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Firm Level Risk Management Through Commodity Marketing

presented by
Richard Dwayne Alderfer

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DECISION SUPPORT SYSTEM COMPONENTS FOR
FIRM LEVEL RISK MANAGEMENT THROUGH
COMMODITY MARKETING

By

Richard Dwayne Alderfer

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ABSTRACT

DECISION SUPPORT SYSTEM COMPONENTS FOR FIRM LEVEL RISK MANAGEMENT THROUGH COMMODITY MARKETING

By

Richard Dwayne Alderfer

Grain farmers can use several cash market and futures market instruments prior to harvest to manage crop income risk. The farm problem is "Which pricing alternatives to use and how many bushels to price, to manage income risk, when production and ending period prices are uncertain?" The research problem was to design and test a decision support system to assist with the farm problem, utilizing the producer's risk attitudes.

Farm Income Risk Management (FIRM) is a series of microcomputer models to solve the farm problem above. FIRM is a single crop, stochastic, non-dynamic model. An option pricing model is used to solve for the implied volatility of the ending period futures distribution (using an efficient market assumption). Futures markets were modeled as normally distributed. Basis and yield distributions were subjectively elicited. These factors form the expected each market gross margin distribution. The first two moments of the expected gross margin distribution seed an "equally likely risky outcome" expert system called ELRISK, to give a subjectively elicited utility curve. The result is a discrete "Bernoullian" utility curve with 9 to 14 points that extends across most of the gross margin distribution.

A non-linear "Box's Complex" subroutine seeks to maximize expected subjective utility of the marketing simulation. The simulation includes all transaction and opportunity costs. Bushels to forward contract, futures hedge, put hedge, and basis contract are recommended for the individual producer and the particular crop.

Richard Dwayne Alderfer

Twenty-nine Michigan soybean producers tested FIRM at four extension/research workshops. All 29 producers for the problem under consideration were risk averse across the gross margin range elicited. Forward contracting was the prevalent pricing alternative, while put options were seldom recommended. Producer utility curves were fitted to four functional forms (linear, quadratic, semi-log and negative exponential). The negative exponential function was judged to be superior based upon R^2 comparisons.

FIRM was judged to be successful in a workshop setting. The concepts used in FIRM could be extended to other risk problems.

Dedicated to Lillian, Nathan, Kristen and our families.

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TABLE OF CONTENTS

LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF ABBREVIATIONS	xii
 CHAPTER ONE - INTRODUCTION	 1
1.1 Background	2
1.2 The Problem	5
1.3 Research Goal	6
1.4 Research Objectives	6
1.5 Research Benefits	7
1.6 Research Methodology	9
1.7 The Dissertation Framework	12
1.8 Summary	13
APPENDIX TO CHAPTER ONE - Terminology	14
1.A Risk and Uncertainty	14
1.B Marketing Terminology	17
1.C Decision Support Systems	19
 CHAPTER TWO - HOW TO DESCRIBE AND DECIDE: A LITERATURE REVIEW ..	 20
2.1 Risk Principles	24
2.1.1 Probability Principles	25
2.1.2 Expected Utility Theory (EUT)	26
2.1.3 Measures of Risk Aversion	30
2.1.4 Utility Functions	34
2.2 Generating Yield Distributions	38
2.3 Representing Distributions	42
2.4 Market Efficiency	43
2.5 Generating Price Distributions	46
2.5.1 Futures Price Distributions	46
2.5.2 Basis Distributions	50
2.6 Eliciting Risk Attitudes	51
2.6.1 Methods	51
2.6.2 Results of Risk Elicitation	61
2.6.3 Problems with Previous Research	63
2.7 Decision Rules and Efficiency Criteria	67
2.7.1 Maximize Expected Utility	68
2.7.2 Stochastic Dominance	70

2.7.3 E-V, MOTAD, M-SD, and Semi-Variance	76
2.7.4 Target MOTAD and Lower Partial Moments	79
2.7.5 Safety First Decision Rules	83
2.8 Previous Efforts	84
2.8.1 Risk Efficiency Studies - Research Oriented	85
2.8.2 Micro-Computer Based Simulations	89
2.9 Summary	91
CHAPTER THREE - THE FIRM MODEL	93
3.1 FIRM Model Overview	94
3.2 The Audience	96
3.3 Generating Yield Distributions (ELICIT)	97
3.4 Generating Price Distributions	100
3.5 Adjusting Monte Carlo Observations	103
3.6 GENRINC	104
3.7 Measuring Risk Attitudes (ELRISK)	106
3.8 Marketing Simulation - The Objective Function	114
3.9 Finding Superior Marketing Plans (MKTOPT)	121
3.10 Post-Optimal Solutions	126
3.11 Issues	128
3.12 Future Improvements to FIRM	131
3.13 Summary	134
CHAPTER FOUR - MODEL VALIDATION	135
4.1 The Base Farm for Testing	136
4.2 Test 1 - Effect of Utility Changes on Marketing Plans	138
4.3 Test 2 - Effect of Utility Changes on Pricing Tools	145
4.4 Test 3 - Changing Put Options Premiums and Utility	148
4.5 Test 4 - Changing Price Distribution Forms	149
4.6 Summary	152
CHAPTER FIVE - WORKSHOP RESULTS	154
5.1 Generating Price Distributions	155
5.2 The Workshop Format	156
5.3 Getting Acquainted	156
5.4 Yields and Probabilities	158
5.5 Estimating Yield Distributions with ELICIT	158
5.6 Crop Costs and Effective Acreage	160
5.7 Running GENRINC	161
5.8 Soybean Outlook and Volatility Forecasting	162
5.9 Estimating Utility Functions with ELRISK	162
5.10 Marketing Solutions	168
5.11 Producer and Presenter Evaluation	171
5.12 Testing Other Utility Curves on a Case Farm	173
5.13 Changing Price Data for the Case Farm	179
5.14 Summary	181

CHAPTER SIX - SUMMARY AND CONCLUSION	183
6.1 The Problem	184
6.2 The Research Objectives	184
6.3 Research Findings and their Implications	185
6.4 Limitations of the Research	188
6.5 Future Research	189
APPEDICES	192
A - Comments From Workshop Participants	192
B - Workshop Program	193
C - Producer Curves	196
D - Discrete Yield Data	201
E - Discrete Price Distributions	204
F - Code for F&BDISTS.EXE	208
G - Code for GENRINC	215
H - Code for ELRISK	217
I - Code for MKTOPT	225
LIST OF REFERENCES	236

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
Table 2.1	Three Common Utility Functions.	35
Table 2.2	Interval Approach Choice Format	57
Table 2.3	Results of Previous Attitude Measurements	62
Table 2.4	Previous studies in Marketing Risk Management for Farmers	86
Table 3.1	Portion of ELICIT Output	99
Table 3.2	BUANDINC.DAT file created by GENRINC	106
Table 3.3	Static Input to MKTOPT	133
Table 4.1	Static Input to MKTOPT	137
Table 4.2	Marketing solutions for 5 Utility Functions.	142
Table 4.3	Pricing Solutions for 5 Utility Functions.	145
Table 4.4	Changing Put Premiums	149
Table 4.5	Comparing Price Distribution Functions	151
Table 5.1	Producer Data	157
Table 5.2	Workshop Summary for GENRINC and ELICIT Results	159
Table 5.3	Function Evaluation in CARA Order	164
Table 5.4	Summary of Producer MKTOPT Results	170
Table 5.5	Producer evaluations	172
Table 5.6	Static Data for Producer CAL3	174
Table 5.7	Utility Value Coordinates for Five Farms	176
Table 5.8	Comparisons of Utility Functions	178
Table 5.9	Testing Futures Price Biases	180
Table 5.10	Changing Biases in Basis	181

