, Gently Undulating
Se	73	.61	2781	.55	48.62	Singsaas Loam, Undulating
Sg	73	.62	3233	.64	49.26	Singsaas-Buse Loams, Gently Undulating

Table C.1 (cont'd.)

Vg	73	.62	440	.09	49.35	Vienna-Buse Loams, Gently Undulating
Ab	72	.55	1290	.26	49.60	Ahnberg-Poinsett Complex, Undulating
Ke	72	.63	5052	1.00	50.60	Kranzburg Silt Loam, Sloping
Pe	72	.55	25426	5.03	55.63	Poinsett Silt Loam, Undulating
Vd	72	.61	893	.18	55.81	Vienna Sandy Loam, Gently Undulating
Vc	70	.61	13583	2.69	58.50	Vienna Loam, Sloping
Sc	68	.59	1090	.22	58.71	Sinai Silty Clay Loam, Sloping
Ve	68	.59	509	.10	58.81	Vienna Sandy Loam, Undulating
La	67	1.35	38936	7.70	66.51	Lamoure Silty Clay Loam, Nearly Level
Fe	67	.63	770	.15	66.67	Flandreau Loam, Deep over Till, Sloping
Sb	66	.59	707	.14	66.81	Singsaas-Buse Loams, Undulating
Lb	65	1.30	1560	.31	67.11	Leota Silty Clay Loam, Nearly Level
Ph	65	.54	10046	1.99	69.10	Poinsett-Buse-Pierce Soils, Undulating
Sk	65	.58	677	.13	69.24	Singsaas-Buse-Pierce Loams, Undulating
So	65	1.10	17043	3.37	72.61	Solonon Clay, Nearly Level
Vo	65	1.30	2712	.54	73.14	Volga Loam, Somewhat Poorly Drained, Nearly Level
Vp	65	1.30	18090	3.58	76.72	Volga Silty Clay Loam, Somewhat Poorly Drained, Nearly Level
Vh	64	.59	3308	.65	77.38	Vienna-Buse Loams, Undulating
Vm	63	.58	707	.14	77.51	Vienna-Buse-Pierce Loams, Undulating
Eh	61	.52	7314	1.45	78.96	Estelline Silt Loam, Moderately Shallow, Nearly Level
Pa	61	1.00	5613	1.11	80.07	Parnell Silty Clay Loam, Nearly Level
Fp	58	.61	839	.17	80.24	Fordville Loam, Deep, Nearly Level
Ea	57	.70	638	.13	80.36	Egeland Sandy Loam, Nearly Level
Ec	57	.70	2046	.40	80.77	Egeland Sandy Loam, Deep over Loamy Drift, Nearly Level
Fm	56	.41	18583	3.68	84.44	Fordville Loam, Nearly Level
Fo	56	.48	7149	1.41	85.86	Fordville Loam, Thick Solum, Nearly Level
Fr	56	.48	1070	.21	86.07	Fordville Sandy Loam, Nearly Level
Hb	56	.64	3908	.77	86.84	Hecla Sandy Loam, Nearly Level
Hc	56	1.13	1935	.38	87.23	Hidewood Silty Clay Loam, Nearly Level
Oc	56	1.13	9849	1.95	89.17	Oldham Silty Clay Loam, Nearly Level
Ha	54	.61	1593	.32	89.49	Hecla Loam, Undulating
Fn	53	.57	2208	.44	89.93	Fordville Loam, Gently Undulating
Fs	53	.57	200	.04	89.97	Fordville Sandy Loam, Gently Undulating
Da	52	.70	842	.17	90.13	Dickey Sandy Loam, Gently Undulating
Bc	51	.53	1400	.28	90.41	Buse Complexes, Undulating
Bg	51	.53	341	.07	90.48	Buse Stony Complexes, Undulating
Eb	48	.64	460	.09	90.57	Egeland Sandy Loam, Gently Undulating
Ed	48	.61	1087	.22	90.78	Egeland Sandy Loam, Deep over Loam Drift, Gently Undulating
Ma	47	.70	696	.14	90.92	Maddock Sandy Loam, Nearly Level
Tb	47	.95	340	.07	90.99	Tetonka Silty Clay Loam, Nearly Level
Db	44	.65	190	.04	91.02	Dickey Sandy Loam, Undulating
Mb	44	.70	190	.04	91.06	Maddock Sandy Loam, Undulating
Rb	39	.56	2578	.51	91.57	Renshaw Sandy Loam, Nearly Level
Rc	39	.56	750	.15	91.72	Renshaw Sandy Loam, Gently Sloping
Be	30	.47	7479	1.48	93.20	Buse Complexes, Hilly
Mc	10	.40	9381	1.86	95.06	Marsh
Ra	10	1.00	720	.14	95.20	Rauville Silty Clay Loam, Nearly Level
Vr	10	1.30	6797	1.34	96.54	Volga Silty Clay Loam, Poorly Drained, Nearly Level
				0	96.54	
Bd	NR	.47	4482	.89	97.43	Buse Complexes, Rolling
Bh	NR	.40	1162	.23	97.66	Buse Stony Complexes, Rolling
Pb	NR	.51	1422	.28	97.94	Pierce Complexes, Hilly
Pk	NR	.47	6755	1.34	99.28	Poinsett-Buse-Pierce Soils, Rolling
Sm	NR	.52	760	.15	99.43	Singsaas-Buse-Pierce Loams, Rolling
Sn	NR	.34	250	.05	99.48	Sioux Gravelly Loam, Gently Undulating
Ta	NR	.52	1580	.31	99.79	Terrace Escarpments, Sloping
Vk	NR	.52	440	.09	99.88	Vienna-Buse Loams, Steep
Vn	NR	.52	630	.12	100.00	Vienna-Buse-Pierce Loams, Rolling

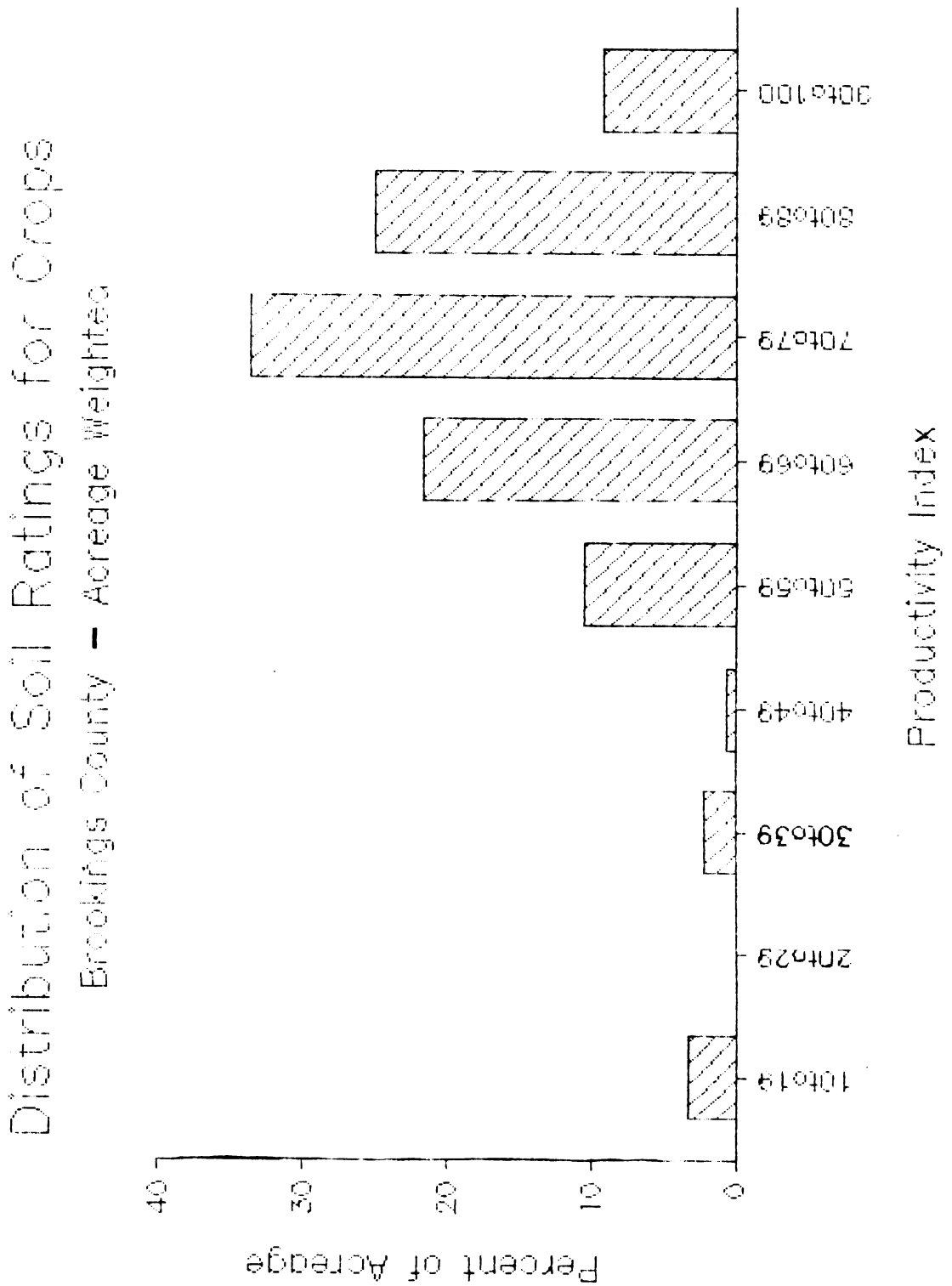

Figure C.1 **Acreage Weighted Distribution of Soil Productivity Ratings in Brookings County, South Dakota.**

Table C.2 Whole-Farm Average Soil Productivity Productivity Ratings for Producer Sample in Brookings County, South Dakota.

Soil Productivity Ratings for Brookings County Producers
Included in the Elicitation of Crop Yield Probabilities

Surveyed Producers	Section Numbers & Map Sheet Numbers	Soil Types	Overall Crop Prod. Rating	Square of Crop Rating
Producer 30	Sec. 29 & 30: Sh#60	Pd, Mb, Kd	82.10	6740.41
Producer 31	Sec. 31: Sh#60	Pd, Ma, Pe	82.10	6740.41
Producer 5	Sec. 28 & 33: Sh#47	Ee, Ba, La, Kd	81.90	6707.61
Producer 47	Sec. 9, 10, 15: Sh# 23	Vb, Lb, Va	81.60	6658.56
Producer 53	Sec. 35: Sh#29	Kc, Ba, Va	81.50	6642.25
Producer 27	Sec. 16 & 21: Sh#1 & 9	Pe, Ma, Pd	81.30	6609.69
Producer 35	Sec. 26 & 27: Sh#15	Kc, Ba, Kd	81.30	6609.69
Producer 55	Sec. 16, 17, 21: Sh#20, 28	Md, Ec, Bb	81.10	6577.21
Producer 28	Sec. 32: Sh#9	Pd, Pe, Ma	80.80	6528.64
Producer 22	Sec. 11: Sh#50	Aa, Pd, Pc	80.10	6416.01
Producer 37	Sec. 4: Sh#7	Kc, Vb, Bb	79.80	6368.04
Producer 26	Sec. 18: Sh#49	Pd, Sb	79.70	6352.09
Producer 58	Sec. 21: Sh#43	Pd, Oc, Ma	79.60	6336.16
Producer 25	Sec. 33: Sh#57	Sb, Pe, Mb	79.20	6272.64
Producer 52	Sec. 5 & 6: Sh#20	Va, Vb, Lc	79.20	6272.64
Producer 29	Sec. 32: Sh#9	Pd, Pe	78.80	6209.44
Producer 61	Sec. 19 & 20: Sh#25	Pd, Pe, Oc	78.60	6177.96
Producer 23	Sec. 25 & 36: Sh#58	Sb, Pd, Pe	77.90	6068.41
Producer 38	Sec. 1: Sh#8	Sd, Se, Ob	77.80	6052.84
Producer 62	Sec. 5: Sh#17	Pd, Pe, Oc	77.80	6052.84
Producer 51	Sec. 4, 21, 27: Sh#31, 23	Va, Vb, Vc	77.40	5990.76
Producer 57	Sec. 24, 25, 31: Sh#43, 44, 35	Ee, Kd, Vp	77.40	5990.76
Producer 24	Sec. 27 & 34: Sh#57	Sb, Pd, Pe,	77.30	5975.29
Producer 42	Sec.18 & 16: Sh#50 & 51	Ee, Ac, Ph	77.10	5944.41
Producer 36	Sec. 32: Sh#15	Vb, Va, Vh	76.50	5852.25
Producer 9	Sec. 17: Sh#37	La, Va, Vb, Ld	75.90	5760.81
Producer 44	Sec. 1 & 12: Sh#51 & 52	Ee, So, La, Ac	75.40	5685.16
Producer 54	Sec. 9, Sh#20	La, Kc, Ba	74.50	5550.25
Producer 56	Sec. 24 & 25: Sh#62	Kc, Fd, Kd	74.10	5490.81
Producer 43	Sec. 4 & 9: Sh#51	Pd, Ph, Pc, Mb	73.80	5446.44
Producer 13	Sec. 32: Sh#41	Pe, Ph, Pd	73.50	5402.25
Producer 59	Sec. 8: Sh#34	Pe, Ph, Mb	73.50	5402.25
Producer 33	Sec. 19& 20: Sh#14, 15	Vc, Kd, Ke	73.00	5329
Producer 14	Sec. 4: Sh#33	Pe, Mb, Pd	72.40	5241.76
Producer 34	Sec. 34 & 35: Sh#15	Vc, Vh, Kc, La	72.30	5227.29
Producer 49	Sec. 13, 14, 24: Sh#24, 23, 32	Vc, Va, Vb, Bd	72.10	5198.41
Producer 60	Sec. 32: Sh#42	Pd, Pe, Fo	72.10	5198.41
Producer 15	Sec. 24: Sh#42	Pe	72.00	5184
Producer 18	Sec. 7: Sh#56; Sec. 33: Sh#63	Kd, Eh, Fa, Bb	68.60	4705.96
Producer 20	Sec.10: Sh#24	Sh, Ob	70.00	4900
Producer 46	Sec. 7 & 18: Sh#40	Fe, La, Kd, Vc	70.00	4900
Producer 41	Sec. 21 & 28: Sh#58 & 59	Pe, Ph, Pd	69.80	4872.04
Producer 3	Sec. 9: Sh#22; Sec. 5: Sh#21	Eh, Kc, Ba	69.50	4830.25
Producer 6	Sec. 18: Sh#39	La, Mb, Ka, Ee	68.40	4678.56
Producer 19	Sec. 20: Sh#12	Vd, Fa, Ha	68.20	4651.24
Producer 16	Sec. 37: Sh#37	La, So, Ba	67.80	4596.84
Producer 12	Sec. 29 & 30: Sh#45; Sec. 8: Sh#37	La, Vp, Fg, Vb, Vc	67.40	4542.76
Producer 8	Sec. 10 & 14: Sh#38	La, Ha, Ee	67.00	4489

Table C.2 (cont'd.)

Producer 50	Sec. 34 & 35: Sh#31	La, Fe, Vb, Vc	66.80	4462.24
Producer 7	Sec. 9: Sh#6	Fe, La, Bb, Kb	66.34	4400.996
Producer 48	Sec. 12: Sh#24	Be, Vb, Va	65.90	4342.81
Producer 45	Sec. 36: Sh#11	La, Fe, Ve	65.20	4251.04
Producer 21	Sec. 4: Sh#24	Sd, Be, Sh, La	64.40	4147.36
Producer 1	Sec. 7 & 8: Sh#21; Sec. 16: Sh#22	Eh, Ee, Fe, Hc, Kc	64.00	4096
Producer 4	Sec.12: Sh#40	Ha, Fe, La, Vc	64.00	4096
Producer 17	Sec. 12W: Sh#35	La, So, Vp, Fe	63.90	4083.21
Producer 11	Sec. 33: Sh#46	So, Fe, La	63.80	4070.44
Producer 2	Sec. 10: Sh#10	Eh, Vp, Ac	62.00	3844
Producer 10	Sec. 16: Sh#38	Hb, La	59.00	3481
Producer 40	Sec. 14 & 23: Sh#19 & 27	Fe, Vp, So	58.10	3375.61
Producer 32	Sec. 13: Sh#53	La, Fe, Rb	57.70	3329.29
Producer 39	Sec. 13: Sh#19 & 20	Eb, Rc, La	57.20	3271.84

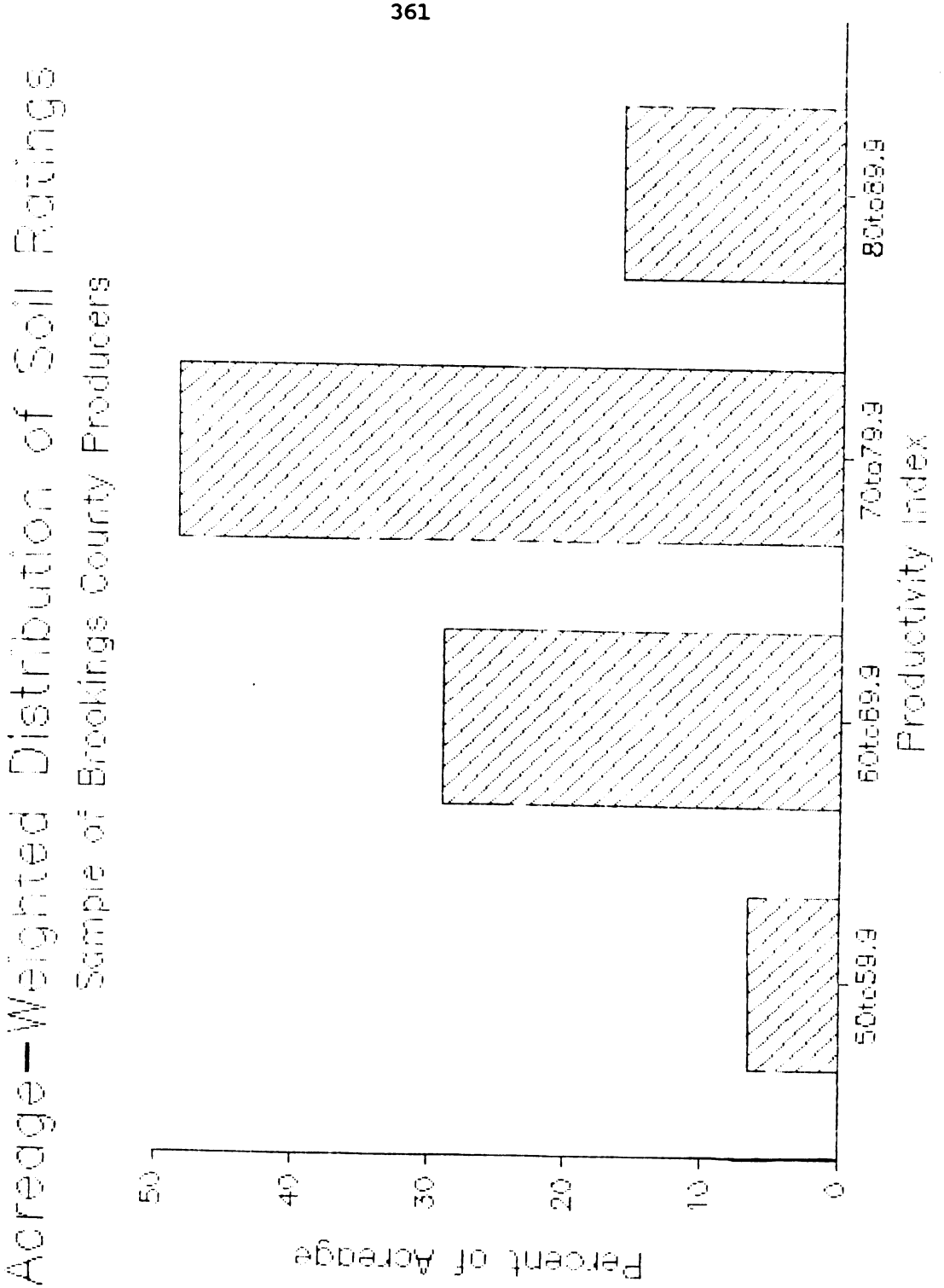

Figure C.2 Acreage Weighted Distribution of Whole-Farm Average Soil Productivity Ratings for Producer Sample in Brookings County, South Dakota.