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
Figure 1.1	Components of a Modern DSS	19
Figure 2.1	Comparing Income Distributions	23
Figure 2.2	Basic Utility Concepts	29
Figure 2.3	Plotting Bernoullian Utility Curves	55
Figure 2.4	First Degree Stochastic Dominance (FSD)	71
Figure 2.5	Second Degree Stochastic Dominance (SSD)	73
Figure 3.1	Components of FIRM and their linkages	95
Figure 3.2	The Case Farm Yield Distribution (pdf)	98
Figure 3.3	Structure of Situations 1 and 2 in ELRISK	108
Figure 3.4	Case Farm ELRISK Situations 1 and 2	111
Figure 3.5	Output from ELRISK	113
Figure 3.6	Schematic of Complex	123
Figure 3.7	Part of the Sample Farm Output	126
Figure 3.8	Additional MKTOPT Output	128
Figure 4.1	Case Farm Gross Margin Distribution	138
Figure 4.2	Five Negative Exponential Utility Functions	139
Figure 4.3	Log-Normal versus Normal Prices	150
Figure 5.1	Negative Exponential Functions	165
Figure 5.2	Discrete and Fitted Utility Curves for FRA5	177
Figure C.1	Utility Curves for all producers	196

LIST OF ABBREVIATIONS

Abbreviations	Page
ARMS	Agricultural Risk Management Software 89
ASCII	American Standard Code for Information Interchange 40
ARA	Absolute Risk Aversion a function - $R(X)$ 32
ARIMA	Autoregressive Integrated Moving Average 45
BASIC	Beginner's All-Purpose Symbolic Instruction Code 47
BEAR	Budgeting Enterprises and Analyzing Risk 90
BOPM	Black's (1976) Option Pricing Model 47
CARA	Constant Absolute Risk Aversion 36
CBOT	Chicago Board of Trade 45
CV	Coefficient of variation 48
CDF	Cumulative Distribution Function 22, 25
DARA	Decreasing Absolute Risk Aversion 36
DEU	Direct Elicitation of Utility 51
DSS	Decision Support Systems 19
DY/dX	derivative of the function Y with respect to X 34
ELRO	Equally Likely Risky Outcome 56
EUT	Expected Utility Theory 26
E-SD	Mean-standard deviation 76
E-SV	Expected value - SemiVariance 79
E-V	Expected value - Variance 76
E[X]	Expected value operator 28
FIRM	Farm Income Risk Management 6
FSD	First degree stochastic dominance 70
IV	Implied Volatility 47
IARA	Increasing Absolute Risk Aversion 36
LPM	Lower Partial Moment 79
MOTAD	Minimization Of Total Absolute Deviations 78
OEB	Observed Economic Behavior 51
pdf	Probability density function 25
QP	Quadratic programming 77
r^2	Correlation coefficient 37
$R(X)$	- $U''(X)/U'(X)$ called ARA 31
RP	Risk premium 29
SSD	Second degree stochastic dominance 72
SDWRF	Stochastic Dominance With Respect to a Function" (SDWRF) 59
TSD	Third degree stochastic dominance 74
$U(X)$	Utility of income 28

Abbreviations	Page
VAR Vector Auto Regression	45
vN-M Von Neumann-Morgenstern (1944),	54
WFRM Whole Farm Risk Rating Model	90
Xce Certainty equivalent	29

CHAPTER ONE

INTRODUCTION

1.1 Background	2
1.2 The Problem	5
1.3 Research Goal	6
1.4 Research Objectives	6
1.5 Research Benefits	7
1.6 Research Methodology	9
1.7 The Dissertation Framework	12
1.8 Summary	13
APPENDIX TO CHAPTER ONE - Terminology	14
1.A Risk and Uncertainty	14
1.B Marketing Terminology	16
1.C Decision Support Systems (DSS)	18



1.1 Background

Commercial grain farmers can use several cash market and futures market instruments prior to harvest to manage crop income risk. The farm problem is "Which pricing alternatives to use and how many bushels to price, to manage income risk, (for a particular grain commodity) when production and ending period prices are uncertain?" Commercial grain farmers face production, futures, and basis uncertainty resulting in substantial income risks.

Newbery and Stiglitz (1981) noted in their assessment of price stabilization schemes that: "If the riskiness of agriculture is reduced, it may allow more ... powerful incentives to increase output. Price stabilization may therefore generate additional efficiency gains which are very desirable".¹ In an effort to create more ways to manage income risks, the Commodity Futures Trading Commission has subsequently approved trading of options on several agricultural commodity futures contracts (CBOT; 1985, Cox and Rubinstein; 1985). Buying put options² provides "price insurance" for producers that lead to more efficient risk contingency markets. This means that farmers and elevators can get price insurance, but how much insurance should they buy, or should they just hedge or sell some of the expected production?

A 1988 survey indicated that less than 5 percent of the producers and less than half of the commercial elevators were using options on futures contracts in pricing grains in Illinois (Whitacre and Olmstead, 1988). The survey focused on minimum pricing contracts which are a cash market instrument based upon options on futures.

¹ p. 169

² Marketing and risk terminology are described in a special appendix to this chapter.

Sixty-nine percent of the elevator managers surveyed indicated that the major reason for low use of minimum pricing contracts by producers was a lack of knowledge about their mechanics and application (an information gap). Several other surveys showed a minority of United States farms use futures and options directly (Helmuth, 1977; Patrick et al., 1985; Harwood et al., 1987; and Shapiro and Brorsen, 1988).

Patrick et al. (1985) found that acquiring market information was the most important management response for reducing farm income risk of the 149 farmers they surveyed (in 12 states). They also found that the farmers surveyed felt product prices were the most important source of farm income risk. Branch and Olson (1987) found similar results in a study of Wyoming ranchers.

Arthur Anderson and Company (1982), in conjunction with the University of Illinois, surveyed 535 commercial Illinois producers. Ninety percent of those surveyed felt management assistance in marketing would be important in the future. Most felt present marketing services were inadequate, and nine out of ten felt that marketing consultants would also be important in five years.

Brown and Collins (1978) surveyed 782 farmers from 10 states, and found that marketing was the number one informational need. Other survey efforts were summarized by Hughes et al. (1981) leading to similar conclusions that farmers need and want improved marketing information.

Batte et al. (1988) surveyed 215 Ohio grain farmers. Sixty-nine percent of the respondents said marketing information needs were adequately met. One possible reason for this difference is that respondents were not instructed on the difference between data and information. Davis and Olson (1985) and Hodge et al. (1984) noted that data and information are quite dissimilar. Data needs to be processed before it

can become useful information. The Ohio survey asked for rankings of marketing "information" sources, where some alternatives suggested were data oriented (e.g. local newspapers) and other alternatives information oriented (e.g. marketing consultants).

Perhaps farmers receive enough marketing data, but desire more marketing information. If the conflicting findings of Batte et al. (1988) are reconciled as farmer's lack of desire for additional marketing data, then there is consensus. In fact, Batte (1985) suggested "that a new area of emphasis in risk management research be to improve information quality and quantity. This involves a shift of emphasis from measuring risk to improving information available to farmers so as to reduce the uncertainty in the decision environment".³

Surveyed producers and agricultural economists have generally concluded that farmers need more marketing information in order to manage risk. The introduction of new pricing alternatives (i.e. hedging with options and minimum pricing contracts) have accentuated this need, especially since these new pricing alternatives involve "price insurance," and do not set a price for the commodity.

Pre-harvest marketing implies that total production is not known. This is a much different (and more difficult) problem than post-harvest. After harvest, marketing becomes a storage and pricing problem, since the quantity produced is known. If output is known with certainty, the entire crop can be sold and there is no more income risk due to price. There may remain some small storage risk, if a forward contract is used to price grain later in the marketing year.