APPENDIX D

Aggregated Crop Yield Probability Density Functions for Sampled Brookings County Corn Producers

APPENDIX D

Aggregated Crop Yield Probability Density Functions for Sampled Brookings County Corn Producers

ENTER/REVISE SCORES

Name: BKGS MGMT#1 (HIST.)

Crop: CORN

Yield Measure: BUSHEL

Date: 09/31/87

Yield Range	Scores
0.0- 10.0	1
10.0- 20.0	2
20.0- 30.0	6
30.0- 40.0	11
40.0- 50.0	20
50.0- 60.0	33
60.0- 70.0	59
70.0- 80.0	70
80.0- 90.0	75
90.0-100.0	100
100.0-110.0	65
110.0-120.0	30
120.0-130.0	13
130.0-140.0	3
140.0-150.0	2

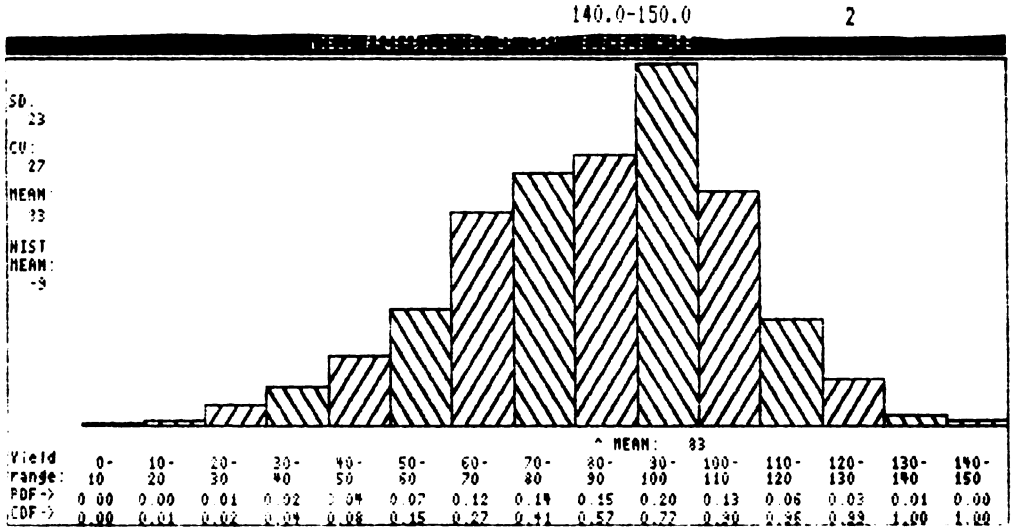

Figure D.1 Aggregated Crop Yield Probability Distribution for the Sample of Brookings County Corn Producers with a Historical Mean Yield within the 91-101 Bu/Ac Interval.

ENTER/REVISE SCORES

	Yield Range	Scores
Name: BKGS MGMT#2 (HIST.)	0.0- 10.0	3
	10.0- 20.0	6
Crop: CORN	20.0- 30.0	9
	30.0- 40.0	13
Yield Measure: BUSHEL	40.0- 50.0	21
	50.0- 60.0	34
Date: 08/31/87	60.0- 70.0	53
	70.0- 80.0	90
	80.0- 90.0	100
	90.0-100.0	57
	100.0-110.0	24
	110.0-120.0	9
	120.0-130.0	3
	130.0-140.0	1

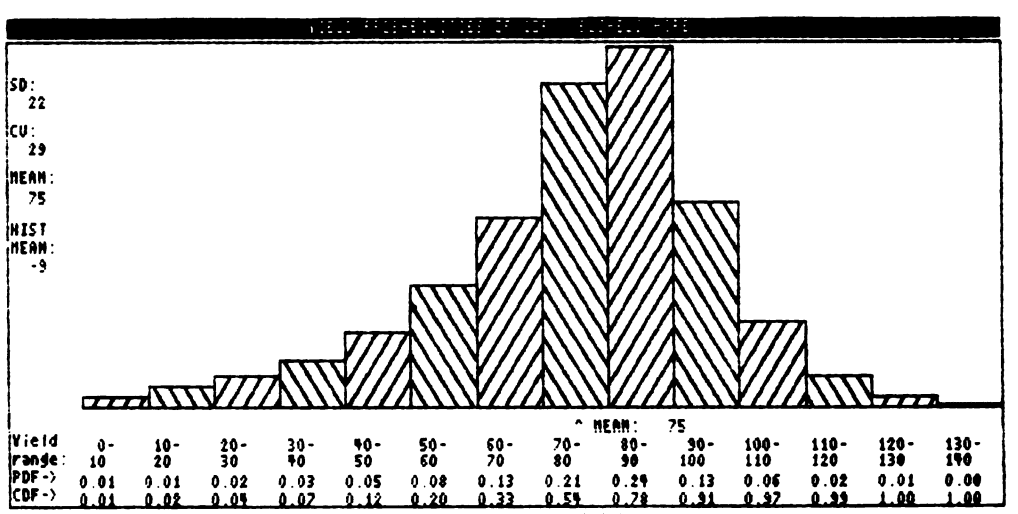

Figure D.2 Aggregated Crop Yield Probability Distribution for the Sample of Brookings County Corn Producers with a Historical Mean Yield within the 80-90 Bu/Ac Interval.

ENTER/REVISE SCORES

Name: BRGS MGMT#3 (HIST.)

Crop: CORN

Yield Measure: BUSHEL

Date: 09/31/87

Yield Range	Scores
0.0- 10.0	2
10.0- 20.0	5
20.0- 30.0	13
30.0- 40.0	21
40.0- 50.0	40
50.0- 60.0	59
60.0- 70.0	91
70.0- 80.0	100
80.0- 90.0	64
90.0-100.0	34
100.0-110.0	22
110.0-120.0	9
120.0-130.0	5
130.0-140.0	1

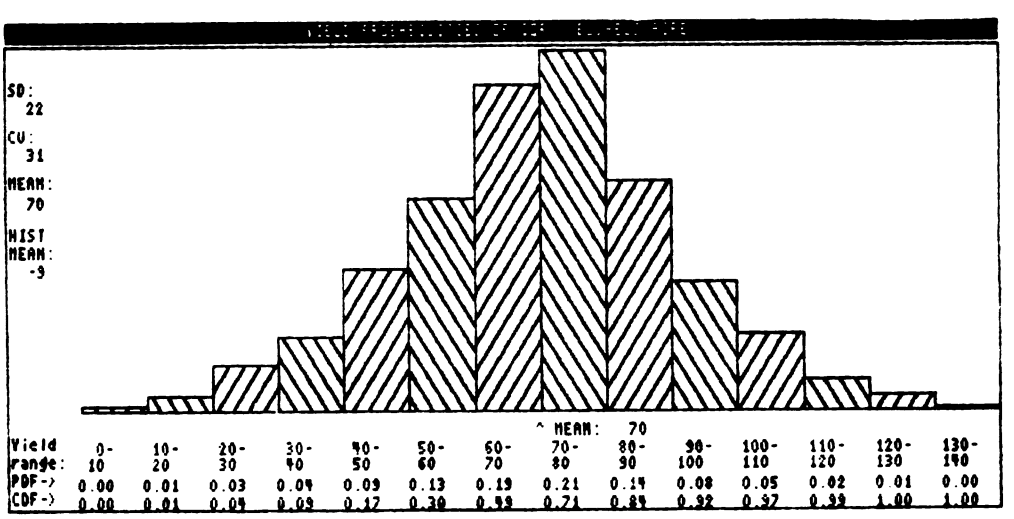

Figure D.3 Aggregated Crop Yield Probability Distribution for the Sample of Brookings County Corn Producers with a Historical Mean Yield within the 69-79 Bu/Ac Interval.

ENTER/REVISE SCORES

	Yield Range	Scores
Name: BKGS MGMT#4 (HIST.)	0.0- 10.0	2
	10.0- 20.0	5
Crop: CORN	20.0- 30.0	8
	30.0- 40.0	16
Yield Measure: BUSHEL	40.0- 50.0	35
	50.0- 60.0	69
Date: 08/31/87	60.0- 70.0	100
	70.0- 80.0	89
	80.0- 90.0	51
	90.0-100.0	18
	100.0-110.0	5

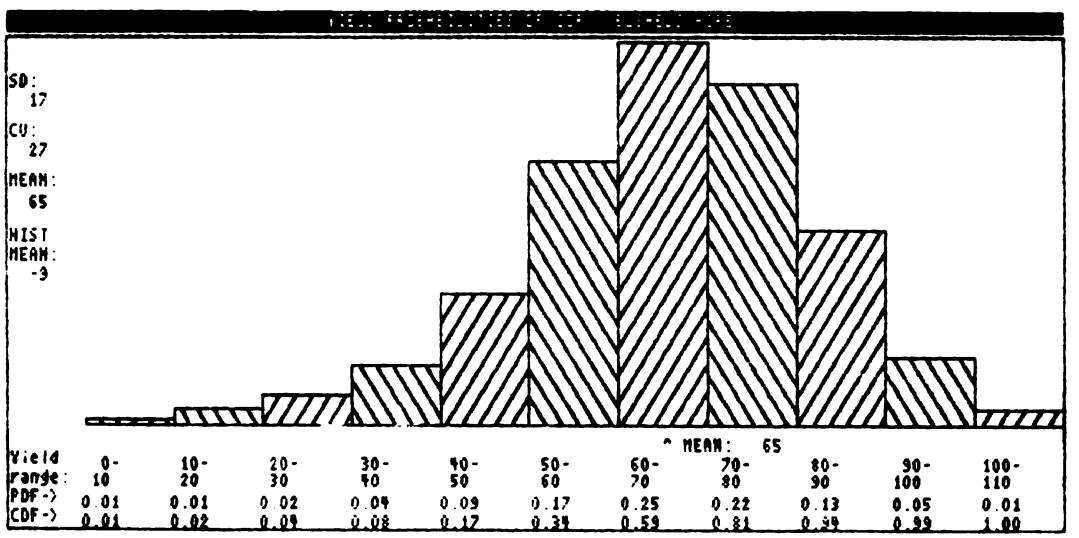

Figure D.4 Aggregated Crop Yield Probability Distribution for the Sample of Brookings County Corn Producers with a Historical Mean Yield within the 58-68 Bu/Ac Interval.

ENTER/REVISE SCORES

Name: BRIGGS MGMT#5 (HIST.)

Crop: CORN

Yield Measure: BUSHEL

Date: 08/31/87

Yield Range	Scores
0.0- 10.0	6
10.0- 20.0	10
20.0- 30.0	18
30.0- 40.0	28
40.0- 50.0	45
50.0- 60.0	68
60.0- 70.0	100
70.0- 80.0	39
80.0- 90.0	10
90.0-100.0	5

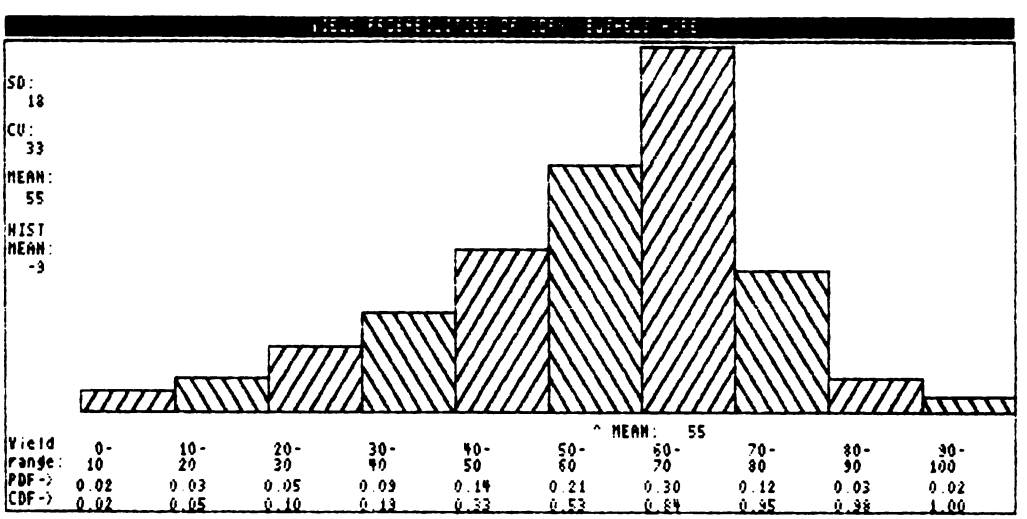

Figure D.5 Aggregated Crop Yield Probability Distribution for the Sample of Brookings County Corn Producers with a Historical Mean Yield within the 39-57 Bu/Ac Interval.

APPENDIX E

Results and Information on Crop Yield Capacity Function Estimations

APPENDIX E

Results and Information on Crop Yield Capacity Function Estimations

Table E.1 OLS Estimation Results for Model of Corn Yield as a Function of a Lagged Price Ratio in Brookings County, South Dakota.

Dependent Variable: Brookings County-Level Corn Yield
Independent Variable: Ratio of Lagged Annual Corn Price to Fertilizer Price Index

Estimated Parameter	Crop Modeled by CYCF Technique: Brookings County Corn
β Coefficient	1085.09 (2.18)*
Constant	41.38 (6.99)
$\bar{R}^2$	0.12
F-Statistic (1, 28)	4.77
Error Term Variance ($\sigma^2(U_t)$)	303.88

*Numbers in parentheses were t-values. A 90% confidence limit was used. The critical t-value at the 0.10 level was 1.70. The critical F-value at the 0.05 level was 3.35.

Table E.2 OLS Estimation Results for Model of Corn Yield as a Function of Corn Acres Planted in Brookings County, South Dakota.

Dependent Variable: Brookings County-Level Corn Yield
Independent Variable: Acres of Corn Planted in Brookings County

Estimated Parameter	Crop Modeled by CYCF Technique: Brookings County Corn
δ Coefficient	-61.00 (1.11)*
Constant	86.19 (2.81)
$\bar{R}^2$	0.01
F-Statistic (1, 28)	1.24
Error Term Variance ($\sigma^2(U_t)$)	342.73

*Numbers in parentheses were t-values. A 90% confidence limit was used. The critical t-value at the 0.10 level was 1.70. The critical F-value at the 0.05 level was 3.35.

Table E.3 COLS Estimation Results for a Stochastic Corn Yield Capacity Function in Brookings County, South Dakota, where Technological Trend was the Sole Explanatory Variable (see Equation 6.5 in Chapter Six).

Dependent Variable: Brookings County-Level Corn Yield
Independent Variable: Linear Technological Trend

Estimated Parameter	Crop Modeled by CYCF Technique: Brookings County Corn
α Coefficient	46.10 (8.08)*
Φ Coefficient	1.68 (6.60)
$\bar{R}^2$	0.60
F-Statistic (2, 28)	43.63
Error Term Variance ($\sigma^2(U_t)$)	134.67
Capacity Variance ($\sigma^2 = \sigma^2_\theta + \sigma^2_\Omega$)	353.23
Ω_t Variance (σ^2_Ω)	2.86
θ_t Variance (σ^2_θ)	350.37
θ_t Standard Deviation (σ_θ)	18.72
θ_t Mean ($\mu = (\sqrt{[2/\pi]}) \cdot \sigma_\theta$)	14.93
ϕ Parameter for COLS Estimation ($\phi = \sigma_\theta/\sigma_\Omega$)	11.08
U_t Skewness (α_3)	-1.08
U_t Kurtosis (α_4)	1.67

*Numbers in parentheses were t-values. A 90% confidence limit was used. The critical t-value at the 0.10 level was 1.70. The critical F-value at the 0.05 level was 3.35.

Table E.4 Comparison of COLS Capacity, Actual and OLS Fitted Yields for a Stochastic Corn Yield Capacity Function Based on the Technological Trend in Corn Yields in Brookings County, South Dakota. (See Equation 6.5 in Chapter Six, and also Table E.3 and Figure E.1 in Appendix E).