³ p. 197

1.2 The Problem

Commercial grain farmers can use several cash and futures market instruments prior to harvest to manage their crop income risk. The producer problem is, "Which pricing alternatives should I use and how many bushels to price for a particular grain commodity, when production and ending period prices are uncertain?" This type of market information is not currently available to individual farmers, except perhaps through marketing consultants. Furthermore, this question, "How to sell and how much?" needs to be frequently re-examined during the growing season, as new market data emerges and growing conditions change. Answers to the "How and how much?" question, are influenced by the risk attitudes of the producer.

Producers presented with improved market information should be able to more easily appraise market conditions and more fully comprehend the income risks. With this knowledge, managers can make more rational decisions related to income risks. be better able to understand income risks, and through the selection of appropriate pricing alternatives, manage income risks. Agricultural economists have contributed substantially to literature on risk theory, decision analysis, pricing alternatives, and farm records systems, but have yet to combine these efforts into a set of decision tools to provide farmers with improved farm marketing information. The research problem is to improve marketing information by developing and testing microcomputer tools that help farmers consider their risks and decide how many bushels to price, with each pricing method.

1.3 Research Goal

The goal of this research is to design, construct and evaluate microcomputer-based software components that help farmers evaluate grain market conditions, production and pricing risks and to evaluate preharvest pricing instruments. Grains were chosen for their seasonal characteristics, strong market structure and substantial yield and price uncertainty. This microcomputer decision software is designed to manage risk through selection of commodity marketing alternatives for a single grain commodity.

1.4 Research Objectives

Several objectives must be accomplished in order to meet the research goal. These objectives are:

1. To review and summarize relevant portions of systems science methods, probability theory, risk theory, decision analysis, commodity marketing, decision support systems, and management literature related to the farmer's marketing problem. This will help in the selection of methods used to address the problem.
2. To develop a marketing model, "Farm Income Risk Management" (FIRM) that will provide improved information to commercial grain producers regarding income risks related to commodity marketing. This model addresses the farm problem; "Which pricing alternatives to use and how many bushels to price, when production, futures and basis are uncertain (for a particular grain

commodity)? FIRM will be developed for use in a workshop setting and as a research tool.

3. To test the usefulness, "workability"⁴ (effectiveness), and whether the recommendations of the model correspond to previous experiences and marketing thumb rules.

4. To identify those areas of theory and knowledge that this research has contributed and discuss research areas that need further exploration.

1.5 Research Benefits

Disciplinary and subject matter work is verified, not only by other related research efforts, but also by the application of those theories to actual problems. This research. Problem solving research has a responsibility, to point out disciplinary and subject matter research areas that need further studying. Subject matter and disciplinary researchers should benefit from the identification of those economic issues where further understanding and insight are needed.

Since FIRM will be tested for workability by grain producers, it should improve their understanding of the risks they face in producing and pricing grain and their ability to manage those risks. If an "end-user" product is ultimately developed as an extension of this research, FIRM users will be able to evaluate grain marketing decisions more frequently and thoroughly, and manage their income risk more efficiently.

⁴ Johnson (1986) further defines workability.

FIRM will be a package in the Decision Support System (see Chapter 1 Appendix). As such, its components or modules could be adapted by problem solving researchers for solving related problems. FIRM could be adapted to other commodities, livestock, other marketing strategies, non-commodity products and government commodity program benefits.

FIRM could serve as a teaching tool for farm management, commodity marketing, applied risk management and/or systems science, by showing the subject matter components as well as the modeling methods. Appropriate audiences could be upper level undergraduates and graduate students, as well as extension workshop participants. Efforts in this area are not explicitly part of the research objectives, but are realistic possibilities.

FIRM will not be designed to directly increase aggregate or individual producer income over time. If FIRM is successful for individual producers, it will allow them to manage expected grain income/risk tradeoffs consistent with their desired risk attitudes. As Newbery and Stiglitz (1981) noted earlier this may bring indirect gains in efficiency over time. Regarding evaluation of decisions rules, von Winterfeldt and Edwards (1986) noted:

...rules for decision making should never be evaluated on the basis of their results (p. 2). ... the quality of decisions really means the quality of the process by which they are made, and that can be evaluated only on the basis of information available before their outcomes occur or become certain. Rational decisions are made and must be evaluated with foresight, not hindsight.⁵

If farmers are not currently operating in the area of their desired income/risk preferences, and/or they are choosing marketing alternatives that are inefficient by

⁵ p. 3

income/risk standards, then successful use of FIRM should bring improved farm performance. This improved farm performance must be measured by the same income/risk criteria. If bankers see that a producer is managing risk more efficiently, cost of capital could be lower and/or increase borrowing capacity might be possible bringing potential indirect profit improvements in the long run.

Agricultural futures and option markets have been under-utilized by producers, if agricultural economists are correct in assessing their risk reducing benefits and costs (see Holt and Brandt, 1985 for a review). FIRM will be able to more completely evaluate grain pricing mechanisms, such as futures and options (from a risk standpoint), allowing producers who have not used a particular pricing tool, to easily consider them. A farmer with little or no understanding of futures and options will have impetus for learning about futures and options, if these marketing mechanisms are suggested to him or her by FIRM. Marketing and management consultants, farm lenders, extension personnel and elevator service personnel could benefit from their own analysis and use of FIRM, as well as perform analyses for farm clientele.

Testing FIRM on a group of producers will generate empirical information regarding risk behavior and the efficiency of various commodity marketing alternatives for the test group. To the extent that the evaluated farmers (and their risky environments) are similar to farmers in general, these findings may be helpful to other problem solving and subject matter researchers.

1.6 Research Methodology

Research Methodology is not to be confused with research methods. Machlup (1978) defined methodology as:

The study of the principles that guide students of any field of knowledge, and especially of any branch of higher learning (science) in deciding whether to accept or reject certain propositions as a part of the body of ordered knowledge in general or of their own discipline (science).⁶

Webster's New World Dictionary (Guralnik, 1972) defined methodology as "the science of method, or orderly arrangement; specifically, the branch of logic concerned with the application of the principles of reasoning to scientific and philosophical inquiry."

Researchers may use different methods, but hold similar methodological views, or hold different methodological perspectives and use similar research methods.

Remaining chapters will discuss research methods, but discussion of the researcher's methodology is an important prerequisite to thorough research.

The research methodology employed is predominantly pragmatism and is an important reference point for the reader. Many efforts in risk literature are positivistic or conditionally normative. Bayesian approaches to statistics are in fact a cornerstone of risk theory, and are perhaps best described as conditionally normative. Johnson (1986) noted that "conditional normativism has the distinct merit of permitting a positivistically inclined economist to engage in problem-solving and subject-matter research".⁷

This research will employ tools common to positivistic or conditionally normative research, but its pragmatic nucleus is still asserted. Problem-solving research, particularly involving system science methods and structure, is by nature pragmatic. Knowledge about values is called normative and descriptive or largely value free knowledge is called positivistic. While normative and positivistic knowledge

⁶ p. 54

⁷ p. 86

might exist separately, the pragmatist views them as interdependent in the problem context. Conditional normativists view both types of knowledge, but discount their interdependence.

Problem-solving results in prescriptive knowledge. The pragmatist relies largely on the test of workability of the consequences in addition to tests of correspondence, coherence and clarity when validating his or her research. With those tests in mind, the product of this research should correspond to related previous knowledge, be logically consistent, lack ambiguity, but most importantly, work well enough to solve the problem of risk management described earlier.

Pragmatism has its strengths and weaknesses. Its strengths include ability to address real problems and the capacity to merge the value and value free sides of the problem. This somewhat holistic approach also breeds complexity. It is not as well-suited to problems that are chiefly value free (e.g. physical science research) or heavily value laden (e.g. social science research). Further weaknesses are that truth is conditional to the particular problem. In response to these weaknesses, firm level risk management will necessarily involve both value and value-free information. The prescriptive knowledge generated for a particular decision-maker will be unique or conditional to the problem situation. For some research this is a weakness, but in decision support systems it is a vital characteristic.

Positivists perform tests to accept or reject hypotheses at some specified confidence level. The test of workability, which is a cornerstone of pragmatism, is not usually easy to measure. "How well must the decision support system work, and what percentage of the time must it work well?" are important questions. The pragmatist must resolve these questions with the same experience, knowledge and

intuition that the positivist uses in selecting the appropriate confidence level. For FIRM the test of workability will be aided by a series of producer workshops that will include formal and informal surveys of the participants.

1.7 The Dissertation Framework

Chapter one defines the goals and objectives of this research. An appendix to Chapter one discusses important terminology that is used in the remainder of the research. The appendix contains three sections of terms. The first section is risk and uncertainty, the second is commodity marketing, and the third is Decision Support Systems.

Chapter two examines literature on procedures used to describe the problem and methods employed in deciding which solutions to the problem are preferred. Chapter two also contains an extensive review of risk-related literature, followed by a review of pertinent research efforts. This review will identify advantages and disadvantages for decision methods to be considered for FIRM, as well as characteristics of the problem set, that impact the decision methods.

Chapter three presents a more complete description of the problem environment, the target audience, state and control variables. Chapter three also presents the FIRM model. A case farm and results of that farm are used to illustrate how the model operates. Chapter four is model validation. Tests of hypothetical producers are designed to validate the FIRM model and see if results correspond to what is already known about risk reduction and commodity marketing.

Chapter five summarizes information about producer participation in the four extension/research workshops. Risk attitudes of the workshop participants and the



marketing recommendations of FIRM are summarized. The later part of Chapter five presents workability tests, to examine how well FIRM operates with farmer/managers.

Chapter six is a summary and conclusion chapter. Chapter six also presents the research findings and opportunities for further research.

The computer code for FIRM components is included in the appendix, along with workshop evaluation forms, workshop data, and utility functions of the producers.

1.8 Summary

Improving the quality of marketing information is an important factor in reducing farm income risks, according previous research efforts. This research will formulate, document and test decision support system (DSS) modules for grain producers to manage farm income risks through selection of pre-harvest commodity marketing alternatives. Research goals and objectives were presented in this chapter.

APPENDIX TO CHAPTER ONE - Terminology

The following subsections describe fundamental terminology of the important subject matter areas. These brief subsections are included here rather than with the remainder of the appendices at the end of the dissertation, to encourage their reading.

1.A Risk and Uncertainty Terminology

Any work involving decision-making in conditions of risk and uncertainty would be incomplete without clarifying the author's use of terms "risk" and "uncertainty." Knight (1921) made an early attempt to differentiate between risk and uncertainty. He felt risky situations were those where the decision-maker had empirical information available to develop more objective probabilities. Uncertainty involved less familiarity with the situation leading to subjective probabilities. See Debertin (1986) for parallel ideas.

To Knight, a coin toss or roll of the die would be viewed as risky, not uncertain. Consider the event of whether a particular person will be rained on one week from today. If that person were a meteorologist, such an expectation would likely be based on a greater deal of familiarity and therefore characterized as risky. Using Knight's terminology, for most persons the event of rain one week hence is uncertain.

Robison and Barry (1987) argued that whether the decision-maker has familiarity or empirical evidence regarding the situation, he or she must still form personal probabilities regarding the possible outcomes and form a decision (See also Anderson et al., 1977). With this argument, the distinction that Knight (1921) used becomes less useful. Robison and Barry (1987) found it more valuable to consider

risky events as a subset of uncertain events. Uncertain events are those which result in two (or more) possible outcomes or states. According to Robison and Barry (1987) risky events are "those uncertain events whose outcomes alter the decision-maker's well being"⁸ By this distinction, a mere coin toss is an uncertain event that becomes risky to the person(s) involved when differing rewards or punishments are determined by the outcome of the toss.

Both attempts to differentiate risk and uncertainty have intuitive appeal as well as limitations. Robison and Barry (1987) left little room for economists use of the word uncertainty, except where "risky" would more accurately describe the situation. Uncertain events which are not risky would be trivial to the economist and the decision-maker. Using this more recent distinction only risky events have utility for economists.

In this dissertation, the terms risk and uncertainty will be used interchangeably. This does not mean the terms are perfect synonymous. By intuition, risk implies potential for welfare change more so than uncertainty. Throughout this text, few uncertain events will be discussed that hold no welfare consequences for the decision-maker. This is not an admission that the difference between risk and uncertainty is insignificant or does not exist. Stronger conclusions were reached by Sonka and Patrick (1984) when they state that "the distinction between risk and uncertainty is unimportant".⁹

Foregoing Knight's (1921) distinction between risk and uncertainty, creates the need for terms to delineate situations where probabilities are formed with greater or

⁸ p. 13

⁹ p. 94



lesser confidence. With limited meteorological data, the chance of next year's April showers exceeding seven inches in Washington D.C. could be elicited from most persons, with very little confidence. Making odds on a coin toss coming up heads is likely done with much greater confidence. This author will use the terms objective probability to represent the coin toss type situations and subjective probability to describe cases like the April showers example.

Of course, decision-makers almost never face probabilities that are purely objective or subjective, but rather on a continuum between the extremes. Knight (1921) faced this same difficulty with the terminologies he chose, and there seems little way to clearly describe all of the situations between the extremes. The practical solution is to describe situations that are largely "risky" in Knight's (1921) terms as objective, and those he would have classified "uncertain" as subjective probabilities. This same nomenclature and similar arguments were also presented in Bessler (1984 and 1985). Decision-makers often integrate objective and subjective probabilities in decision analysis. Thus the two terms become useful, but are not independent.

1.B Marketing Terminology

Agricultural Economists have used the term "marketing" to include every item passing in and out the farm gate, and on to the consumers' table or textile mill. Subtopics of marketing include, transportation, distribution, processing, standards and grading, wholesale and retail sales pertaining to food, fiber and other agricultural products and inputs. There is little doubt that the subject of marketing covers vast territory. Only a small portion of this broad topic is addressed in this particular research. This segment involves farm-level marketing of grain commodities such as

corn, soybeans and wheat. The decision support system (DSS) to be developed will deal primarily with pricing these commodities, through standard pricing alternatives (e.g. futures hedging and cash forward contracting).

Pricing will be used in terms such as pricing tools, pricing alternatives or pricing commitments, to indicate the process of establishing a price (or portion of the price) for some number of bushels, through a contractual agreement, for a specified delivery or contract period. Marketing, as used by this author, is a superset of pricing that could include different time periods, as well as a combination or portfolio of several pricing alternatives. A database of previous pricing commitments for the farm would best be described as a marketing database, since the portfolio of commitments could involve various time periods, several pricing alternatives and more than one crop.

Several commodity marketing terms have local meanings, and may be understood differently in different parts of the country. In this document the terminology used in the Chicago Board of Trade (1985) Commodity Trading Manual will be used where possible. Some critical terms are summarized and boldface in the remainder of this section.

There are two major markets, the cash market and the futures and options markets. The cash market involves delivery of the physical commodity, either now or at some date in the future to a specified location. Any two individuals can make an exchange in the cash market. An exchange made now is called a spot sale. There are cash contracts for future delivery. Such contracts may include the entire price or value (called a forward contract) of the commodity or some agreed upon portion of



the price (such as a basis contract). Forward contracts and spot sales can take place in any volume and location agreed upon by both the buyer and seller.

Futures markets are highly structured forward markets for standardized commodities, at specified months, uniform quantities and federally supervised locations. Futures contracts are bought and sold on the futures markets. The buyer [seller] of a futures contract must sell [buy] the contract back before it expires, or upon contract expiration pay the futures contract price and take possession [receive the contract price and make delivery] of the same quantity and quality of the commodity at a terminal location.