Dependent Variable: Brookings County-Level Corn Yield
Independent Variable: Linear Technological Trend

Year	Observation #	Corn: COLS Capacity Yield OLS Residuals	Corn Initial COLS Estimate of Capacity Corn Yield	Actual Yield	OLS Fitted Yield
1957	1.000000	-11.10	46.10	35.000300	31.169300
1958	2.000000	-17.10	46.10	29.000300	31.169300
1959	3.000000	-21.60	46.10	24.500300	31.169300
1960	4.000000	-7.78	47.78	40.000090	32.845090
1961	5.000000	-4.46	49.46	44.999801	34.520801
1962	6.000000	-13.63	51.13	37.499512	36.196512
1963	7.000000	4.19	52.81	57.000222	37.872222
1964	8.000000	-9.48	54.48	44.999933	39.547933
1965	9.000000	-20.16	56.16	35.999643	41.223643
1966	10.000000	-22.83	57.83	35.000354	42.899354
1967	11.000000	-24.51	59.51	35.000065	44.575065
1968	12.000000	-11.19	61.19	49.999775	46.250775
1969	13.000000	-9.86	62.86	53.000486	47.926486
1970	14.000000	-18.54	64.54	46.000196	49.602196
1971	15.000000	-23.21	66.21	42.999907	51.277907
1972	16.000000	-7.89	67.89	59.999618	52.953618
1973	17.000000	-10.56	69.56	59.000328	54.629328
1974	18.000000	-36.24	71.24	35.000039	56.305039
1975	19.000000	-30.02	72.92	42.899749	57.980749
1976	20.000000	-50.79	74.59	23.800460	59.656460
1977	21.000000	-11.77	76.27	64.500171	61.332171
1978	22.000000	-9.94	77.94	67.999881	63.007881
1979	23.000000	-7.92	79.62	71.699592	64.683592
1980	24.000000	-18.09	81.29	63.200302	66.359302
1981	25.000000	-4.97	82.97	78.000013	68.035013
1982	26.000000	5.25	84.65	89.899724	69.710724
1983	27.000000	-27.82	86.32	58.500434	71.386434
1984	28.000000	-14.30	88.00	73.699450	73.061450
1985	29.000000	-8.37	89.67	81.299855	74.737855
1986	30.000000	-3.35	91.35	87.999566	76.413566
	Average =	-14.934834	67.218169	52.283336	52.283302

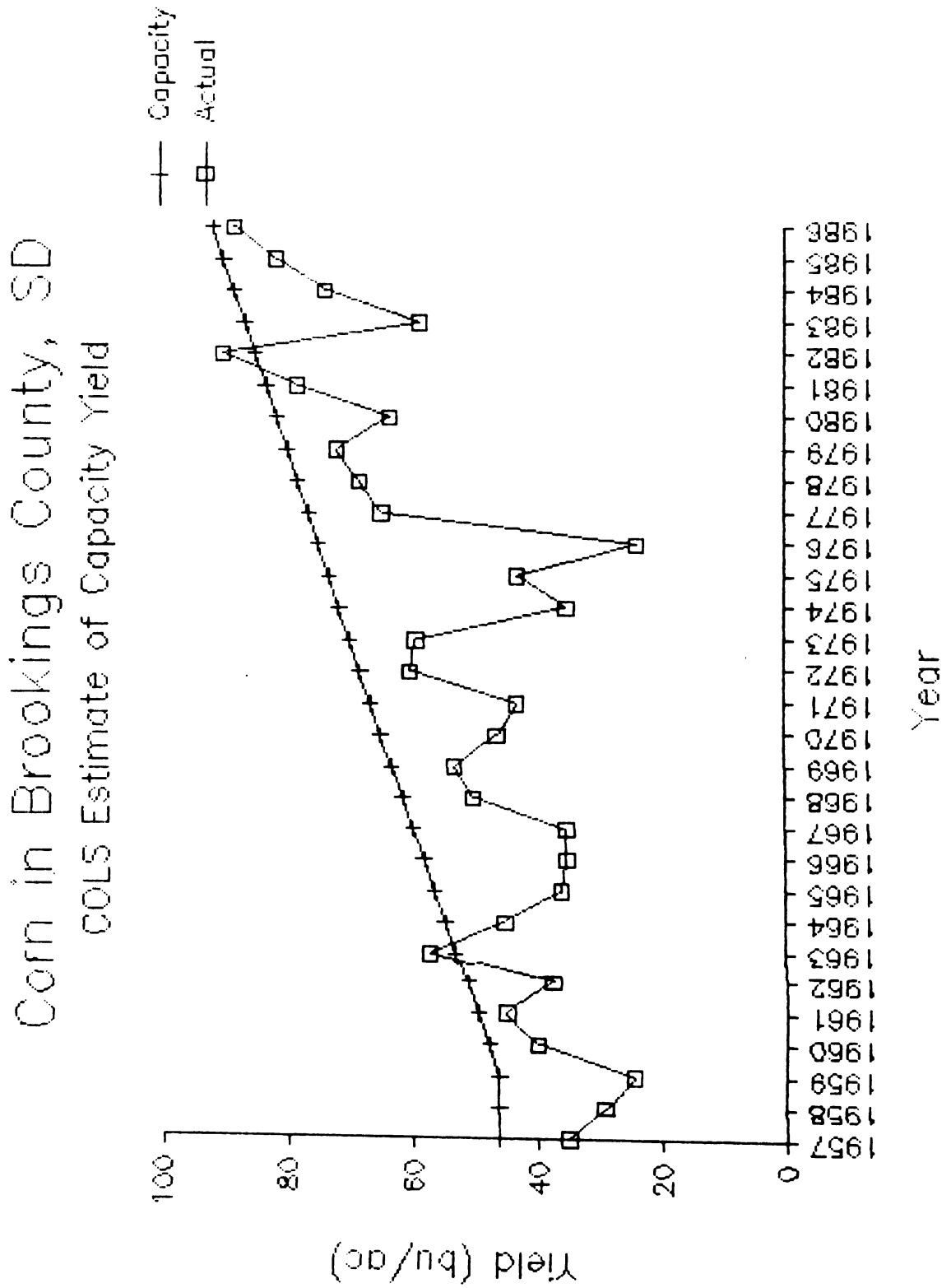

Figure E.1 Comparison of COLS Capacity and Actual Corn Yields Based on the Technological Trend in Corn Yields in Brookings County, South Dakota. (See Equation 6.5 in Chapter Six, and Tables E.3 and E.4 in Appendix E).

Table E.5 Comparison of COLS Capacity, Actual and OLS Fitted Yields for a Stochastic Corn Yield Capacity Function Based on Technological Trend and Lagged Output/Input Price Ratio in Brookings County, South Dakota. (See Equation 6.4 and Table 6.2 in Chapter Six, and Figure E.2 in Appendix E).

Dependent Variable: Brookings County-Level Corn Yield
Independent Variable: Linear Technological Trend
Independent Variable: Ratio of Lagged Annual Corn Price to Fertilizer Price Index

Year	Observation #	Corn: COLS Capacity Yield OLS Residuals	Corn: Initial COLS Estimate of Capacity Corn Yield	Actual Yield	OLS Fitted Yield
1957	1.000000	-2.98	37.97	34.995000	26.660000
1958	2.000000	-20.54	49.54	28.998000	38.230000
1959	3.000000	-22.56	47.06	24.503000	35.750000
1960	4.000000	-9.02	49.01	39.997000	37.700000
1961	5.000000	-9.28	54.28	45.000000	42.970000
1962	6.000000	-14.79	52.29	37.505000	40.980000
1963	7.000000	4.52	52.48	57.002000	41.170000
1964	8.000000	-9.90	54.90	44.999000	43.590000
1965	9.000000	-15.65	51.65	36.004000	40.340000
1966	10.000000	-17.73	52.73	35.003000	41.420000
1967	11.000000	-16.16	51.16	35.000000	39.850000
1968	12.000000	-4.93	54.93	49.998000	43.620000
1969	13.000000	-.10	53.09	52.996000	41.780000
1970	14.000000	-9.03	55.03	46.002000	43.720000
1971	15.000000	-7.75	50.75	43.001000	39.440000
1972	16.000000	-.50	60.50	60.004000	49.190000
1973	17.000000	-5.70	64.70	59.004000	53.390000
1974	18.000000	-23.20	58.19	34.995000	46.880000
1975	19.000000	-22.54	65.44	42.900000	54.130000
1976	20.000000	-37.45	61.24	23.796000	49.930000
1977	21.000000	1.62	62.88	64.504000	51.570000
1978	22.000000	-8.90	76.90	68.002000	65.590000
1979	23.000000	-8.88	80.58	71.699000	69.270000
1980	24.000000	-24.16	87.35	63.196000	76.040000
1981	25.000000	-1.45	79.45	77.998000	68.140000
1982	26.000000	-.49	90.39	89.900000	79.080000
1983	27.000000	-28.64	87.14	58.501000	75.830000
1984	28.000000	-8.25	81.95	73.700000	70.640000
1985	29.000000	-8.74	90.04	81.305000	78.730000
1986	30.000000	-6.19	94.19	88.003000	82.880000
	Average =	-11.312687	63.596354	52.283667	52.283667

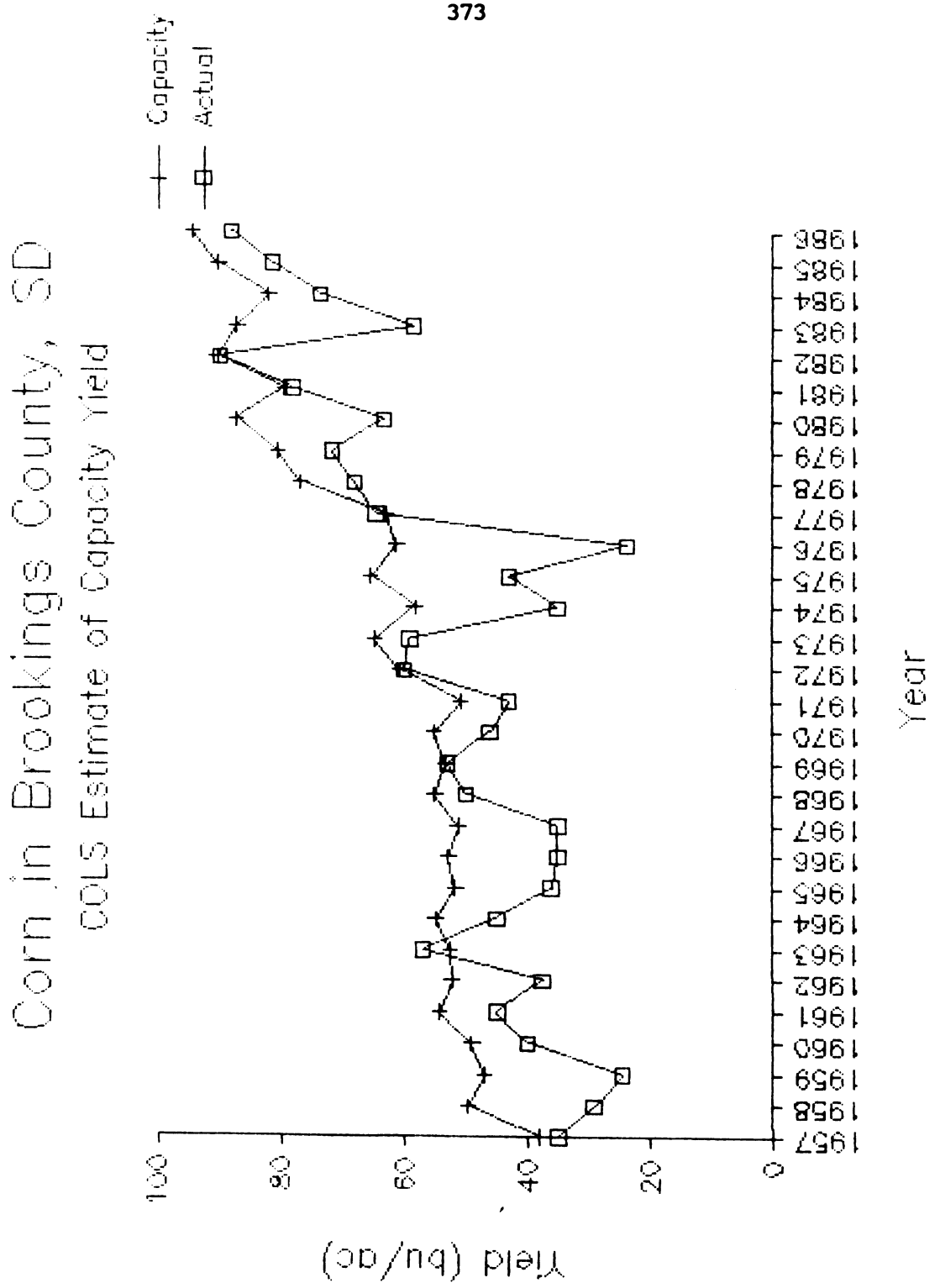

Figure E.2 Comparison of COLS Capacity and Actual Corn Yields Based on Technological Trend and Lagged Output/Input Price Ratio for Yields in Brookings County, South Dakota. (See Equation 6.4 and Table 6.2 in Chapter Six, and Table E.5 in Appendix E).

Table E.6 Comparison of COLS Capacity, Actual and OLS Fitted Yields for a Stochastic Soybean Yield Capacity Function in Brookings County, South Dakota. (See Equation 6.5 in Chapter Six, and Figure E.3 in Appendix E).

Dependent Variable: Brookings County-Level Soybean Yield
Independent Variable: Linear Technological Trend

Year	Observation #	Soybeans: COLS Capacity Yield OLS Residuals	Soybeans: Initial COLS Estimate of Capacity Yield (bu/ac)	Actual Yield	OLS Fitted Yield
1957	1	-3.339774	16.842774	13.503000	11.560000
1958	2	-7.339774	16.842774	9.503000	11.560000
1959	3	-6.409774	17.412774	11.003000	12.130000
1960	4	-2.978774	17.982774	15.004000	12.700000
1961	5	-.548774	18.552774	18.004000	13.270000
1962	6	-6.617774	19.112774	12.495000	13.830000
1963	7	2.313226	19.682774	21.996000	14.400000
1964	8	-4.256774	20.252774	15.996000	14.970000
1965	9	-9.825774	20.822774	10.997000	15.540000
1966	10	-6.395774	21.392774	14.997000	16.110000
1967	11	-10.464774	21.962774	11.498000	16.680000
1968	12	-5.533774	22.532774	16.999000	17.250000
1969	13	-3.103774	23.102774	19.999000	17.820000
1970	14	-7.672774	23.672774	16.000000	18.390000
1971	15	-8.742774	24.242774	15.500000	18.960000
1972	16	-1.811774	24.812774	23.001000	19.530000
1973	17	-6.380774	25.382774	19.002000	20.100000
1974	18	-8.950774	25.952774	17.002000	20.670000
1975	19	-5.619774	26.522774	20.903000	21.240000
1976	20	-18.689774	27.092774	8.403000	21.810000
1977	21	-2.258774	27.662774	25.404000	22.380000
1978	22	-1.228774	28.232774	27.004000	22.950000
1979	23	-2.697774	28.792774	26.095000	23.510000
1980	24	-4.066774	29.362774	25.296000	24.080000
1981	25	-4.736774	29.932774	25.196000	24.650000
1982	26	.694226	30.502774	31.197000	25.220000
1983	27	-2.275774	31.072774	28.797000	25.790000
1984	28	-10.044774	31.642774	21.598000	26.360000
1985	29	-5.113774	32.212774	27.099000	26.930000
1986	30	-4.383774	32.782774	28.399000	27.500000
	Averages:	-5.282774	24.545774	19.263000	19.263000

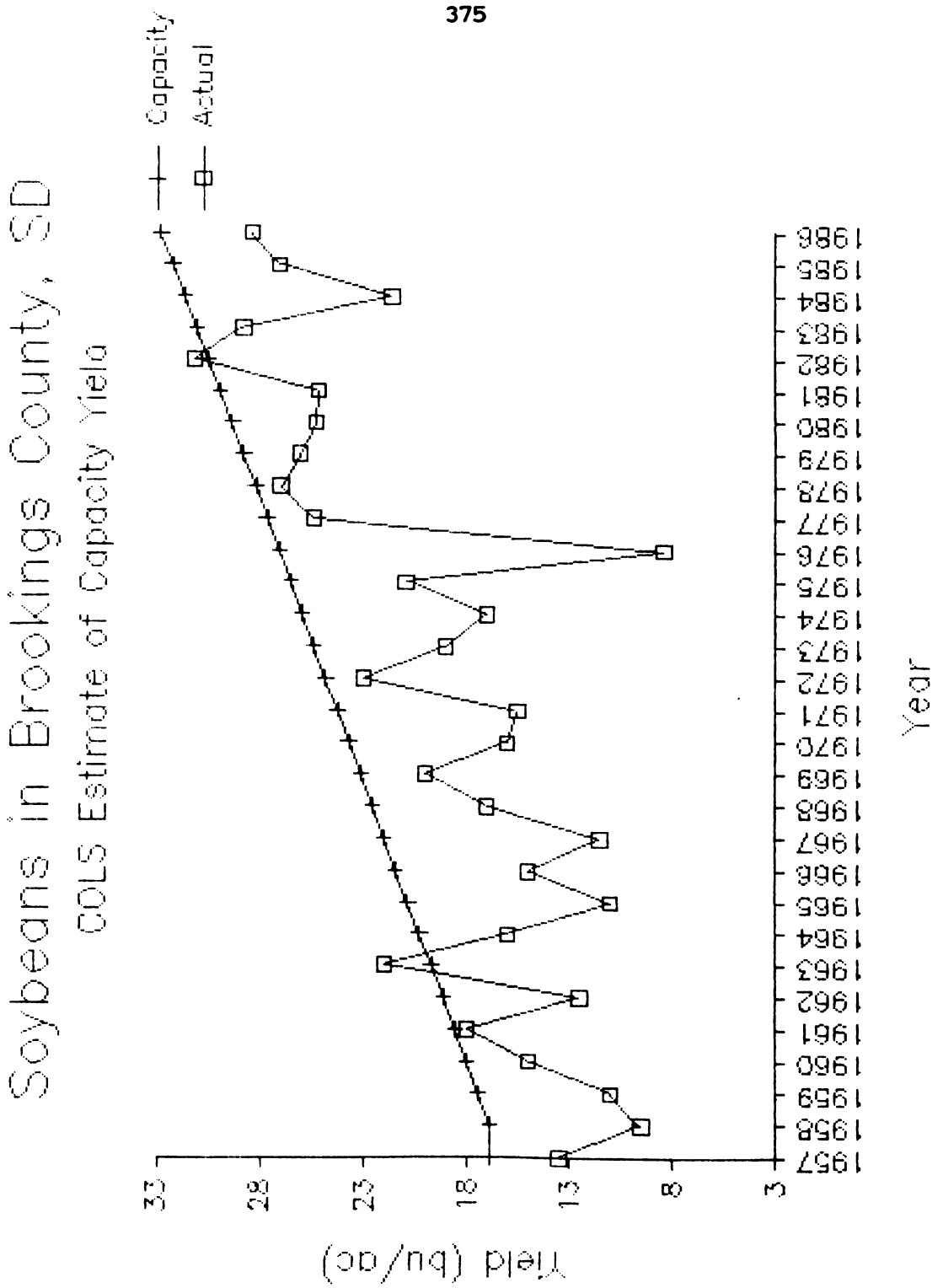

Figure E.3 Comparison of COLS Capacity and Actual Soybean Yields Based on the Technological Trend in Soybean Yields in Brookings County, South Dakota. (See Equation 6.5 in and Table 6.3 in Chapter Six, and Table E.6 in Appendix E).