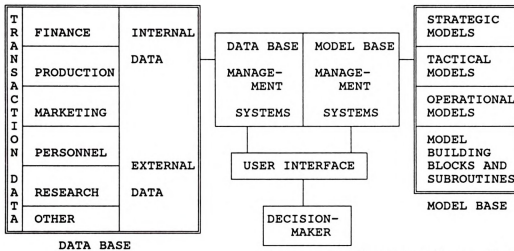
Options can be purchased [alternatively sold first] on the underlying futures contract for a specified strike price at a negotiated premium. A put option [call option] gives the buyer the right, but not the obligation, to sell [buy] the underlying contract in the futures market at the strike price. Options are traded on an underlying futures contract. They serve as futures market's price insurance.

The basis (in this research) is defined as the cash market price minus the appropriate futures market price, at a specific location and time. The basis for spot sales today is the spot price minus the nearest futures contract price. The basis for January soybeans is the January forward contract price minus the January soybean futures price. The soybean, corn and wheat basis is usually a negative number in the major grain producing states.

1.C Decision Support Systems (DSS)

Sprague and Carlson (1982) described DSS as computer-based systems that help decision-makers confront ill-structured problems through direct interaction with

data and analysis models. More specifically, Sprague and Watson (1983) outlined the conceptual design of a DSS and its components as shown in Figure 1.1. The three principle components of a DSS are the data base, model base and decision-maker. The integration of data and models into a DSS reduces data entry, since production and financial records are available to the model base.



Sprague & Watson (in House; 1983, p. 22)

Figure 1.1 Components of a Modern DSS

House (1983) is a good source for further DSS concepts and examples. Harsh (1987A and 1987B) detailed DSS in the context of agriculture, including a description of the Integrated Decision Support System project at Michigan State University. FIRM is part of this larger DSS project which is being designed to operate on powerful micro-computers (Intel 80286 and 80386 based machines).

CHAPTER TWO

HOW TO DESCRIBE AND DECIDE:

A LITERATURE REVIEW

2.1 Risk Principles	24
2.1.1 Probability Principles	25
2.1.2 Expected Utility Theory (EUT)	26
2.1.3 Measures of Risk Aversion	30
2.1.4 Utility Functions	34
2.2 Generating Yield Distributions	38
2.3 Representing Distributions	42
2.4 Market Efficiency	43
2.5 Generating Price Distributions	46
2.5.1 Futures Price Distributions	46
2.5.2 Basis Distributions	50
2.6 Eliciting Risk Attitudes	51
2.6.1 Methods	51
2.6.2 Results of Risk Elicitation	61
2.6.3 Problems with Previous Research	63
2.7 Decision Rules and Efficiency Criteria	67
2.7.1 Maximize Expected Utility	68
2.7.2 Stochastic Dominance	70
2.7.3 E-V, MOTAD, M-SD, and Semi-Variance	76
2.7.4 Target MOTAD and Lower Partial Moments	79
2.7.5 Safety First Decision Rules	83
2.8 Previous Efforts	84
2.8.1 Risk Efficiency Studies - Research Oriented	85
2.8.2 Micro-Computer Based Simulations	89
2.9 Summary	91



Recall from section 1.2 that the farmer's problem is "Which pricing alternatives to use and how many bushels to price, (for a particular grain commodity) when production is uncertain?" Such a problem implies uncertain futures price, basis, yield and total costs.

The purpose of this chapter is to review literature to help find $D(\bar{x})$; where, $\bar{x}$ is uncertain crop income for a single crop, and $D()$ is a decision rule or efficiency criteria, or some method to measure of the desire for income $(\bar{x})$ from the crop (under the related marketing problem).

For the case of deciding pre-harvest marketing...

$$D(\bar{x}) = g(f, \bar{b}, \bar{y}, C(a), c(y, a), a, S, m, n, \text{Cov}(f, \bar{b}, \bar{y})) \quad (2.1)$$

where: $D()$ decision method - may depend on more than $\bar{x}$
 $\bar{x}$ income distribution
 g the marketing function
 $\bar{b}$ basis distribution
 f futures distribution
 $\bar{y}$ yield distribution
 $(1..m)$ subscripts for the particular pricing methods
 $n(1..m)$ the number of bushels to market in each of the m methods
 C direct costs per acre (seed, chemicals, fuel, not land)
 c yield dependant variable costs (on a per bushel basis)
 a acreage (cash and owned plus portions of share crop)
 $\text{Cov}(f, \bar{b}, \bar{y})$ covariance matrix between distributions
 S static market information. Static information involves interest rates, today's cash market quotes, option premiums, time until option expiration and more. The control variables are $n(1..m)$.

For this decision domain, the direct costs (C) do not vary with yield, but would vary if a different crop were grown or a different yield target. Often direct costs for crops are allocated on a per acre basis. Per bushel costs for the problem described include harvesting, trucking, drying and other handling expenses.

Equation 2.1 is a general form because selection of a particular $D()$ will affect a more specific formation of the problem. It is possible that other factors should be considered besides uncertain income. These factors could include, but certainly are not limited to, the decision-maker's desire for income, leisure, debt, financial constraints and understanding of pricing methods. Without an intrapersonally-valid common denominator between these other factors, no unique solution may exist. Multiple criteria decision making is possible (if other criteria are deemed important), but cannot guarantee a solution exists, and if one exists, that it is unique (Manetsch and Park;1988). For the marketing problem uncertain income was deemed the important decision factor, because most other factors would not be affected from one marketing plan to another. While financial constraints may be very real, the best or acceptable $D()$ should have ways of working with such constraints. Depending on the decision methods chosen, it may be important to know the attitudes the producer has about income/risk tradeoffs.

This chapter begins with overviews in risk principles, probability principles, and expected utility theory. In a later section the right hand side of equation 2.1 will be discussed further, with special focus on how uncertain variables can be evaluated and represented. The chapter continues with decision rules or ways to decide, followed by previous related research, and finally a summary.

Uncertain crop income can be represented by a "Cumulative Distribution Function" (CDF) in Figure 2.1. A CDF shows the probability of getting equal or less income at every income level. Changing the number of bushels to be priced in each of the pricing alternatives considered in the $g()$ function (above), could give different income distributions, like those in Figure 2.1. Any of the three distributions shown in

Figure 2.1 could be the "best" depending on how they are evaluated. Some evaluation methods or decision criteria offer analysis for large classes of producers and others are very specific for the individual producer and their attitudes about risk.

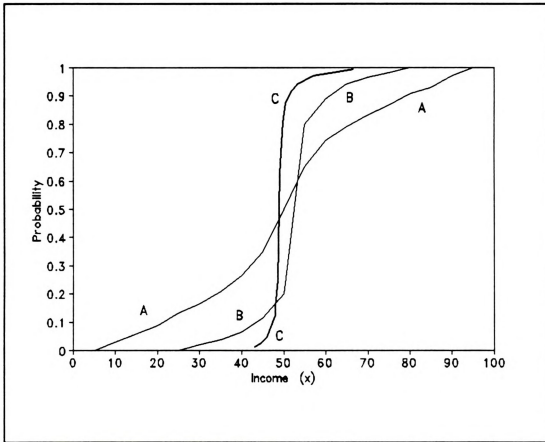


Figure 2.1 Comparing Income Distributions

Before constructing "Decision Support System" (DSS) tools to manage income risk through commodity marketing, there are a number of background areas that need examining. Exploring these areas will hopefully lead to a more objective selection of decision methods (the "D()"). This should help develop a common understanding of numerous terms in risk and decision theory, as well as introductory probability theory.

In addition, this research will certainly benefit from a review of methods previously developed, even if many of them are not used.

Decision theory, with special attention to decision rules, risk efficiency and risk preference elicitation will be a critical part of the research foundation. An understanding of commodity markets and price behavior, with particular attention to market efficiency, futures price volatility and how to estimate and represent uncertain variables are prerequisites to the research.

In this chapter there are a number of technical terms which are used to describe risk, but which should not be used with farmers or decision makers. Decision theorists create games, gambles or lotteries with probabilities of payoffs or outcomes. The word "games" may accurately describe the situation for a theorist, but perhaps not for the manager or decision-maker. Managers make plans and selections based on the situations they face. They may get good results or bad, but they don't "play games." (See Musser and Musser;1984 for more) In this chapter the theory terms will be used, giving way in later chapters to terms that represent management activities.

2.1 Risk Principles

Daniel Bernoulli (1731) proposed the idea that people act as if they make risky decisions by adding up the utilities times the probabilities of each possible outcome. The Latin term he used for this process translates to "mean utility." In his collection of letters and papers he demonstrated this particular view with several examples.

Except for Bernoulli's early work, risk is a relatively new topic in economics, with much of the research progress being made after World War II. The subjects of

risk and decision-making are shared across several disciplines including (but not limited to) management science, economics, medicine, psychology, and statistics. In this section the focus on risk is largely from the perspective of economics, management science, and statistics. Previous efforts and terminology related to risk form an important foundation for the development of the DSS components to follow.

2.1.1 Probability Principles

Two terms critical to probability and risky decision-making must be defined. The "probability density function" (pdf), denoted by $f(x)$ (where x is the uncertain value, of a variable X), is $f(x) = p[X=x]$. Where $x = x_1, x_2, \dots$, and the sum of the probabilities for all x , under consideration is one. Lowercase p indicates the probability of the event in the subsequent bracket. A related function called the "Cumulative Distribution Function" (CDF), and denoted by $F(x)$ is simply, $F(x) = p[X \leq x]$. Where $x = x_1, x_2, \dots$. For continuous random variables, the pdf is a function whose probability at a particular value x is infinitely small, since X is continuously divisible. However, a common practice with continuous variables is to form histograms of equal interval. The CDF for continuous random variables is expressed as an integral of its related pdf function, taken from minus infinity to some value of the variable X . The value of the CDF probability is bounded by zero and one.

With continuous random variables only the CDF can be graphed with numerical values on both axes. The $p[X = x]$ for a continuous variable is infinitely small, but pdf's are often sketched for continuous variables with no values on the probability axis. For most persons, probabilities (values of the pdf) are more easily understood than the CDF (von Winterfeldt and Edwards, 1986). For this reason,

empirical work with continuous random variables usually involves converting the distribution to a discrete one and eliciting probabilities of intervals. An alternative is to elicit percentiles, where the 20th percentile is the value of X for which $F(x) = .20$, and the 50th percentile is the median of the distribution. With enough elicitations a discrete CDF is formed which may then be smoothed if the underlying variable is continuous.

The k th moment of a probability distribution about the origin is $E[X^k]$. Thus, when $k=1$, the first moment of a distribution about the origin is the mean of the distribution. Higher moments about the origin are seldom discussed. More useful measures are higher moments about the mean. The k th moment of a probability distribution about its mean is $M^k = E[X - E(X)]^k$. Where M^k is the k th moment of a distribution about its mean, X is a random variable and E represents the expected value of the bracketed expression. The second moment of a distribution about its mean (M^2) is the variance. M^3 is a measure of symmetry or skewness. If $M^3 = 0$, the distribution is symmetric (e.g. Normal distribution) and M^4 is kurtosis. Kurtosis modifies the normal distribution to give it a thinner higher peak and thicker longer tails. Skewness and kurtosis are used in testing normality of futures price movements (Gordon, 1985; Gordon and Heifner, 1985; Mann and Heifner, 1976).

2.1.2 Expected Utility Theory (EUT)

"Expected Utility Theory" (EUT) is the cornerstone for most risk research in economics. In fact, while Bernoulli did not name his concepts EUT, he easily could have. A number of authors have referred to risk related utility functions as Bernoullian

utility functions (Lin and Chang;1978, Buccola and French;1978, Ramaratnam et al.;1986).

Numerous authors, (von Neumann and Morgenstern, 1944; Friedman and Savage, 1948; Luce and Raffia, 1957; and Machina, 1983), have contributed to the theory through fundamental axioms and deductions that result. Summaries of EUT primary axioms and implications can be found in Robison and Barry (1987), Anderson et al. (1977), Machina (1983a, 1983b), and Copeland (1983). The following is a brief overview.

Using Machina's (1983a) nomenclature, the three primary axioms of EUT are (1) completeness, (2) transitivity and (3) independence. Completeness (by some authors called "ordering of choices") simply means that any two choices (of all available choices) can be compared; and the decision-maker will either prefer one of the two choices or be indifferent between the two choices. Decision makers may weakly prefer or strongly prefer one item over another. Weak preferences indicate either preference or indifference, while strong preferences indicate no indifference and only preference.

The transitivity axiom says, "If a decision-maker weakly prefers choice A to B, and weakly prefers choice B to C (with at least one strong preference), then choice A must be strongly preferred to choice C. This axiom indicates that decision-makers have the ability to ordinally rank preferences.

The first two axioms deal with preferences for choices under certainty, although they imply individual's preferences may be represented by a "preference functional" defined over a probability distributions. In other words, the decision-maker's choices could be between gamble A and gamble B. The most critical and often questioned

axiom is that of independence. To quote Machina (1983a), the independence axiom is: "a risky prospect A is weakly preferred (preferred or indifferent) to a risky prospect B if and only if a $p:(1 - p)$ chance of A or C respectively is weakly preferred to a $p:(1 - p)$ chance of B or C, for arbitrary positive probability p and risky prospects A, B, and C".¹ This standard independence axiom implies that person's preferences are linear in the probabilities. Machina (1983a and 1983b) details a more general and recent form of the independence axiom which extends the breadth of the EUT.

From these three axioms come simple, but important theorems. The theorems are proven in most of the risk literature previously cited, as well as in Varian (1984). If a decision-maker obeys the axioms, then the utility of a gamble is equal to the sum of the utility of individual outcomes times the probabilities of their occurrences. This implies a Bernoullian utility function representing decision-maker preferences and subjective probabilities formed by the decision-maker who has accepted some gamble from a set of possible gambles (the results of Theorem #1).

A related theorem (#2), is that "for any gamble there exists some certain outcome (called a certainty equivalent), such that the expected utility of the gamble and the utility of the certain outcome will be equal, and the decision-maker will be indifferent between the gamble and the certain outcome (measured in the income units)."

The idea of a certainty equivalent for a gamble was described in Robison and Barry (1987) and is shown graphically in Figure 2.2. The horizontal axis is the income (or lottery payoffs or just X), the utility of income ($U(X)$) is plotted on the vertical axis. $E[X]$ is the expected gamble income and is proportionally distanced between the two

¹ p. 2

lottery payoffs according to their respective probabilities. In Figure 2.2 the gamble is a .5 probability of an \$80,000 income and a .5 probability of \$40,000. With a utility curve (A-B) in Figure 2.1, the $E[U]$ for the gamble is 200. This is simply $.5 U(80,000) + .5 U(40,000)$. The "certainty equivalent" (X_{ce}) is the amount of certain income whose utility would equal the utility of the gamble. In Figure 2.1 the X_{ce} is \$50,000. There is a \$10,000 difference between the X_{ce} and the $E[X]$ due to the degree of risk aversion (bend) in the utility curve. This \$10,000 difference is called the "Risk Premium" (RP).