Table E.7 Comparison of COLS Capacity, Actual and OLS Fitted Yields for a Stochastic Oats Yield Capacity Function in Brookings County, South Dakota. (See Equation 6.5 in Chapter Six, and Figure E.4 in Appendix E).

Dependent Variable: Brookings County-Level Oats Yield
Independent Variable: Linear Technological Trend

Year	Observation #	Oats: COLS Capacity Yield OLS Residuals	Oats: Initial COLS Estimate of Capacity Yield	Actual Yield	OLS Fitted Yield
1957	1.00	-10.38	51.38	41.00	41.35
1958	2.00	-4.88	51.38	46.50	41.35
1959	3.00	-26.88	51.38	24.50	41.35
1960	4.00	-3.00	52.00	49.00	41.97
1961	5.00	-3.61	52.61	49.00	42.58
1962	6.00	-14.23	53.23	39.00	43.20
1963	7.00	-18.85	53.85	35.00	43.82
1964	8.00	-18.46	54.46	36.00	44.43
1965	9.00	-4.08	55.08	51.00	45.05
1966	10.00	-15.20	55.70	40.50	45.67
1967	11.00	-4.31	56.31	52.00	46.28
1968	12.00	1.07	56.93	58.00	46.90
1969	13.00	-2.05	57.55	55.50	47.52
1970	14.00	-8.66	58.16	49.50	48.13
1971	15.00	-5.78	58.78	53.00	48.75
1972	16.00	-14.40	59.40	45.00	49.37
1973	17.00	-6.11	60.01	53.90	49.98
1974	18.00	-9.83	60.63	50.80	50.60
1975	19.00	-6.55	61.24	54.70	51.22
1976	20.00	-32.36	61.86	29.50	51.83
1977	21.00	-1.48	62.48	61.00	52.45
1978	22.00	-14.19	63.09	48.90	53.07
1979	23.00	-5.71	63.71	58.00	53.68
1980	24.00	-11.33	64.33	53.00	54.30
1981	25.00	-7.24	64.94	57.70	54.92
1982	26.00	4.44	65.56	70.00	55.53
1983	27.00	-20.28	66.18	45.90	56.15
1984	28.00	-8.89	66.79	57.90	56.77
1985	29.00	-6.61	67.41	60.80	57.38
1986	30.00	-21.03	68.03	47.00	58.00
	Average =	-10.028407	59.148374	49.119967	49.120000

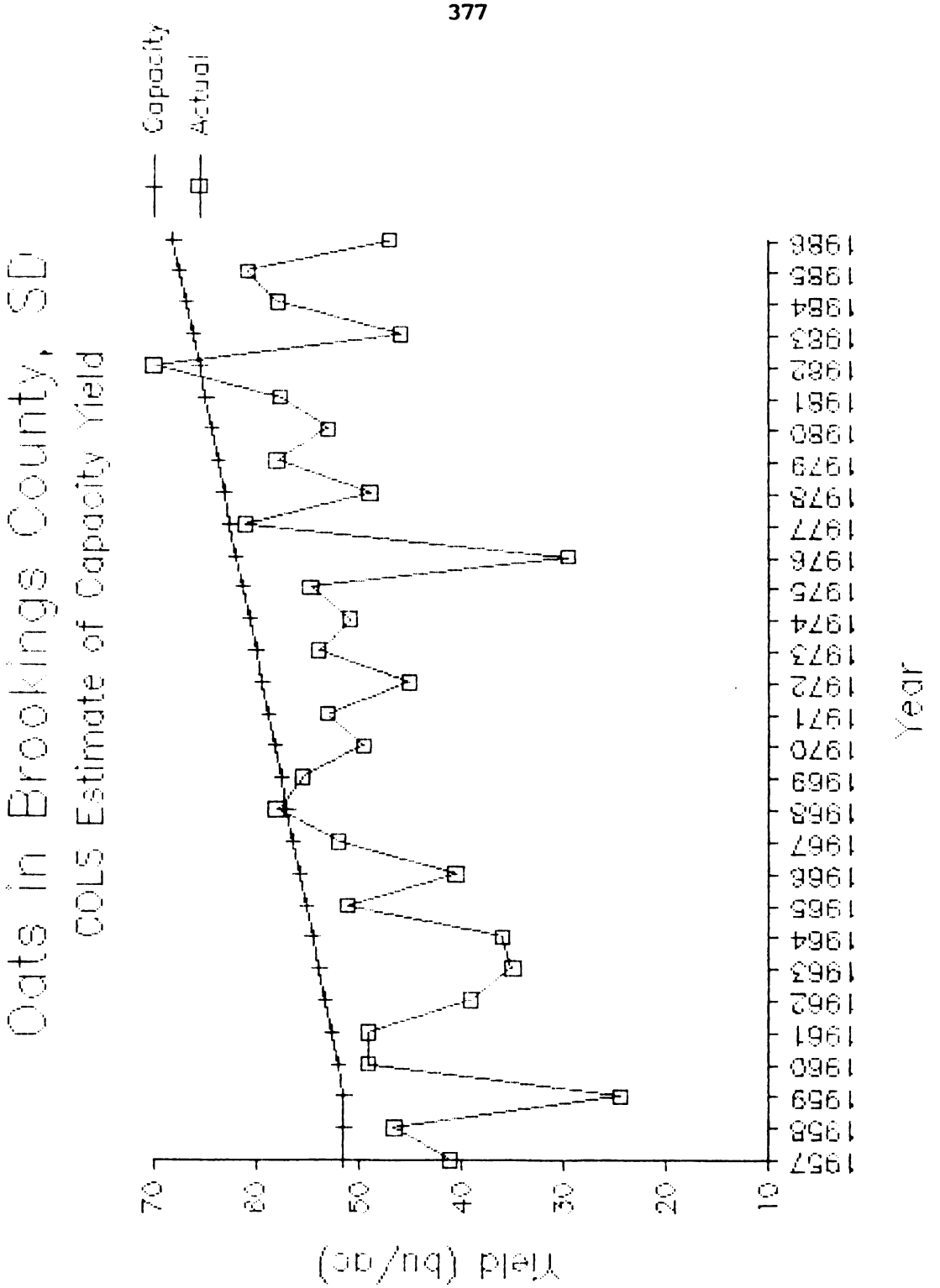

Figure E.4 Comparison of COLS Capacity and Actual Oats Yields Based on the Technological Trend in Oats Yields in Brookings County, South Dakota. (See Equation 6.5 in and Table 6.4 in Chapter Six, and Table E.7 in Appendix E).

APPENDIX F

Graphical Comparisons of Cumulative Density Functions for Aggregated-Elicited, Capacity-Derived and Historical-Frequency Crop Yield Probability Distributions

APPENDIX F

Graphical Comparisons of Cumulative Density Functions for Aggregated-Elicited, Capacity-Derived and Historical-Frequency Crop Yield Probability Distributions

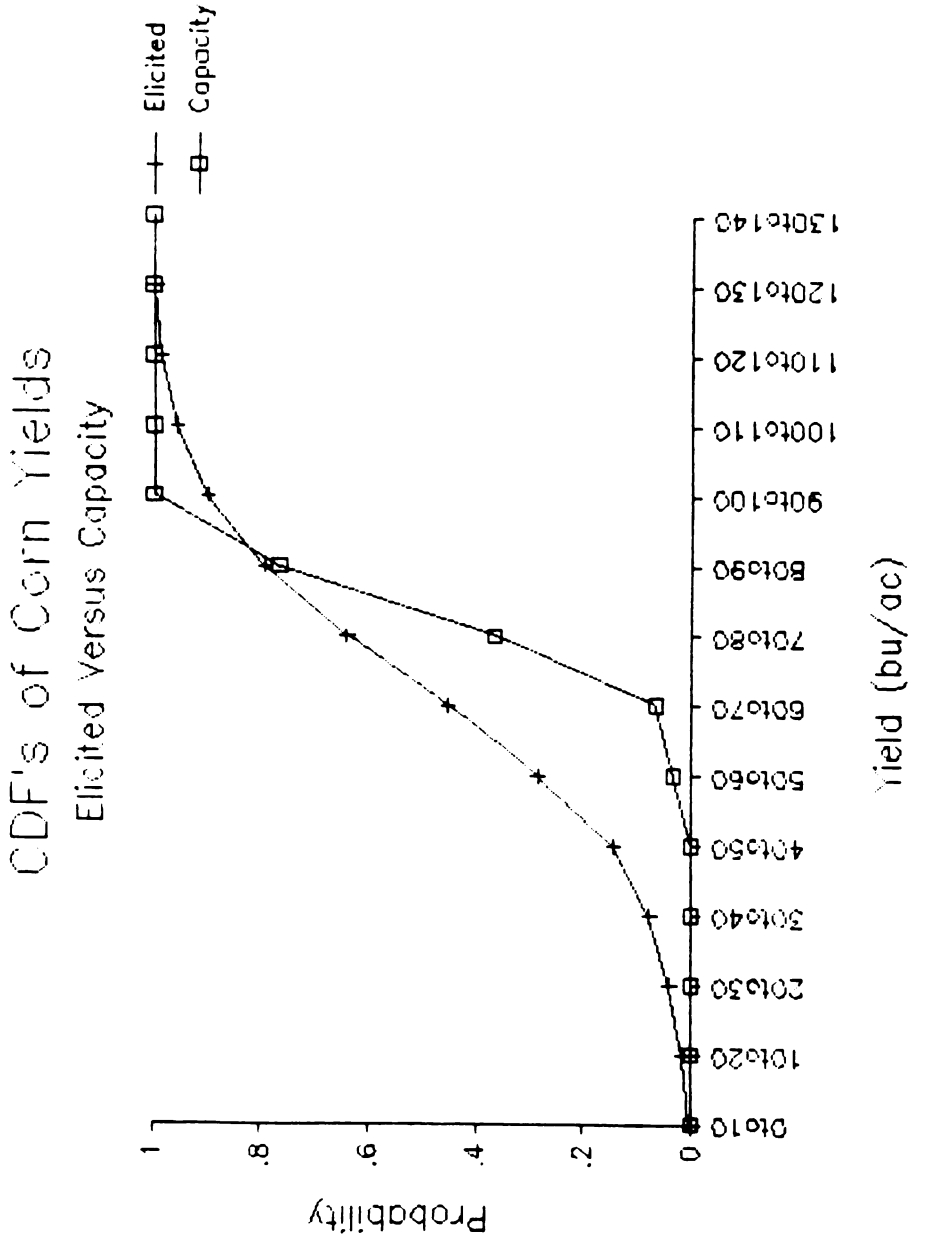

Figure F.1 Comparison of Aggregated-Elicited and Capacity-Derived Cumulative Density Functions for Corn Yield Probability Distributions in Brookings County, South Dakota.

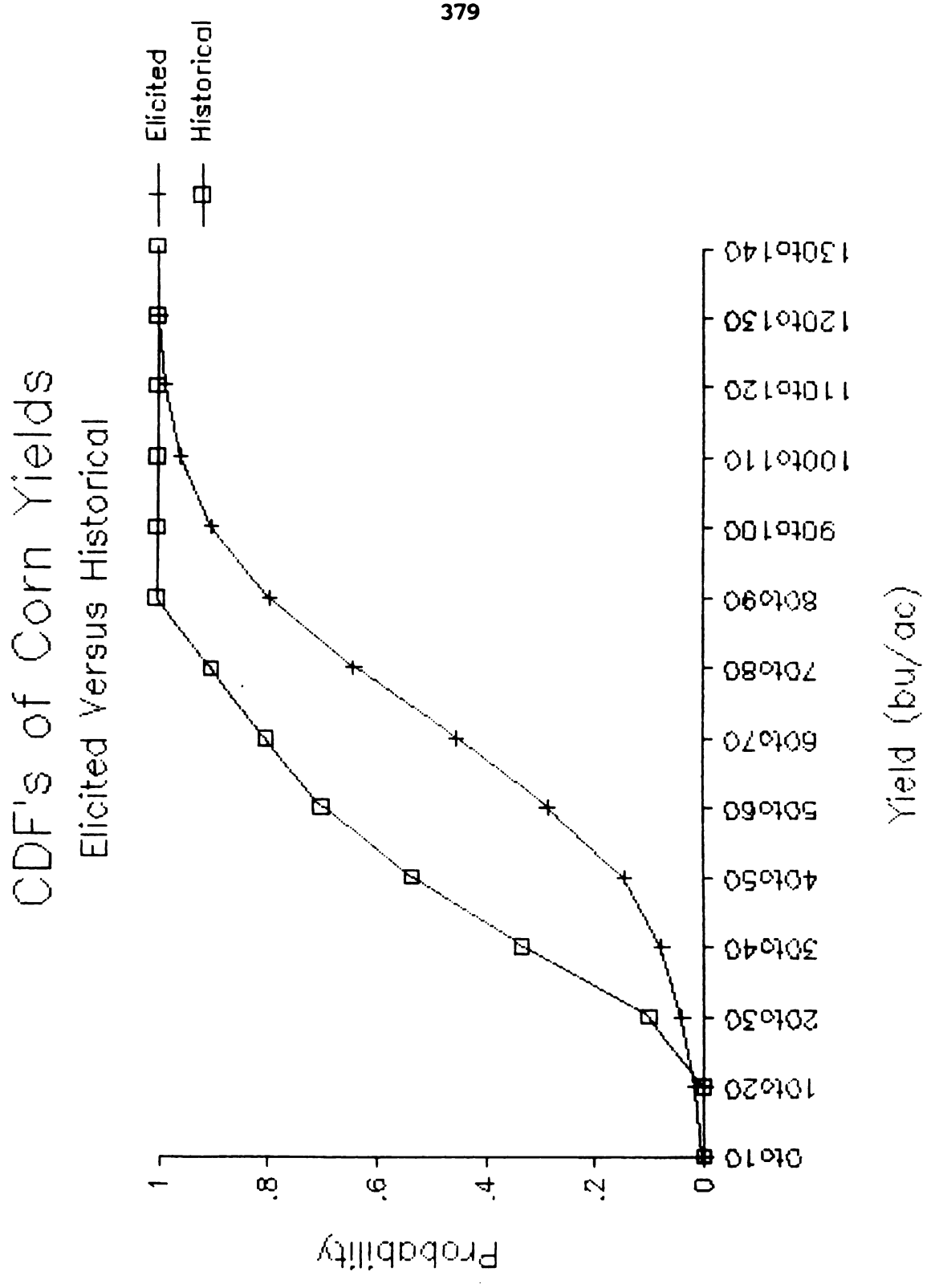

Figure F.2 Comparison of Aggregated-Elicited and Historical-Frequency Cumulative Density Functions for Corn Yield Probability Distributions in Brookings County, South Dakota.

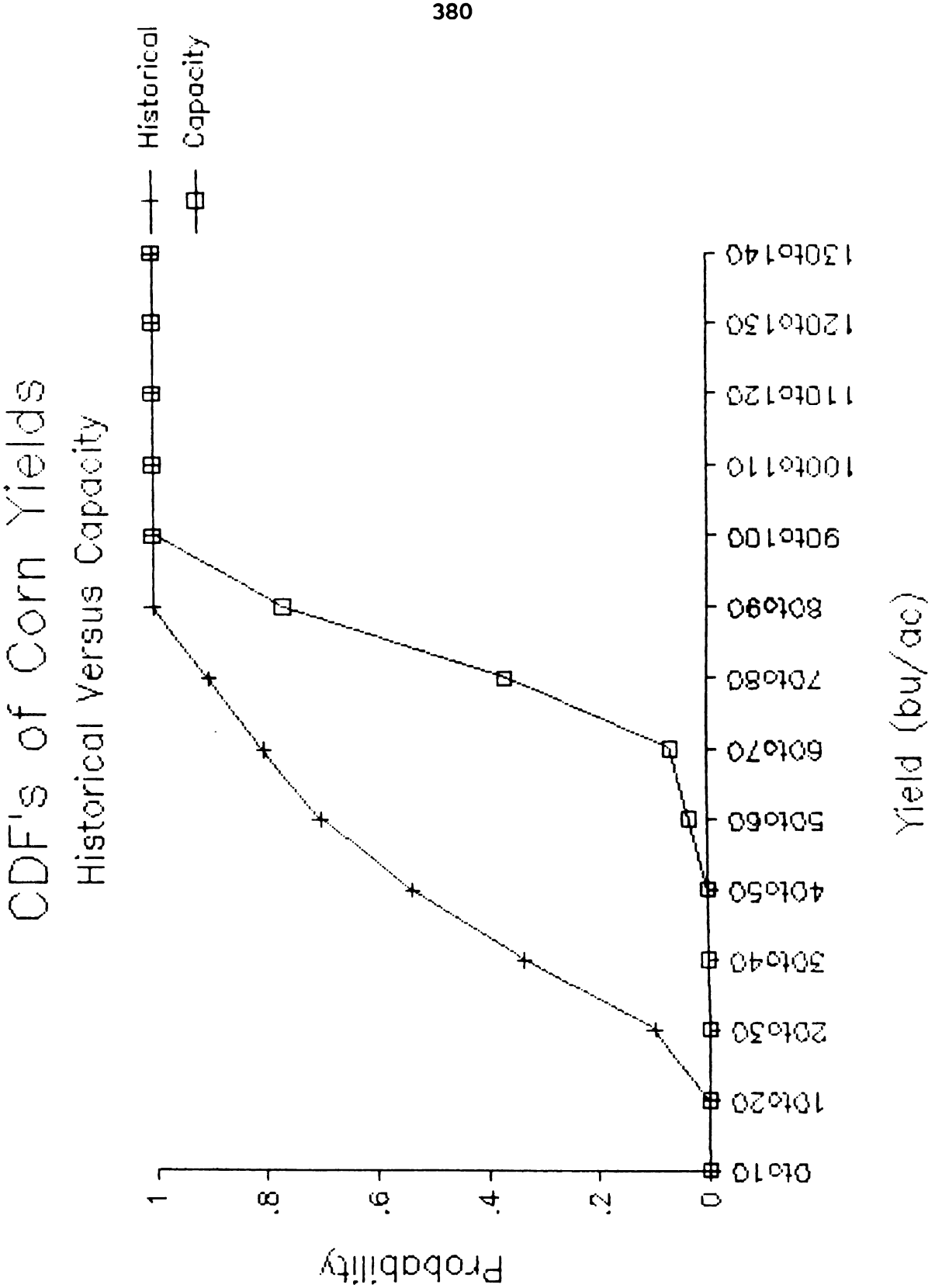

Figure F.3 Comparison of Capacity-Derived and Historical-Frequency Cumulative Density Functions for Corn Yield Probability Distributions in Brookings County, South Dakota.