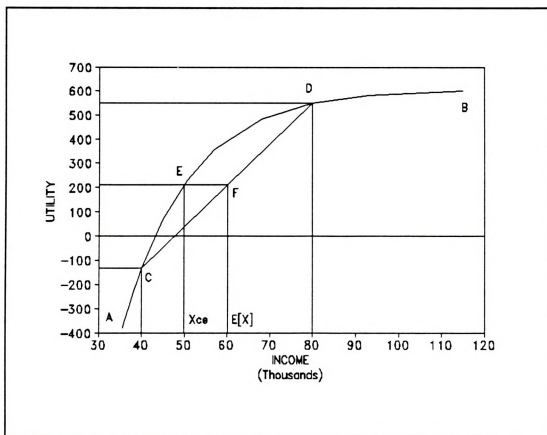


Figure 2.2 Basic Utility Concepts

A decision-maker with a concave utility function like that shown in Figure 2.2 would be willing to accept some certain income less than $E[X]$ rather than accept the gamble. This behavior is called risk averse since $E[X]$, the expected income of the gamble (measured in X), exceeds the X_{ce} of the gamble.

Persons with utility functions that are globally (locally) concave in income would be globally (locally) risk averse. Utility function convexity if global (local) would show a global (local) preference for risk. Similar arguments hold for linearity of the utility function implying risk neutrality.

A utility function like Figure 2.2 is called a Bernoullian or sometimes von Neumann-Morgenstern (1944) (vN-M) utility function. Bernoullian utility functions are not equivalent to utility functions in traditional consumer demand theory because the former involve uncertainty and risk preferences, where the latter do not. In addition, Bernoullian utility functions are cardinal, since they are unique up to a linear transformation of the utility measurement. Utility functions in modern consumer theory are ordinal and, therefore, unique up to any monotonic transformation. Risk theory seldom involves ordinal utility functions of consumer theory, but relies heavily on the Bernoullian utility function. As a result, all references to utility in this document will be to Bernoullian utility, unless it is specifically stated that the utility is of an "ordinal" nature.

2.1.3 Measures of Risk Aversion

Utility is measured on an arbitrary scale. As Varian (1984) mathematically showed, changing the location and/or scale of utility (a linear transformation of the y axis) results in an identical expected utility function (expected risk behavior). Robison

and Barry (1987) showed this graphically by shifting each point on the utility function in Figure 2.2 some equal distance upward (a change in location). When this is done the certain equivalent for the two utility functions (persons) remains identical. Similar graphical evidence can be made for changes in the utility scale. This lack of appropriate units with which to measure utility means that cardinal measure of utility is not an important characteristic for measuring risk preferences, but rather the bending rate of the utility function.

Using Figure 2.2, it is easy to see that as the utility function bends more sharply, the certainty equivalent of the gamble is farther from the expected outcome of the gamble (both measured in X). The second derivative of the utility function plays an important part in measuring the rate of bending and, therefore, risk aversion. Most decision-makers operate in a range where more is preferred to less; thus $U'(X) > 0$ (the first derivative of income utility, is positive). The utility function is upward sloping when income (X) is plotted on the horizontal axis and $U(X)$ on the vertical axis. Knowing $U'(X) > 0$ says nothing about whether the decision-maker is even risk averse or preferring, since the utility function could be concave or convex.

When the second derivative of income utility, $U''(X)$, is negative (positive, zero) the decision-maker is risk averse (preferring, neutral) as previously discussed, and the utility function is concave (convex, linear). The size of $U''(X)$ indicates the degree of bending in the utility function, but because utility is unitless, $U''(X)$ needs to be "normalized." Pratt (1964) set $R(X) = -U''(X)/U'(X)$ called an "absolute risk aversion" (ARA) function. $R(X)$ can be useful for measuring degrees of risk aversion/preference when the decision-maker conforms to the realistic axioms of EUT.

The value of the ARA function, $R(X)$, evaluated at a particular income is called the ARA coefficient. The ARA function is not affected by linear transformations of the underlying utility functions, allowing some comparison of risk behavior across individuals. However, the ARA coefficient is a local measure of risk aversion that is dependant upon the income level at which it is being measured (Raskin and Cochran; 1986). This is true for all reasonable utility functions, except the negative exponential utility function and linear functions of risk (risk neutral).

ARA coefficients for two different individuals (different utility functions) allow comparison of risk attitudes, provided that X is measured in common units, the values of X at which the ARA is calculated and interpretation of X are equivalent for the two persons. The larger the value of the ARA coefficient the greater the degree of risk aversion, and the expected income from a gamble will be greater than the certainty equivalent (for positive $R(X)$). The equation is $RP = E[X] - X_{ce}$, where RP is the risk premium, $E[X]$ is the expected income from the gamble, and X_{ce} is the certainty equivalent of the gamble (all measured in units of X). The more positive (negative) the value of the ARA coefficient the more risk averse (preferring) the decision-maker is, and the larger (smaller) the risk premium. When the ARA coefficient is zero, the decision-maker is locally risk neutral and the risk premium is zero. Such a person is locally a profit maximizer.

$R(X)$ is a local measure of risk aversion, but RP can be applied at any income level. In fact, if a person is offered a discrete lottery of winning or losing \$10,000 based on a fair coin toss, the value of $U'(X)$ evaluated at the mean (zero) may be zero leaving $R(X)$ undefined, but the RP will always be defined. If a subject indicated he or she would pay \$50 to avoid such a gamble, then the $X_{ce} = -\$50$, the $E[X] = 0$ and

$RP = \$0 - (-\$50)$ or $\$50$. Thus, in some situations RP is more useful as a risk measure than $R(X)$. This issue is useful in designing risk analysis software, since RP has units that producers should understand. Lin and Chang (1978) outline many reasonable utility functions, most of which have $R(X)$ values that become undefined when evaluated at certain income levels.

To this point utility has been a function of net income. It is possible to rewrite utility to make it a function of wealth. The inclusion of wealth into utility results in the same value of the ARA coefficient when the starting wealth or endowment is constant (see Raskin and Cochran; 1986, theorem 2). If $W = X + k$, where W is wealth, X is uncertain income, and k is the endowment (a constant regardless of the gamble), then $R(W) = R(X)$. This is true because $dU(W(k + X)dx)$ is $U'(X)$ and k , being constant, drops out. Thus $U'(X) = W'(X+k)$ when k is constant. The second derivatives follow from the first and the $R(X) = R(W)$. When k is allowed to change, as in examining a decision-maker at two different wealth levels, or when X has some correlation to k during the uncertainty period, then $R(W)$ will not equal $R(X)$, (since k can't drop out). If the beginning endowment changes due to uncertain income from the crop under consideration, before the crop is sold, then the utility should perhaps be called Enterprise Utility. Other factors such as excellent income from wheat, might alter mid-season risk attitudes for corn and soybeans. These same arguments apply to gross margins, where some static variable representing fixed costs such as land, is no longer needed, just like the fixed endowment (k).

2.1.4 Utility Functions

Table 2.1 shows three commonly used utility functions; their related absolute risk aversions; $R(X)$, and the derivative of the absolute risk aversions with respect to X , where $R'(X) = dR(X)/dX$. A lower case d is used for partial derivatives, so that dY/dX is the derivative of the function Y with respect to X .

The quadratic, semi-logarithmic, and negative exponential are often used in analytical risk research as approximations for decision-maker utility functions. The semi-logarithmic is the least common of the three, owing to its inability to deal with negative incomes. It was proposed by Bernoulli (1738) in one of the first discussions of utility functions. In the problem Bernoulli presented (called the St. Petersburg paradox), all of the income possibilities are positive so the semi-logarithmic provides a reasonable solution to that problem.