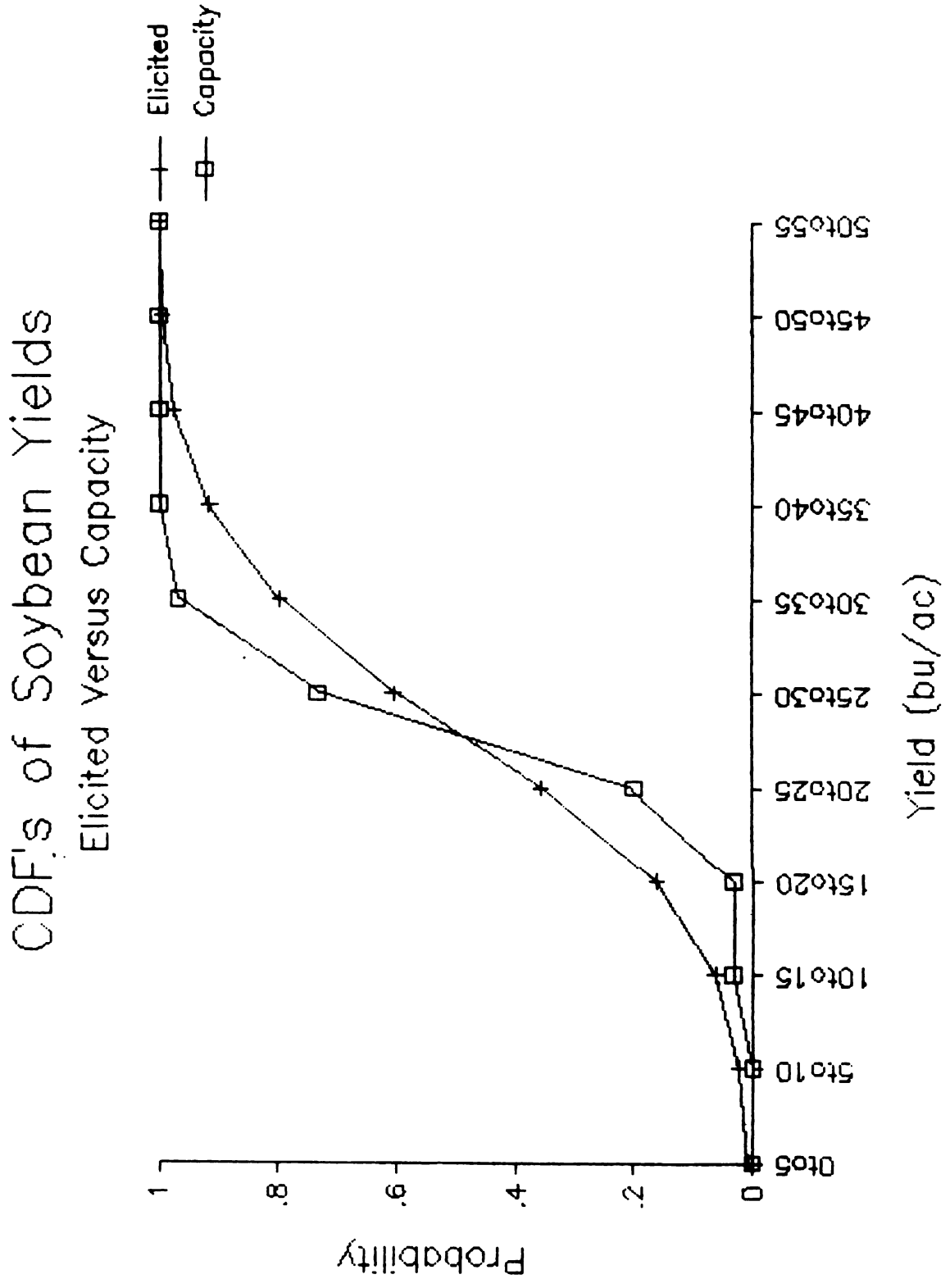

Figure F.4 **Comparison of Aggregated-Elicited and Capacity-Derived Cumulative Density Functions for Soybean Yield Probability Distributions in Brookings County, South Dakota.**

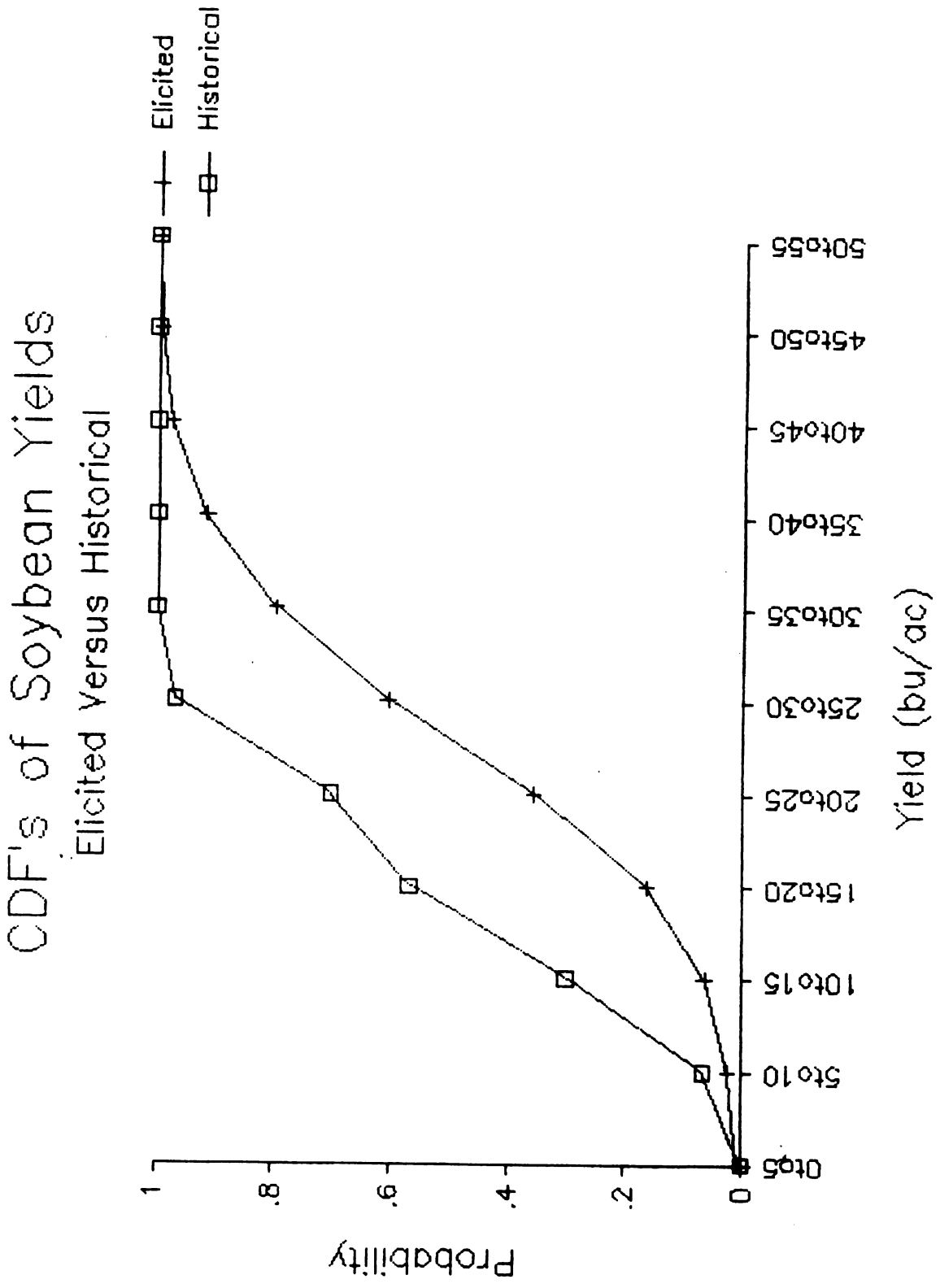

Figure F.5 **Comparison of Aggregated-Elicited and Historical-Frequency Cumulative Density Functions for Soybean Yield Probability Distributions in Brookings County, South Dakota.**

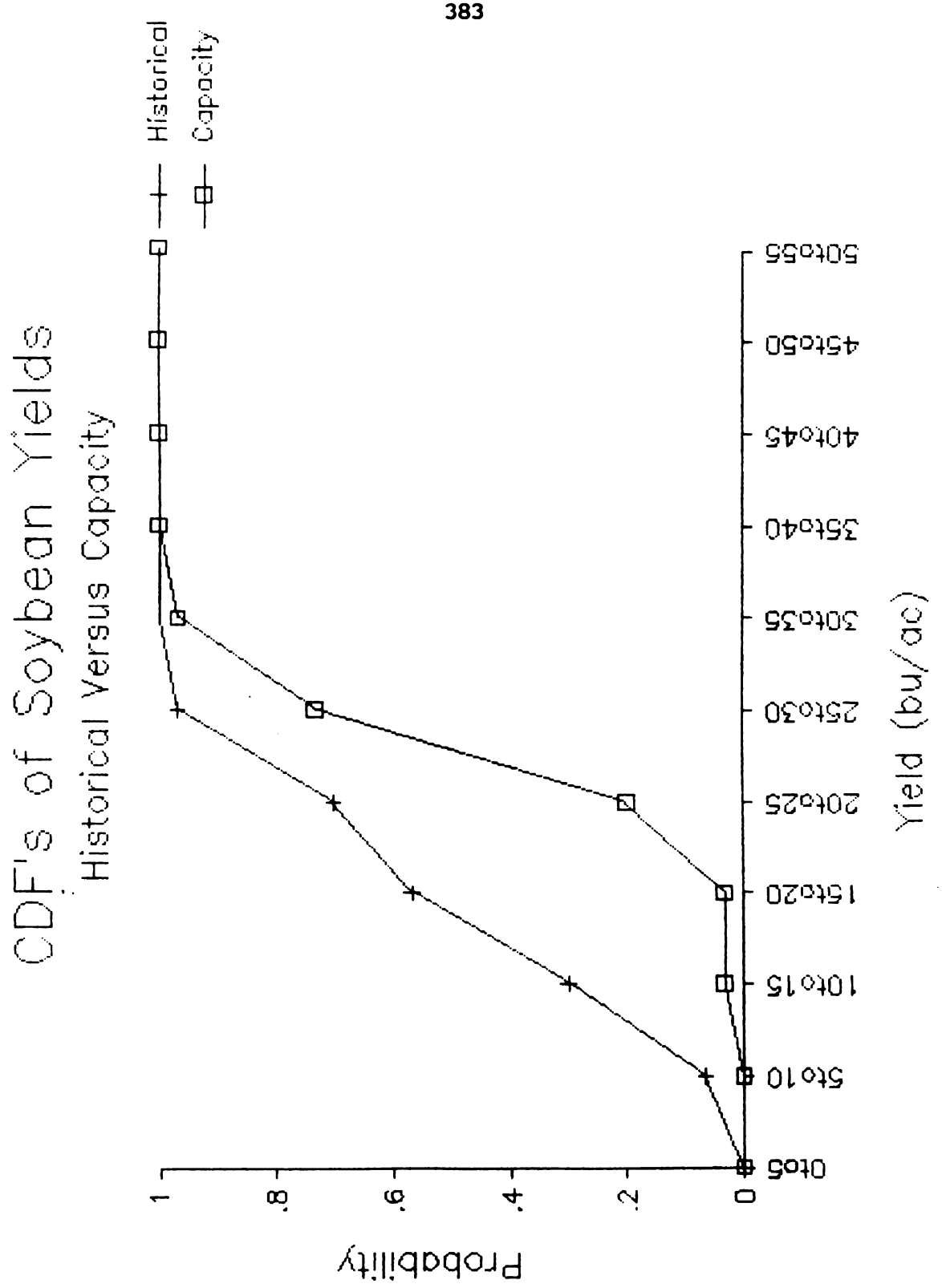

Figure F.6 Comparison of Capacity-Derived and Historical-Frequency Cumulative Density Functions for Soybean Yield Probability Distributions in Brookings County, South Dakota.

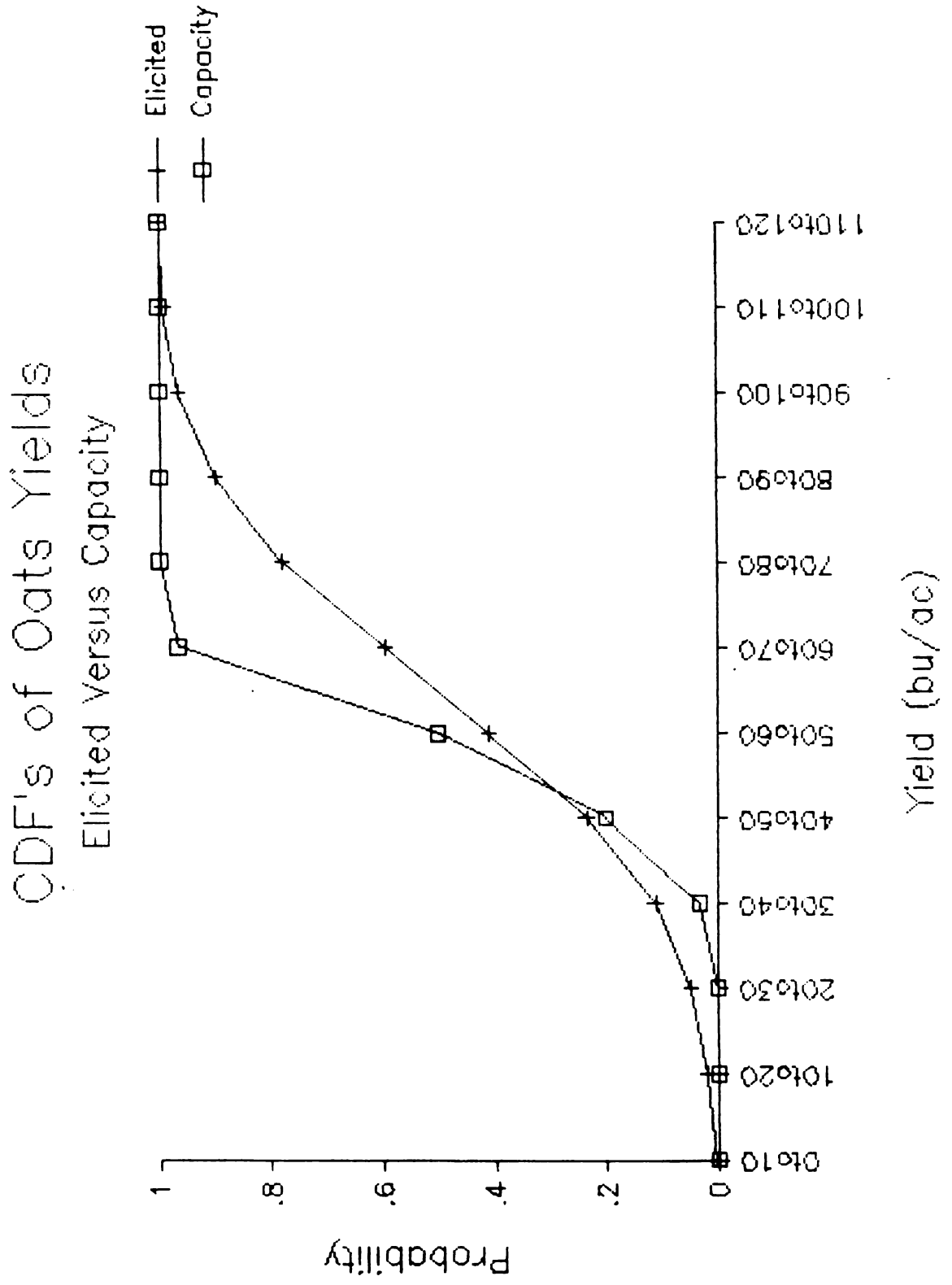

Figure F.7 Comparison of Aggregated-Elicited and Capacity-Derived Cumulative Density Functions for Oats Yield Probability Distributions in Brookings County, South Dakota.

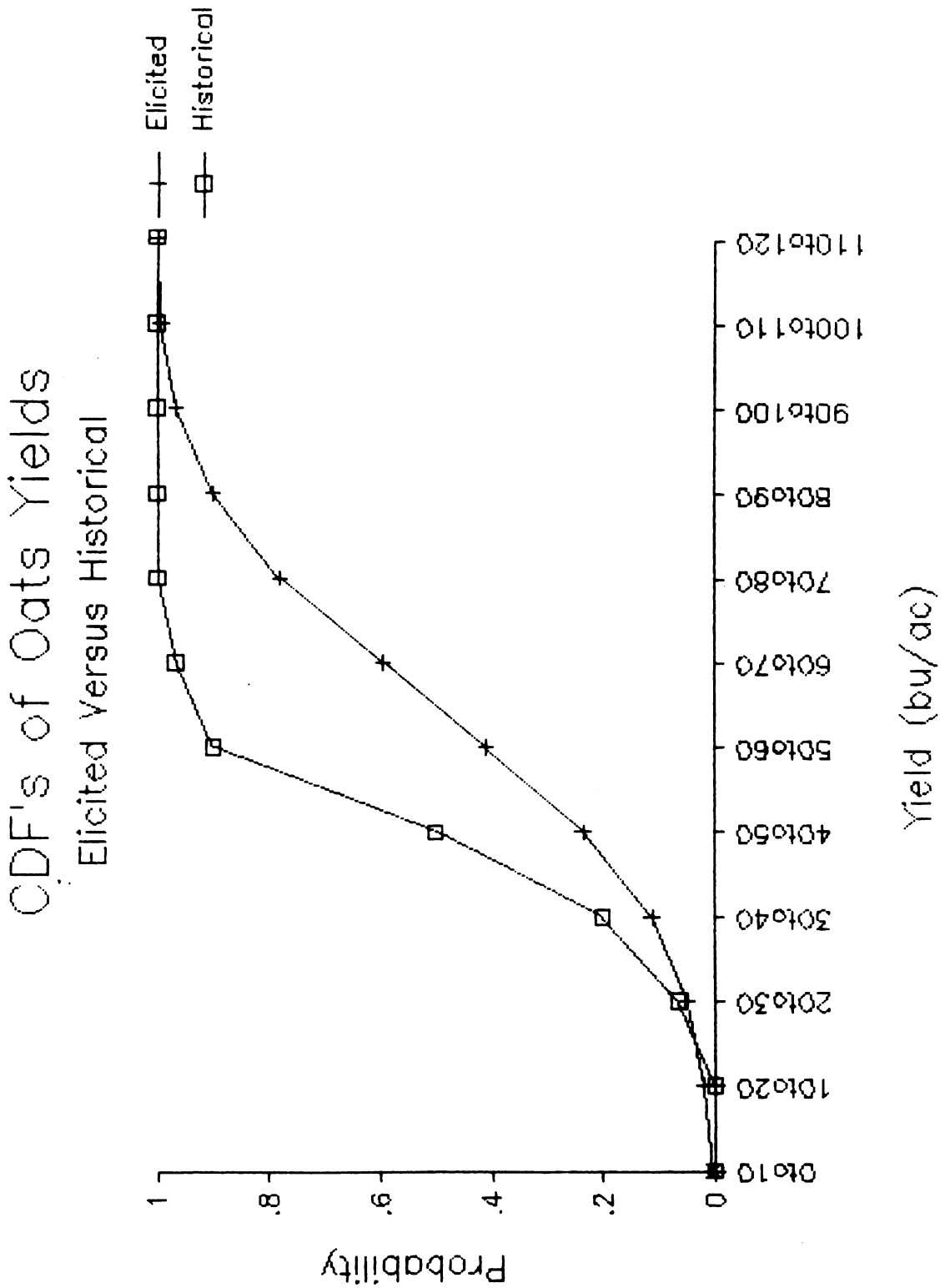

Figure F.8 Comparison of Aggregated-Elicited and Historical-Frequency Cumulative Density Functions for Oats Yield Probability Distributions in Brookings County, South Dakota.

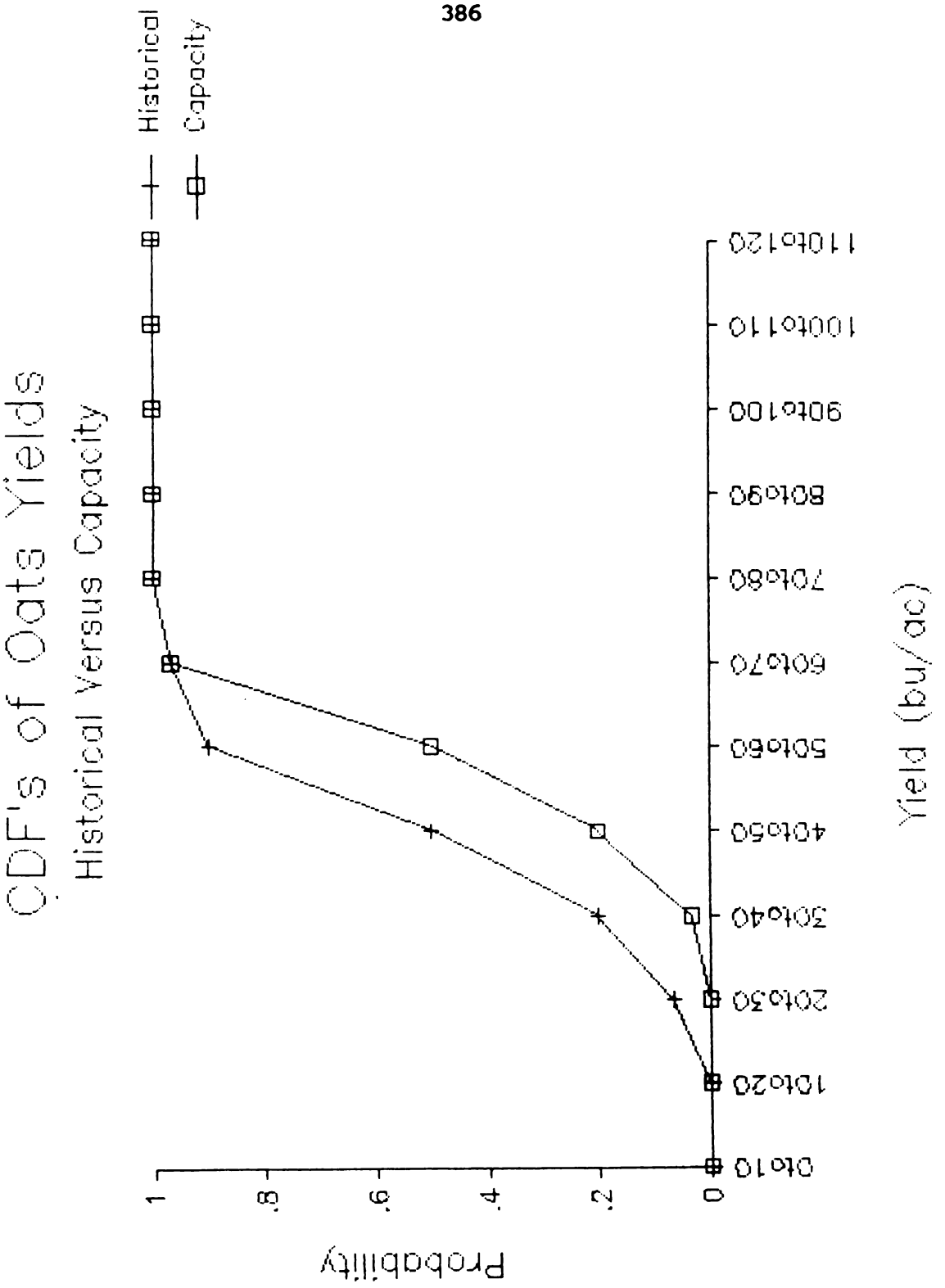

Figure F.9 Comparison of Capacity-Derived and Historical-Frequency Cumulative Density Functions for Oats Yield Probability Distributions in Brookings County, South Dakota.

APPENDIX G

Turbo-Pascal Code for a Computer Algorithm Designed to Model a Producer's Multiple Peril Crop Insurance (MPCI) Purchase Decision

APPENDIX G

Turbo-Pascal Code for a Computer Algorithm Designed to Model a Producer's Multiple Peril Crop Insurance (MPCI) Purchase Decision

```
{************************************************************
* PROGRAM: BROOKINGS_SD          FOR FILE: BSD91101.PAS  *
*                                                        *
* NOTE: PROGRAM WAS AN APPLICATION OF ROY BLACK'S        *
*       ANALYSIS OF AN MPCI PURCHASE DECISION FOR        *
*       WHEAT IN BANNER COUNTY, NEBRASKA.                *
*                                                        *
* Program calculates the mean, standard deviation and    *
* percentiles for yields and net cash flow with and      *
* without multiple peril crop insurance (MPCI). Model    *
* inputs include coverage, product price, costs, MPCI    *
* premium/acre, acres, crop yield probabilities, and     *
* initial wealth.                                        *
*                                                        *
* One module calculates expected utility.                *
*                                                        *
* Program can solve for the MPCI premium/acre that       *
* generates the same expected utility as generated by    *
* the no MPCI purchase strategy.                         *
*                                                        *
* Roy Black, Agr. Economics, Michigan State Univ,        *
* East Lansing, MI 48824                                 *
* Revised -- 4/27/88                                     *
*         -- 5/30/88                                     *
* Edited  -- 8/09/88 by Gerald Toland, South Dakota      *
*                                    State University    *
************************************************************}

program Brookings_SD; { Analysis of MPCI purchase decision
                        for coverage on a producer's corn
                        crop enterprise in Brookings
                        County, SD }
uses
   crt,printer;
```

```
type
   armax = array[1..1000] of real;          { array of dimension 1000 used for
                                              making random draws from a crop
                                              yield probability distribution
                                              (CYPD) }
   ar13 = array[1..13] of real;             { array of dimension thirteen for
                                              displaying a distribution in
                                              thirteen percentile intervals }
   st10 = string[10];                       { string for labeling the output }

   name_it = string[15];

var
   i, no_draws, kount:                        integer;

   avg_yield, std_dev_yield,
   avg_yield_MPCI, std_dev_yield_MPCI,
   coverage, yield_guarantee,
   Indifference_MPCI_premium,
   avg_net_cash_flow, std_dev_net_cash_flow,
   initial_wealth, avg_premium,
   std_dev_premium, EU_w_MPCI, EU_wo_MPCI,
   avg_BEFR, std_dev_BEFR,
   MPCI_yield_indemnity,
   avg_net_cash_flow_w_MPCI,
   std_dev_net_cash_flow_w_MPCI,
   local_risk_aversion, avg_yield_coverage,
   avg_sim_yield, std_dev_sim_yield,
   avg_sim_sd_yield, std_dev_sim_sd_yield :   real;

   yield, yield_MPCI, net_cash_flow,
   array_premium, array_BEFR,
   net_cash_flow_w_MPCI,
   array_yield, array_sd_yield :              armax;

   percentile :                               ar13;

const
 ACTUAL_MPCI_PREMIUM = 3.12;
      WEALTH_INITIAL = 38400.00;
 MPCI_PRICE_ELECTION = 1.50;
       MPCI_COVERAGE = 0.50;
           FILE_NAME = 'BSD91101.PAS ';
  MPCI_COVERAGE_PLAN = 'APH Plan';
       KOUNT_CONTROL = 10;
```

```
{ ********************************************************
* PROCEDURE: GENERATE_YIELDS                             *
* This procedure generates a vector of random variates   *
* called yield. There are N draws generating a vector    *
* yield of dimension N. The underlying probability       *
* distribution is empirical. The distribution is         *
* derived from elicitations of producers' personal       *
* crop yield probabilities.                              *
*                                                        *
* See A.M. Law and W.D. Kelton. 1982. Simulation Modeling *
* and Analysis. McGraw Hill. pp. 261 ff.                 *
*                                                        *
* CDF for producers with a historical mean in the 91 - 101*
* bu/acre range. Brookings County, SD.                   *
******************************************************** }

procedure generate_yields(N: integer;
                    var x: arrmax);
   var
      cdf,i : integer;
   begin
      for i := 1 to N do begin
         cdf := random(1000);
         case cdf of
            0 ..    2: x[i] :=  0.0 + ((cdf -   0.0) /   2.0) * 10.0;
            3 ..    6: x[i] := 10.0 + ((cdf -   3.0) /   4.0) * 10.0;
            7 ..   18: x[i] := 20.0 + ((cdf -   7.0) /  12.0) * 10.0;
           19 ..   41: x[i] := 30.0 + ((cdf -  19.0) /  22.0) * 10.0;
           42 ..   82: x[i] := 40.0 + ((cdf -  42.0) /  41.0) * 10.0;
           83 ..  149: x[i] := 50.0 + ((cdf -  83.0) /  67.0) * 10.0;
          150 ..  269: x[i] := 60.0 + ((cdf - 150.0) / 120.0) * 10.0;
          270 ..  412: x[i] := 70.0 + ((cdf - 270.0) / 143.0) * 10.0;
          413 ..  565: x[i] := 80.0 + ((cdf - 413.0) / 153.0) * 10.0;
          566 ..  769: x[i] := 90.0 + ((cdf - 566.0) / 204.0) * 10.0;
          770 ..  902: x[i] :=100.0 + ((cdf - 770.0) / 133.0) * 10.0;
          903 ..  963: x[i] :=110.0 + ((cdf - 903.0) /  61.0) * 10.0;
          964 ..  990: x[i] :=120.0 + ((cdf - 964.0) /  27.0) * 10.0;
          991 ..  996: x[i] :=130.0 + ((cdf - 991.0) /   6.0) * 10.0;
          997 .. 1000: x[i] :=140.0 + ((cdf - 997.0) /   4.0) * 10.0;
         else writeln('error');
        end; { case }
      end; { for }
   end; { generate_yields }
```

```
{ ********************************************************
* PROCEDURE: CALC_STAT                                   *
* Procedure calculates the mean and variance of a vector *
* x with dimension 'N'. The procedure returns the mean   *
* and the standard deviation.                            *
******************************************************** }

procedure calc_stat (N:       integer;
                     x:       armax;
                 var mean,
                     std_dev: real);
   var
      i: integer;
      sum_1, sum_2, deviation: real;

    begin
      sum_1 := 0.0;
      for i := 1 to N do
         sum_1 := sum_1 + x[i];
      mean := sum_1/N;

      sum_2 := 0.0;
      for i := 1 to N do begin
        deviation := (x[i] - mean);
        sum_2 := sum_2 + deviation*deviation;
    end;

    std_dev := sqrt(sum_2/(N-1));

end; { calc stat }



{ ********************************************************
* PROCEDURE: PRINT_STAT                                  *
* Procedure prints the mean and variance of a vector     *
* x with dimension 'N'. The  procedure 'calc_stat'       *
* must be run first to obtain the mean and the standard  *
* deviation.                                             *
******************************************************** }

procedure print_stat (title:   st10;
                      mean,
                      std_dev: real);

   begin
      writeln( lst, title,
                  ' mean = ',mean:12:2,
                  '  std dev = ',std_dev:12:2);
   end; { print_stat }
```

```
{ ********************************************************
* PROCEDURE: SHELLSORT                                   *
* Procedure sorts a vector 'x' of  dimension N into      *
* ascending order using the shell sort procedure. The    *
* shell sort algorithm was applied to this program by    *
* J. Roy Black, AgEcon Dept, Michigan State University.  *
* ******************************************************** }

procedure shellsort (N: integer;
                     var x: armax);
   label 0;
   var
      v: real;
      i, j, h: integer;
   begin
      h := 1;
     repeat
        h := 3*h + 1
     until h > N;
     repeat
        h := h div 3;
        for i := h + 1 to N do begin
           v := x[i]; j := i;
           while x[j - h] > v do begin
              x[j] := x[j - h];
              j := j - h;
              if j <= h then goto 0
           end; { while }
        0: x[j] := v
        end; { for }
     until h = 1;
   end; { shell sort }
```

```
{ ********************************************************
* PROCEDURE: CALC_PERCENTILES                            *
* Procedure takes a  vector 'x' of  dimension N thats    *
* been sorted into ascending order and calculated the    *
* associated percentiles. They are identified according  *
* to the rule that the location of the n'th percentile is *
* N*percentile.                                          *
* ******************************************************** }

procedure calc_percentiles (N: integer;
                            x: armax;
                        var percentile: ar13);
  const
     p: array[1..13] of real =
    (0.01,0.03,0.05,0.10,0.20,0.30,0.40,0.50,0.60,0.70,0.80,0.90,0.95);

  var
     i:        integer;
     location: array[1..13] of integer;
     temp:     real;

    begin
      writeln;
      for i := 1 to 13 do
       begin
        temp := p[i]*N;
        if temp <= 0.5 then
         begin
          location[i] := 1;
          percentile[i] := x[location[i]];
         end
        else
         begin
          location[i] := round(temp);
          percentile[i] := x[location[i]];
          { writeln(i:10,location[i]:10,percentile[i]:10:2); }
         end; { else }
       end; { for do statement }
  end;  { calc_percentiles }
```

```
{ ************************************************************
* PROCEDURE: PRINT_PERCENTILES                               *
* The procedure print_percentiles takes the output of        *
* the procedure calc_percentiles and sends it either to      *
* a CRT computer screen or a computer printer.               *
************************************************************ }

procedure print_percentiles(title: st10;
                            percentile: ar13);
   const
      p: array[1..13] of real =
        (1, 3, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95);
   var
      i: integer;

   begin
      writeln( { lst, } 'percentile '
                ,title);
      for i := 1 to 13 do
        writeln( { lst, }  p[i]:5:0,
                      '   ',
                   percentile[i]:12:4);
   end;
```

```
{ ********************************************************
* PROCEDURE: FILE_OUT_PERCENTILES                       *
* This procedure takes the output of the calc_percentile *
* procedure and places it in an ASCII file. The ASCII    *
* file will eventually be inputted to a spreadsheet,     *
* and the spreadsheet will be used to construct graphs   *
* of the cumulative density functions of yields and net  *
* cash flows.                                            *
******************************************************** }
procedure file_out_percentiles(title: st10;
                               percentile: ar13);

 const
     p: array[1..13] of real =
       (1, 3, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95);
   var
          i:  integer;
     outfile:  text;

   begin
     {$I-}
     assign(outfile,'APHIW3C3.TXT');
     reset(outfile);
     if ioresult <> 0 then writeln('new file');
     {$I+}
     append(outfile);
     writeln(outfile, 'percentile '
               ,title);
     for i := 1 to 13 do
       writeln(outfile, p[i]:5:0,
                     ' ',
                   percentile[i]:12:4);
     close(outfile);
   end; { file_out_percentiles }
```

```
{ ********************************************************
* PROCEDURE: CALC_STATISTICS                             *
* This procedure calculates the mean, variance, and      *
* percentiles associated with a vector 'x' of dimension  *
* N. The resultant statistics are printed.               *
* ******************************************************** }

procedure calc_statistics(N: integer;
                          x: armax;
                          title: st10;
                      var mean, std_dev: real);
   begin
      calc_stat(N,
                x,
                mean,
                std_dev);

      print_stat(title,
                 mean,
                 std_dev);


      shellsort(N,x);

      calc_percentiles(N,
                       x,
                       percentile);

      print_percentiles(title,
                        percentile);

      file_out_percentiles(title,
                           percentile);


  end; { calc_statistics }
```

```
{ ********************************************************
* PROCEDURE: CALC_STATISTICS_BASIC                      *
* This procedure calculates the mean and variance       *
* associated with a vector 'x' of dimension N.          *
* The resultant statistics are printed.                 *
* ******************************************************** }

procedure calc_statistics_basic(N: integer;
                                x: armax;
                            title: st10;
                var mean, std_dev: real);

   begin
      calc_stat(N,
                x,
                mean,
                std_dev);

      print_stat(title,
                 mean,
                 std_dev);

  end; { calc_statistics_basic }
```

```
{ ************************************************************
* PROCEDURE: CALC_NET_CASH_FLOW                              *
* Procedure calculates net cash flow given yields, price,    *
* costs and premium.                                         *
* ************************************************************ }

procedure calc_net_cash_flow(N: integer;
                             yield: armax;
                             price,
                             deficiency,
                             acres_crop,
                             acres_setaside,
                             ASCS_program_yield,
                             cost_base,
                             cost_proportional,
                             cost_setaside,
                             cost_overhead,
                             cost_land_control,
                             premium: real;
                          var net_cash_flow: armax);

    var
       i: integer;

    begin
       for i:= 1 to N do
        begin
          net_cash_flow[i] :=
             ( price * yield[i] + deficiency * ASCS_program_yield )
                       * acres_crop

             - ( (cost_base + cost_proportional * yield[i] + premium)
                    * acres_crop
                 +  cost_setaside *  acres_setaside
                 + (cost_overhead + cost_land_control)
                    * (acres_crop + acres_setaside) );
        end; { for statement }
    end; {calc_net_cash_flow }
```

```
{ ********************************************************
* PROCEDURE: CALC_YIELD_GUARANTEE                        *
* This procedure calculates the MPCI yield guarantee,    *
* given the mean of the yield distribution and the level *
* of coverage selected.                                  *
*                                                        *
* See Black and Schwab. 1988. MPCI: What is it? Should   *
* you buy it?. Ag Economics Staff Paper 88-3, Michigan   *
* State University for a definition of terms.            *
*                                                        *
******************************************************** }

procedure calc_yield_guarantee(avg_yield,
                               coverage: real;
                           var yield_guarantee: real);

   begin
      yield_guarantee := avg_yield*coverage;
   end; { calc_yield_guarantee);
```

```
{ ********************************************************
* PROCEDURE: GENERATE_MPCI_YIELDS                        *
* This procedure generates a vector of random variates   *
* called yield_MPCI. The procdure requires a vector of   *
* dimension no_draws that contains yields. MPCI yields   *
* are equal to max[yield,yield guarantee]. See Black and *
* Schwab. 1988. MPCI: What is it? Should you buy it?. Ag *
* Economics Staff Paper 88-3, Michigan State University  *
* for a definition of terms.                             *
******************************************************** }

procedure generate_MPCI_yields(N: integer;
                               yield: armax;
                               yield_guarantee: real;
                           var yield_MPCI: armax);
   var
      i: integer;

   begin
      for i := 1 to N do
         if yield[i] < yield_guarantee then
           yield_MPCI[i] := yield_guarantee
         else
           yield_MPCI[i] := yield[i];
   end; { generate_MPCI_yields }
```

```
{ ********************************************************
* PROCEDURE: CALC_NCF_W_MPCI_INDEMNITY                   *
* Procedure calculates net cash flow given yields, price,  *
* costs and premium. The purchase of MPCI is incorprated   *
* to include the effects of both indemnities and premiums  *
* on a producer's net cash flow.                           *
* ******************************************************** }

  procedure calc_ncf_w_MPCI_indemnity (N: integer;
                            yield: armax;
                            yield_guarantee,
                            mpci_price_election,
                            price,
                            deficiency,
                            acres_crop,
                            acres_setaside,
                            ASCS_program_yield,
                            cost_base,
                            cost_proportional,
                            cost_setaside,
                            cost_overhead,
                            cost_land_control,
                            premium: real;
                        var net_cash_flow: armax);
     const
        ZERO = 0.0;

     var
                          i: integer;
        MPCI_yield_indemnity: real;

      begin
       for i:= 1 to N do
        begin
          if yield[i] < yield_guarantee then

           begin
            MPCI_yield_indemnity := yield_guarantee - yield[i];
            net_cash_flow[i] :=
              (MPCI_yield_indemnity * mpci_price_election  +
               price * yield[i]  +  deficiency * ASCS_program_yield )
               * acres_crop
            - ( (cost_base + cost_proportional * yield[i] + premium)
                 * acres_crop
               +  cost_setaside *  acres_setaside
               + (cost_overhead + cost_land_control)
                  * (acres_crop + acres_setaside) );
          end { if true }
```

```
    else

     begin
      MPCI_yield_indemnity := ZERO;
      net_cash_flow[i] :=
         (MPCI_yield_indemnity * mpci_price_election +
          price * yield[i] + deficiency * ASCS_program_yield )
          * acres_crop
        - ( (cost_base + cost_proportional * yield[i] + premium)
             * acres_crop
           +  cost_setaside * acres_setaside
           + (cost_overhead + cost_land_control)
             * (acres_crop + acres_setaside) );
     end; { else }

   end; { for do statement }
end; { procedure calc_net_cash_flow }
```

```
{ ************************************************************
* PROCEDURE: CALC_EXPECTED_UTILITY                           *
* This procedure calculates the expected utility associated  *
* with a particular MPCI insurance strategy. The procedure   *
* requires a 'net cash flow' vector of dimension 'N'         *
* MPCI yields are equal to                                   *
*           max [yield,yield guarantee].                     *
* See Black and Schwab. 1988. MPCI: What is it? Should you   *
* buy it?. Ag Economics Staff Paper 88-3, Michigan State     *
* University  for a definition of terms.                     *
* ************************************************************ }

procedure calc_expected_utility(N: integer;
                                net_cash_flow: armax;
                                initial_wealth: real;
                            var expected_utility: real);
   var
      weight,sum,
      ending_wealth : real;
      i : integer;

   function utility (initial_wealth,
                     net_cash_flow: real): real;

   const
         alpha = 5.0E-10;
         beta  = 40.0;
         rho   = 2.5;


      begin
         ending_wealth := initial_wealth + net_cash_flow;
         utility := exp( (-1.0/rho)
              *ln( beta * ( exp (-rho*ln(ending_wealth)) + alpha) ) )
      end;


      begin
         weight := 1.0 / N;
         sum := 0.0;
         for i := 1 to N do
         sum := sum + weight * utility(initial_wealth, net_cash_flow[i]);
         expected_utility := sum;
      end; { expected_utility }
```

```
{ ********************************************************
* PROCEDURE: BISECTION                                   *
* Solve for the root of a nonlinear equation(s) using the *
* method of bisection. Adapted from L.V. Atkinson and P.J.*
* Harley. 1983. An Introduction to Numerical Methods with *
* PASCAL. Addison_Wesley. Bisection is covered in all    *
* references on numerical  analysis. It is slow,         *
* relatively, but it always converges -- providing a     *
* solution exists.                                       *
********************************************************}

procedure bisection(x0, x1, intercept: real;
                            var x: real);

   const
      tol=0.05;

   var
     fx, EU_w_MPCI:     real;
             its :     integer;
         success :     boolean;
             ncf :     armax;
   function f(x, intercept: real): real;

      begin

           calc_ncf_w_MPCI_indemnity (no_draws,
                                      yield,
                                      yield_guarantee,
                      MPCI_PRICE_ELECTION,      { MPCI price election }
                                      1.82,     { price }
                                      1.21,     { deficiency }
                                      192.00,   { acres_crop }
                                      48.00,    { set_aside }
                                      avg_yield, { ASCS_program_yield }
                                      97.33,    { cost_base }
                                      0.2688,   { cost_proportional }
                                      11.42,    { cost_setaside }
                                      44.92,    { cost_overhead }
                                      29.00,    { cost_land_control }
                                      x,        { premium }
                                      ncf);     { net cash flow }


      calc_expected_utility(no_draws,
                            ncf,
                        WEALTH_INITIAL,
                        EU_w_MPCI);

      f := EU_w_MPCI - intercept;

      {  f := x - exp(1/x) - intercept } { This definition of f is JRB's }

      end;
```

```
procedure bisect(x0,x1,xtol:   real;       { bisect is a nested procedure }
                 maxits:       integer;
                 intercept:    real;
            var root,fatroot: real;
            var noofits:      integer;
            var converged:    boolean);
   var
      x,fx,f0: real;
      itcount :  integer;
      state : (iterating,withintol,maxitsreached);

   begin  { bisect }
      f0 := f(x0, intercept);
      itcount := 0;
      state := iterating;

      repeat
         itcount := itcount+1;
         x := (x0+x1)/2;
         fx := f(x, intercept);
       { writeln(x0:8:5, x1:8:5, x:8:5, f0:15:7, fx:15:7, itcount:4); }

         if ( f0*fx <= 0.0 ) and (f0 > 0) then
             x1 := x
         else
           begin
             x0 := x;
             f0 := fx
           end;

         if ((x1-x0) < xtol) and ((x1-x0) >= 0.0) then
            state := withintol
         else
            if (itcount = maxits) then state := maxitsreached

      until state <> iterating;
      converged := (state = withintol);
      root := (x0+x1)/2; fatroot := f(root, intercept);
      noofits := itcount
   end; { bisect }


begin { bisection }
   x := 1.0;
   bisect(x0, x1, tol, 50, intercept, x, fx, its, success);
 { writeln(x:8:5, fx:15:6, its:4) }
 { writeln(lst,  '  EU_w_MPCI=  ',EU_w_MPCI:4:6); }
end;  { bisection }
```

```
{*************************************************************************
 * PROCEDURE: CALC_LOCAL_RISK_ATTITUDE                                   *
 * This procedure calculates the Pratt-Arrow Absolute Risk Aversion Coef- *
 * ficient's measure of local risk attitude, assuming a particular ini-  *
 * tial level of net wealth and a differentiable parametric utility      *
 * function.                                                             *
 *************************************************************************}

procedure calc_local_risk_attitude(initial_wealth:real;
                                   var risk_aversion:real);

 function absolute_risk_aversion(initial_wealth:real):real;

       const
         alpha = 5.0E-10;
         beta  = 40.0;
         rho   = 2.5;

       begin
        absolute_risk_aversion := (1 + rho) * ( (1/initial_wealth) +

            ( beta / ( ( (beta * exp(-rho*ln(initial_wealth))) + alpha)

              * exp( (1 + rho)*ln(initial_wealth)) ) ) );
       end; { function absolute_risk_aversion }

 begin { calc_local_risk_attitude }
   risk_aversion := absolute_risk_aversion(initial_wealth);
   writeln( lst, 'The Pratt-Arrow Absolute Risk Aversion ');
   writeln( lst, 'Coefficient, at the $',initial_wealth:1:2);
   writeln( lst, 'initial wealth level is equal to ');
   writeln( lst, risk_aversion:0:8, ' assuming that');
   writeln( lst, 'the CES type of utility function is specified.');
   writeln;
 end; { calc_local_risk_attitude }
```

```
{*************************************************************************
* PROCEDURE: MPCI_PURCHASE_DECISION                                      *
* This procedure compares the indifference MPCI premium derived from the *
* CYPD and utility function to the actual MPCI premium obtained from the *
* the FCIC's published actuarial tables. A "BUY" decision occurs if the  *
* indifference premium is larger than the actual premium. Otherwise, a   *
* a "NOT BUY" decision is predicted.                                     *
*************************************************************************}

procedure MPCI_purchase_decision(mpci_indif_p,
                                 actual_p,
                                 mean_sim_yield,
                                 sim_sd_yield,
                                 begin_wealth:real;
                                 name_of_file:name_it;
                                 price_elec,
                                 cov_level:real;
                                 the_plan:name_it;
                                 avg_yield_cov,
                                 risk_aversion:real);

begin
 writeln( lst,  'The results of this simulation were ');
 writeln( lst,  'generated from the file named ', name_of_file);
 writeln;
 writeln( lst, 'The actual MPCI premium rate under the ');
 writeln( lst, the_plan, ' for an average corn yield coverage ');
 writeln( lst, 'of ',avg_yield_cov:1:2, ' bu/ac in Brookings ');
 writeln( lst, 'County, SD was equal to $', actual_p:1:2, '/ac.');
 writeln;
 writeln( lst, 'The average indifference MPCI premium rate ');
 writeln( lst, 'was equal to $', mpci_indif_p:1:2, '/ac.');
 writeln( lst, 'The corn yield standard deviation was ',
                   avg_sim_sd_yield:1:2,' bu/ac.');
 writeln;

 if mpci_indif_p > actual_p then
  begin
   writeln( lst, 'A Brookings County producer with a(n) ');
   writeln( lst, mean_sim_yield:1:2, ' bu/ac expected corn ' );
   writeln( lst, 'yield, and a $', begin_wealth:1:2, ' initial');
   writeln( lst, 'wealth level and a ', risk_aversion:1:8);
   writeln( lst, 'coefficient of local absolute risk aversion,');
   writeln( lst, 'BUYS MPCI at the ', cov_level:1:2, ' coverage');
   writeln( lst, 'level and the $', price_elec:1:2, '/bu price');
   writeln( lst, 'election level.');
  end
```

```
   else
    begin
     writeln( lst, 'A Brookings County producer with a(n) ');
     writeln( lst, mean_sim_yield:1:2, ' bu/ac expected corn ' );
     writeln( lst, 'yield, and a $', begin_wealth:1:2, ' initial');
     writeln( lst, 'wealth level and a ', local_risk_aversion:1:8);
     writeln( lst, 'coefficient of local absolute risk aversion,');
     writeln( lst, 'DOES NOT BUY MPCI at the ', cov_level:1:2, ' coverage');
     writeln( lst, 'level and the $', price_elec:1:2, '/bu price');
     writeln( lst, 'election level.');
    end; { else }
  end; { MPCI_purchase_decision }
```

```
{ ************************************************************
* MAIN PROGRAM                                                *
* Begin 'main'. This is the main program for Brookings_SD.    *
* The main program calls up the procedures to generate the    *
* the output of the program. Some of the procedures in the    *
* program are nested: one procedure calls up another pro-     *
* cedure to perform a given task or operation.                *
* ************************************************************ }

begin  { main }
   clrscr;

   write('No draws = ? '); readln(no_draws);
   write('seed ? '); readln(randseed);

writeln( lst, 'Number of draws = ', no_draws:20);
writeln( lst, '  Random seed # = ', randseed:20);
Indifference_MPCI_Premium := 0;
kount := 0;
while kount < KOUNT_CONTROL do
 begin    { while }
  kount := kount + 1;
  writeln(lst);
  writeln( lst,  'Kount = ', kount:4);

   generate_yields(no_draws,
                   yield);

   calc_statistics(no_draws,
                   yield,
                   'yield     ',
                   avg_yield,
                   std_dev_yield);
```

```
   calc_net_cash_flow (no_draws,
                       yield,
                       1.82,            { price }
                       1.21,            { deficiency }
                       192.00,          { acres_crop }
                       48.00,           { set_aside }
                       avg_yield,       { ASCS_program_yield }
                       97.33,           { cost_base }
                      0.2688,           { cost_proportional }
                       11.42,           { cost_setaside }
                       44.92,           { cost_overhead }
                       29.00,           { cost_land_control }
                       0.00,            { premium }
                       net_cash_flow);  { net cash flow }

{
   for i := 1 to no_draws do
      writeln ( (* lst, *) i:10, net_cash_flow[i]:20:2);
}

   calc_statistics(no_draws,
                   net_cash_flow,
                   'ncf       ',
                   avg_net_cash_flow,
                   std_dev_net_cash_flow);

   calc_expected_utility(no_draws,
                         net_cash_flow,
                         WEALTH_INITIAL,
                         EU_wo_MPCI);

   writeln( lst,  'EU w/o = ',EU_wo_MPCI:20:7);
   writeln(lst);
   writeln(lst);
   writeln(lst);

   calc_yield_guarantee(avg_yield,
                         MPCI_COVERAGE,
                         yield_guarantee);
   writeln( lst, 'Yield guarantee = ', yield_guarantee:10:2);
   writeln(lst);

   generate_MPCI_yields(no_draws,
                         yield,
                         yield_guarantee,
                         yield_MPCI);

   calc_statistics(no_draws,
                   yield_MPCI,
                   'yield MPCI',
                   avg_yield_MPCI,
                   std_dev_yield_MPCI);
```

```
  bisection(0.5, 8.0, EU_wo_MPCI, Indifference_MPCI_premium);


  calc_ncf_w_MPCI_indemnity (no_draws,     { Random draws of
                                             "Actual Yield" from CYPD }
                             yield,        { Actual Yield }
                         yield_guarantee,  { MPCI Coverage }
                   MPCI_PRICE_ELECTION,    { MPCI price election }
                             1.82,         { price }
                             1.21,         { deficiency }
                           192.00,         { acres_crop }
                            48.00,         { set_aside }
                        avg_yield,         { ASCS_program_yield }
                            97.33,         { cost_base }
                           0.2688,         { cost_proportional }
                            11.42,         { cost_setaside }
                            44.92,         { cost_overhead }
                            29.00,         { cost_land_control }
             Indifference_MPCI_premium,    { premium }
                net_cash_flow_w_MPCI);     { net cash flow }


  calc_statistics(no_draws,
                  net_cash_flow_w_MPCI,
                  'NCF_w_MPCI       ',
                  avg_net_cash_flow_w_MPCI,
                  std_dev_net_cash_flow_w_MPCI);

  calc_expected_utility(no_draws,
                        net_cash_flow_w_MPCI,
                        WEALTH_INITIAL,
                        EU_w_MPCI);

  writeln( lst, 'EU w = ',EU_w_MPCI:20:7);

  writeln(lst);
  writeln( lst,  'Indif. MPCI premium = ', Indifference_MPCI_premium:10:2);
  writeln(lst);
  writeln(lst);

  array_premium[kount] := Indifference_MPCI_premium;
  array_BEFR[kount] := avg_yield_MPCI - avg_yield;
  array_yield[kount] := avg_yield;
  array_sd_yield[kount] := std_dev_yield;

end; { while }


      calc_statistics_basic(kount,
                        array_premium,
                        'Indif.MPCI prem ',
                        avg_premium,
                        std_dev_premium);
```

```
        writeln(lst);
        writeln(lst);
{       writeln(avg_premium:10:2,
                std_dev_premium:10:2);  }



        calc_statistics_basic(kount,
                              array_BEFR,
                              'BE Premium Rate      ',
                              avg_BEFR,
                              std_dev_BEFR);
{        writeln(avg_BEFR:10:2,
                std_dev_BEFR:10:2);  }
        writeln(lst);
        writeln(lst);



        calc_statistics_basic(kount,
                      array_yield,
                      'Sim.MeanYield= ',
                      avg_sim_yield,
                      std_dev_sim_yield);

        writeln(lst);
        writeln(lst);


        calc_statistics_basic(kount,
                      array_sd_yield,
                      'SimStdDevYield= ',
                      avg_sim_sd_yield,
                      std_dev_sim_sd_yield);
         writeln(lst);
         writeln(lst);
```

```
avg_yield_coverage := MPCI_COVERAGE * avg_sim_yield;

calc_local_risk_attitude(wealth_initial,
                         local_risk_aversion);

MPCI_purchase_decision(avg_premium,
                       ACTUAL_MPCI_PREMIUM,
                       avg_sim_yield,
                       avg_sim_sd_yield,
                       WEALTH_INITIAL,
                       file_name,
                       MPCI_PRICE_ELECTION,
                       MPCI_COVERAGE,
                       MPCI_COVERAGE_PLAN,
                       avg_yield_coverage,
                       local_risk_aversion);


end. { main }
```

APPENDIX H

Simulation Results for Predicting the MPCI Purchase Decision under the AREA and APH Coverage Plans

APPENDIX H

Simulation Results for Predicting the MPCI Purchase Decision under the AREA and APH Coverage Plans

Table H.1 Predicted MPCI Purchase Decision under the AREA 1 and AREA 2 Plans for Brookings County Producers with High Mean Corn Yield and the Logarithmic Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$0.76	NOT BUY
65%	31.9	$4.92	$7.22	$0.47	NOT BUY
50%	24.5	$3.12	$4.52	$0.22	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$0.77	NOT BUY
65%	31.9	$4.92	$7.22	$0.53	NOT BUY
50%	24.5	$3.12	$4.52	$0.26	NOT BUY

Table H.1 (cont'd.)

Initial Wealth Level (INW) = $38,400

Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$0.97	NOT BUY
65%	31.9	$4.92	$7.22	$0.55	NOT BUY
50%	24.5	$3.12	$4.52	$0.33	NOT BUY

Table H.2 Predicted MPCI Purchase Decision under the AREA 1 and AREA 2 Plans for Brookings County Producers with Medium Mean Corn Yield and the Logarithmic Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$1.45	NOT BUY
65%	31.9	$4.92	$7.22	$0.97	NOT BUY
50%	24.5	$3.12	$4.52	$0.44	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$1.61	NOT BUY
65%	31.9	$4.92	$7.22	$0.99	NOT BUY
50%	24.5	$3.12	$4.52	$0.52	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$1.65	NOT BUY
65%	31.9	$4.92	$7.22	$1.12	NOT BUY
50%	24.5	$3.12	$4.52	$0.57	NOT BUY

Table H.3 Predicted MPCI Purchase Decision under the AREA 1 and AREA 2 Plans for Brookings County Producers with Low Mean Corn Yield and the Logarithmic Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$3.94	NOT BUY
65%	31.9	$4.92	$7.22	$2.57	NOT BUY
50%	24.5	$3.12	$4.52	$1.47	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$3.90	NOT BUY
65%	31.9	$4.92	$7.22	$2.61	NOT BUY
50%	24.5	$3.12	$4.52	$1.36	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

% MPCI Cov. Level	Yield Level Insured (bu/ac)	AREA 1 MPCI Premium ($/ac)	AREA 2 MPCI Premium ($/ac)	Indiff. Prem. for MPCI Purch. ($/ac)	MPCI Pur. Decision for AREA 1 & AREA 2
75%	36.8	$7.67	$12.13	$4.10	NOT BUY
65%	31.9	$4.92	$7.22	$2.77	NOT BUY
50%	24.5	$3.12	$4.52	$1.61	NOT BUY

Table H.4 Predicted MPCI Purchase Decision under the AREA 2 Plan for Brookings County Producers with a High Mean Corn Yield and the CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$1.18	NOT BUY
65%	31.9	$7.22	$0.93	NOT BUY
50%	24.5	$4.52	$0.57	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$1.97	NOT BUY
65%	31.9	$7.22	$1.19	NOT BUY
50%	24.5	$4.52	$0.67	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$2.53	NOT BUY
65%	31.9	$7.22	$2.17	NOT BUY
50%	24.5	$4.52	$1.00	NOT BUY

Table H.5 Predicted MPCI Purchase Decision under the AREA 2 Plan for Brookings County Producers with a Medium Mean Corn Yield and the CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$2.39	NOT BUY
65%	31.9	$7.22	$1.48	NOT BUY
50%	24.5	$4.52	$0.92	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$2.84	NOT BUY
65%	31.9	$7.22	$1.90	NOT BUY
50%	24.5	$4.52	$0.98	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$3.59	NOT BUY
65%	31.9	$7.22	$2.70	NOT BUY
50%	24.5	$4.52	$1.46	NOT BUY

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Table H.6 Predicted MPCI Purchase Decision under the AREA 2 Plan for Brookings County Producers with a Low Mean Corn Yield and the CES Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = CES

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$4.71	NOT BUY
65%	31.9	$7.22	$3.52	NOT BUY
50%	24.5	$4.52	$1.90	NOT BUY

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$5.62	NOT BUY
65%	31.9	$7.22	$4.06	NOT BUY
50%	24.5	$4.52	$2.30	NOT BUY

Initial Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Yield Level Insured (bu/ac)	Actual MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Buy or Not Buy MPCI under AREA 2 Plan
75%	36.8	$12.13	$7.24	NOT BUY
65%	31.9	$7.22	$5.59	NOT BUY
50%	24.5	$4.52	$3.25	NOT BUY

Table H.7 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the APH Plan for Producers with a High Mean Corn Yield and Logarithmic Utility Function.

Expected Mean Yield = APH yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.72	$4.72	$11.87	1.74	4.36
65%	$1.55	$2.77	$5.58	1.79	3.60
50%	$0.59	$1.10	$3.12	1.86	5.29

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.57	$4.62	$11.87	1.80	4.62
65%	$1.56	$2.93	$5.58	1.88	3.58
50%	$0.60	$1.19	$3.12	1.98	5.20

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.62	$5.07	$11.87	1.94	4.53
65%	$1.55	$3.18	$5.58	2.05	3.60
50%	$0.59	$1.34	$3.12	2.27	5.29

Table H.8 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the APH Plan for Producers with a Medium Mean Corn Yield and Logarithmic Utility Function.

Expected Mean Yield = APH yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.81	$4.80	$12.36	1.71	4.40
65%	$1.60	$2.77	$5.87	1.73	3.67
50%	$0.72	$1.30	$1.47	1.81	4.53

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.89	$5.13	$12.36	1.78	4.28
65%	$1.64	$2.99	$5.87	1.82	3.58
50%	$0.69	$1.33	$3.26	1.93	4.72

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.80	$5.32	$12.36	1.90	4.41
65%	$1.58	$3.11	$5.87	1.97	3.72
50%	$0.68	$1.46	$3.26	2.15	4.79

Table H.9 Brookings County Corn Producers' Costs and Benefits of Using MPCI under the APH Plan for Producers with a Low Mean Corn Yield and Logarithmic Utility Function.

Expected Mean Yield = APH yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.95	$4.98	$13.25	1.69	4.49
65%	$1.98	$3.41	$6.33	1.72	3.20
50%	$1.00	$1.76	$3.51	1.76	3.51

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$2.89	$5.05	$13.25	1.75	4.58
65%	$1.85	$3.30	$6.33	1.78	3.42
50%	$0.95	$1.76	$3.51	1.85	3.69

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

Percent MPCI Coverage Level	Break-Even MPCI Premium ($/ac)	Indifference Premium for MPCI Purchase ($/ac)	Actual MPCI Premium ($/ac)	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	$3.00	$5.62	$13.25	1.87	4.42
65%	$1.90	$3.67	$6.33	1.93	3.33
50%	$0.96	$1.95	$3.51	2.03	3.66

Table H.10 Brookings County Corn Producers' Indifference and Actual Premium Ratios under the AREA 1 and AREA 2 Plans for Producers with a High Mean Corn Yield and Logarithmic Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 83 bu/ac
Yield Standard Deviation = 23 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	1.90	19.18	1.90	30.33
65%	1.88	19.68	1.88	28.88
50%	2.00	28.36	2.00	41.09

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	2.03	20.18	2.03	31.92
65%	2.12	19.68	2.12	28.88
50%	2.17	26.00	2.17	37.67

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	2.37	18.71	2.37	29.59
65%	2.50	22.36	2.50	32.82
50%	2.54	24.00	2.54	34.77

Table H.11 Brookings County Corn Producers' Indifference and Actual Premium Ratios under the AREA 1 and AREA 2 Plans for Producers with a Medium Mean Corn Yield and Logarithmic Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 70 bu/ac
Yield Standard Deviation = 22 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	1.79	9.47	1.79	14.98
65%	1.80	9.11	1.80	13.37
50%	1.91	13.57	1.91	19.65

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	1.89	9.02	1.89	14.27
65%	1.94	9.65	1.94	14.16
50%	2.00	12.00	2.00	17.38

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	2.09	9.71	2.09	15.35
65%	2.20	9.65	2.20	14.16
50%	2.28	12.48	2.28	18.08

Table H.12 Brookings County Corn Producers' Indifference and Actual Premiums Ratios under the AREA 1 and AREA 2 Plans for Producers with a Low Mean Corn Yield and Logarithmic Utility Function.

Insurable AREA Yield = 49 bu/ac
Expected Mean Yield = 55 bu/ac
Yield Standard Deviation = 18 bu/ac
Indemnity Price Election = $1.50/bu
Type of Utility Function = Logarithmic

Initial Net Wealth Level (INW) = $70,000
Coefficient of Local Absolute Risk Aversion @ INW = 0.000053

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	1.71	3.33	1.71	5.27
65%	1.75	3.35	1.75	4.91
50%	1.77	3.76	1.77	5.45

Initial Net Wealth Level (INW) = $54,200
Coefficient of Local Absolute Risk Aversion @ INW = 0.000071

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	1.77	3.49	1.77	5.51
65%	1.83	3.44	1.83	5.05
50%	1.89	4.33	1.89	6.28

Initial Net Wealth Level (INW) = $38,400
Coefficient of Local Absolute Risk Aversion @ INW = 0.000111

	AREA 1 PLAN		AREA 2 PLAN	
Percent MPCI Coverage Level	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.	Ratio of Indif. Prem. to BE Prem.	Ratio of Actual Prem. to BE Prem.
75%	1.92	3.58	1.92	5.67
65%	1.99	3.54	1.99	5.19
50%	2.09	4.05	2.09	5.87

APPENDIX I

Simulated Impacts of the MPCI Purchase Decision on a Brookings County Corn Producer's Distribution of Net Cash Flows

APPENDIX I

Simulated Impacts of the MPCI Purchase Decision on a Brookings County Corn Producer's Distribution of Net Cash Flows

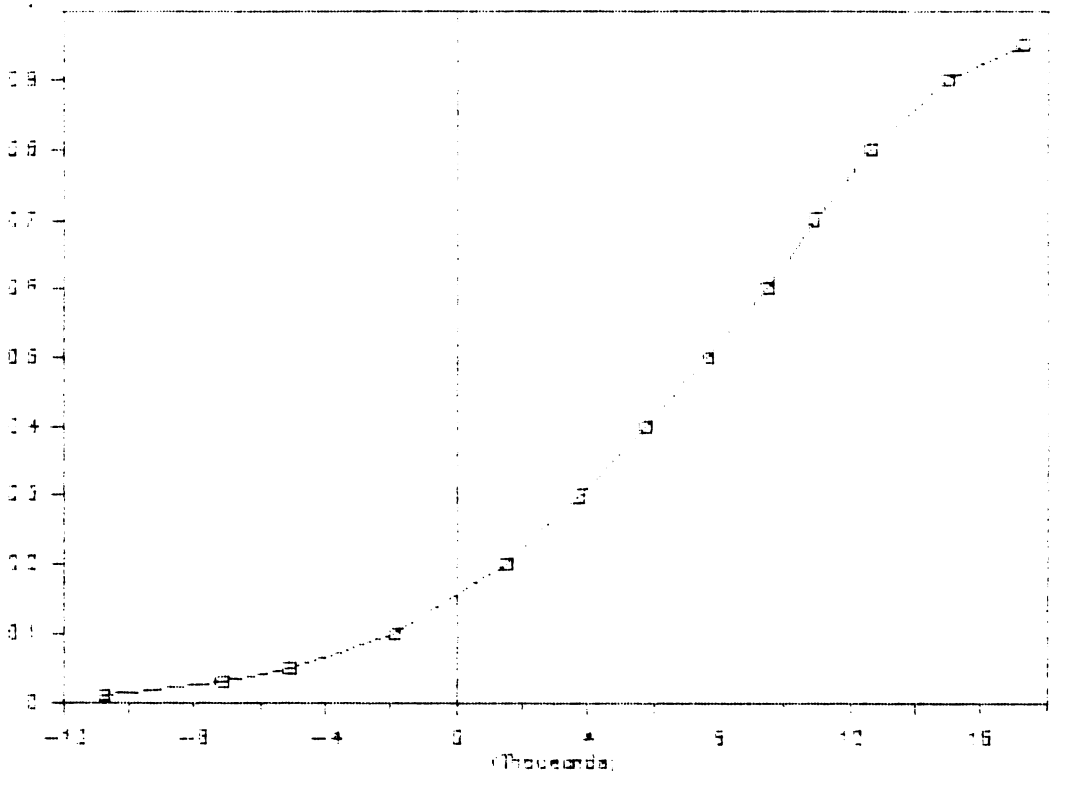

Figure I.1 Cumulative Density Function of Net Cash Flows for a Producer With an 83 bu/ac Mean Corn Yield and No MPCI Purchased. The Mean Net Cash Flow was $7,055 and the Standard Deviation was $6761.

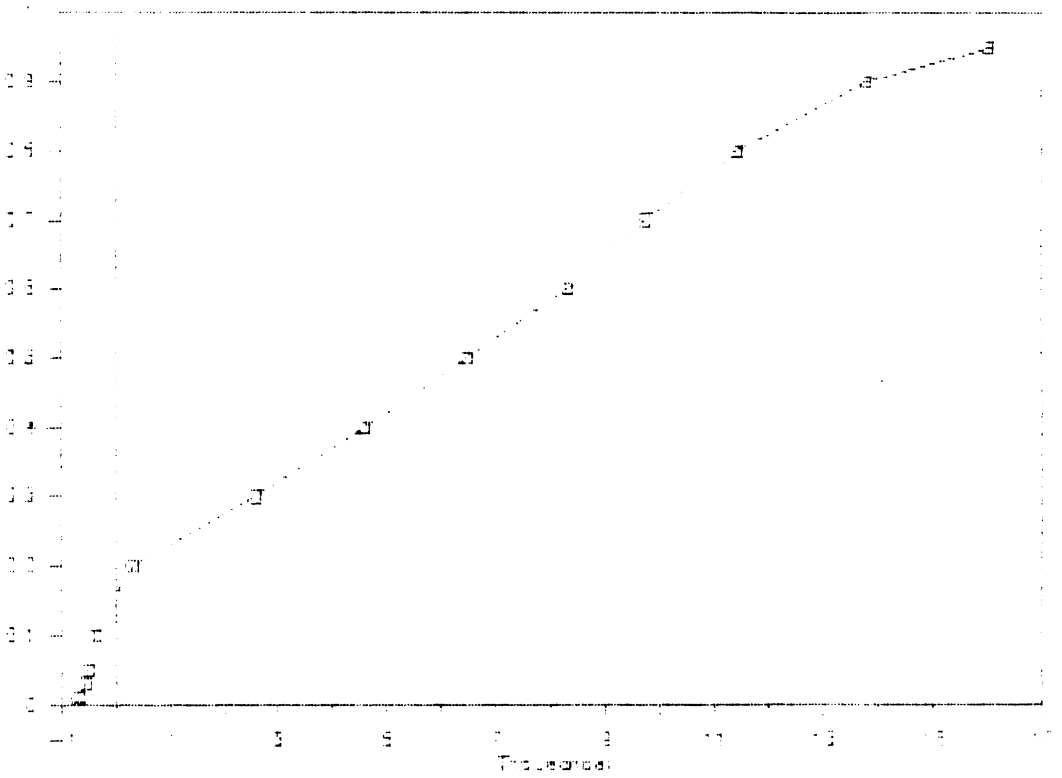

Figure I.2 Cumulative Density Function of Net Cash Flows for a Producer With an 83 bu/ac Mean Corn Yield and MPCI Purchased at the 75 Percent Coverage Level. The Mean Net Cash Flow was $6,598 and the Standard Deviation was $5498.

APPENDIX J

MPCI Actuarial Tables for Brookings County Dryland Corn Produced for Grain in 1987

APPENDIX J

MPCI Actuarial Tables for Brookings County Dryland Corn Produced for Grain in 1987

Table J.1 MPCI Per Acre Premium Rates under the APH Plan for Dryland Corn Raised for Grain in Brookings County.

MPCI Rate and Transitional Yield Factor Table

State: SD County: BROOKINGS Crop: CORN Crop Year: 1987
Practice: NONIRRIGATE Type: GRAIN Class: APH Variety: ALL

Approved Crop Yield	Ins.	Classification	SUBSIDIZED RATES Level 1 (50%) Hail/in	Hail/out	SUBSIDIZED RATES Level 2 (65%) Hail/in	Hail/out	SUBSIDIZED RATES Level 3 (75%) Hail/in	Hail/out
0.0-	30.0	R1	16.6	14.1	23.0	19.5	41.9	35.6
31.0-	38.0	R2	13.9	11.8	19.3	16.5	35.2	29.9
39.0-	47.0	R3	10.6	9.0	14.0	12.5	26.7	22.7
48.0-	56.0	R4	8.5	6.9	11.8	10.0	21.4	18.2
57.0-	64.0	R5	7.1	5.6	9.9	8.4	18.1	15.4
65.0-	73.0	R6	6.2	4.7	8.6	7.1	15.7	13.4
74.0-	82.0	R7	5.5	4.0	7.6	6.1	14.0	11.9
83.0-	90.0	R8	5.0	3.5	6.9	5.4	12.7	10.8
91.0-	9999.9	R9	4.8	3.4	6.7	5.1	12.1	10.3

T Yield Tble : Source Crop CORN T Factor 0.87 Cap 110.0

Table J.2 **MPCI Per Acre Premium Rates under the AREA 1 Plan for Dryland Corn Raised for Grain in Brookings County.**

MPCI Rate and Transitional Yield Factor Table

State:SD County:BROOKINGS Crop:CORN Crop Year:1982
Practice:NONIRRIGATE Type:GRAIN Class:AREA 1 Variety:AREA PLAN

Approved Crop Ins. Yield	Classification	SUBSIDIZED RATES Level 1 (50%) Hail/in	Hail/out	SUBSIDIZED RATES Level 2 (65%) Hail/in	Hail/out	SUBSIDIZED RATES Level 3 (75%) Hail/in	Hail/out
0.0-9999.9	AREA1	8.5	7.1	10.3	8.8	13.9	11.8

T Yield Tble : Source Crop CORN T Factor 1.00 Cap 49.0

Table J.3 MPCI Per Acre Premium Rates under the AREA 2 Plan for Dryland Corn Raised for Grain in Brookings County.

MPCI Rate and Transitional Yield Factor Table

State:SD County:BROOKINGS Crop:CORN Crop Year:1982
Practice:NONIRRIGATE Type:GRAIN Class:AREA 2 Variety:AREA PLAN

Approved Crop Ins. Yield	Classification	SUBSIDIZED RATES Level 1 (50%) Hail/in	Hail/out	SUBSIDIZED RATES Level 2 (65%) Hail/in	Hail/out	SUBSIDIZED RATES Level 3 (75%) Hail/in	Hail/out
0.0-9999.9	AREA2	12.3	10.4	15.1	12.9	20.2	17.2

T Yield Tble : Source Crop CORN T Factor 1.00 Cap 49.0

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