The quadratic utility function is commonly used in expected value-variance models (E-V models) for the following mathematical properties. If $U = X - b \cdot (X^2)$, then from statistic principles we know:

$$E[U] = E[X] - b \cdot E[X^2] \quad (2.2)$$

and, $E[X^2] = V[X] + (E[X])^2$, where $V[X]$ is the variance of X . Subbing this into equation 2.1 gives:

$$E[U] = E[X] - b \cdot (E[X])^2 - b \cdot V[X] \quad (2.3)$$

Using equation 2.2, $dE[U]/dV[U]$ (change in expected utility with respect to variance, holding expected outcome constant) is negative if $b > 0$. This implies that expected utility will be increased if the variance of income is reduced. Also, if b is sufficiently

small ($1/[2b] > E[X]$), increasing $E[X]$ will increase $E[U]$, if $V[X]$ is held constant. That is $dE[U]/dE[X]$ will be positive. The conclusion is that if utility is quadratic then utility can be increased by increasing expected outcome and decreasing variance, which are the criteria for E-V efficiency. However, there are also problems with quadratic utility.

Table 2.1 Three Common Utility Functions.

UTILITY FUNCTIONS ($b, c > 0$, and constant) X = income	ARA function $R(X) = - U''/U'$	(ARA)' $R'(X)$

SEMI-LOG		
$U = b \ln X$ st. $X > 0$	$1/X$	$-1/X^2$
QUADRATIC		
$U = bX - cX^2$	$2c/(b-2cX)$	$(2c)^2/(b-2cX)^2$
NEGATIVE EXPONENTIAL		
$U = -ce^{(-bX)}$	b	0

A positive value of b implies risk aversion, which is a common behavior in applied risk research. For the E-V criteria not to contradict EUT, income must remain sufficiently small for quadratic utility. At high expected income levels $dE[U]/dE[X]$ will be negative so further increases in income, will decrease utility. For nonsatiable

goods like income, this would seem to be an unreasonable conclusion. With $R'(X)$ always positive, quadratic utility implies "Increasing Absolute Risk Aversion (IARA) behavior. It is more commonly believed that most decision makers exhibit "Decreasing Absolute Risk Aversion" (DARA). This later behavior indicates that as the income is increased, willingness to take risks decreases. Robison and Barry (1987) contains a more extensive presentation of IARA, CARA and DARA.

Quadratic utility is often used in applied risk research in spite of the problems mentioned (see Miller;1986, and Alexander et al.; 1986). This is largely due to the analytical simplicity of the function. Its users also point out that, by Taylor series expansion about a point, any function can be approximated by a quadratic (Chang; 1984). The E-V model applies under other conditions besides quadratic utility. A more complete review of the E-V model appears in section 2.7.3.

The negative exponential function has two strong features that make it common in risk research. The first feature is its "Constant Absolute Risk Aversion (CARA)." If a decision-maker has a negative exponential utility function (or a linear transformation of one) and behaves according to the EUT axioms, then the value of the ARA coefficient will be globally constant regardless of the decision-maker's wealth level, or the scale of the gamble. There is only one other CARA function available, and that function is the special case of perfect risk neutrality (a linear function). If two decision-makers are both CARA, then it is simple to compare their risk behaviors by simply comparing their ARA coefficients. These comparisons can only be made for the special case of CARA, when the income under consideration is measured in the same way.

The second reason the negative exponential utility and its CARA properties are commonly used is that they are reasonably supported by empirical research. Ramaratnam et al. (1986) elicited risk preferences from 26 producers and fit the utility observations to four different utility functions for each producer. The negative exponential gave a better fit (higher r^2 , correlation coefficient) than the quadratic and semi-log functions previously mentioned, and was also superior to the log-linear function.

Two properties of CARA utility should be noted. Several surveys have shown that as producers move to higher wealth, risk aversion is not constant but usually declines (DARA). Examples are Binswanger (1980), Dillon and Scandizzo (1978), Patrick et al. (1981), and Moscardi and de Janvry (1977). Secondly, as gambles approach large negative values, the slope of the negative exponential utility function ($dU(X)/dX$) approaches infinity. Kahneman and Tversky (1979) felt that $dU(X)/dX$ should approach zero at large income losses. Such rational indicates that if there is a possibility of losing a \$100,000 then what is another \$1,000. To demonstrate suppose a person must face Game 1 below. How much would the person be willing to bid to avoid lottery A and play the better B? Most decision-makers will have a very different risk premium (bid to choose lotteries) regarding Game 1 and 2.

Play this... lottery A: .5(A=\$0) ~ .5(A=\$-102,000)
or pay to
Game 1 play this
better game. lottery B: .5(B=\$0) ~ .5(B=\$-101,000)

How much will you pay to avoid lottery A and buy the safer B ? ____

Play this... lottery A: $.5(A=\$0) \sim .5(A=-\$2,000)$
 or pay to
 Game 2 play this
 better game... lottery B: $.5(B=\$0) \sim .5(B=-\$1,000)$

How much will you pay to avoid lottery A and buy the safer B ? ____

Lottery outcomes are separated by "~", with payoffs in parenthesis, preceded by their probabilities. In both games above, lottery B has an expected value of \$500 more than lottery A. Intuition suggests decision-makers might be risk neutral when faced with two possible large losses like game 1. If so, they would only pay some small amount for the only slightly safer B. The same decision-maker could be substantially more risk averse (compared to game 1) when faced with the possibility of breaking even, versus moderate losses in game 2. Bids for the safer B in game two will likely be higher than for game 1.

Lin and Chang (1978) have detailed and summarized methods for estimating several additional functional forms for utility. Buccola and French (1978) demonstrated a method for estimating negative exponential utility functions.

2.2 Generating Yield Distributions

Having reviewed the theory necessary for the remainder of this chapter, it is time to begin a study of how the right hand side (descriptive) of the marketing model can be represented for problem solving. Recall that the marketing model was:

$$(\hat{x}) = g(\hat{f}, \hat{b}, \hat{y}, C, c(\hat{y}, a), a, S, m, n, \text{Cov}(\hat{f}, \hat{b}, \hat{y}))$$

To solve for $\hat{x}$, the uncertain $\hat{f}$, $\hat{b}$ and $\hat{y}$, must be forecasted or estimated. In this section, uncertain yield ($\hat{y}$) is examined. In the following section, ways to represent uncertain variables are discussed.

The decision model should be designed to run several times through the growing season. Yield uncertainty could be quite high at planting time. As the season progresses, more information is revealed, and the yield becomes more certain. A mid-season forecast should include all the crop development to date, plus the uncertainties related to the remainder of the season. To capture this process with historical data like USDA yields or farm records would be nearly impossible. The only reasonable sources in this situation are objective professionals or farmers.

One method to assist producers in giving mid-season personal probabilities would be the incorporation of a plant growth model and a weather simulator. With such an addition, it would be possible to enter the weather to date (retrieve it from the database) and Monte Carlo the remaining weather for the crop year. By simulating enough such "years of remaining weather", it would be possible to form probability distributions that are conditional upon the weather to date. Such a model would need to consider the soil type, previous weather, date of planting, the time to maturity of the variety and the latitude of the growing area. There are also many other factors that might also be important. These include the manager's skill, soil fertility, and supplemental drainage and irrigation. This alternative seemed impractical to employ directly, but research with crop growth models (like Ritchie; 1986) could be helpful in this area by providing guidelines for changes in mid-season yield uncertainty.

Previous research and software development on eliciting yield probabilities has already been carried out. Pease and Black(1988) designed a software program called ELICIT to collect discrete pdf's from farmers. ELICIT is used in the Agricultural Risk Management Simulator (ARMS) Version 3.x. as one method of establishing yield pdf's for analysis of Federal All-Risk Crop Insurance.

The "conviction scoring" method used in ELICIT involves first selecting yield intervals, such as five bushels per acre for soybeans. Next, the user selects the yield interval he or she expects to most likely receive. Suppose the user chose the interval 30-35 bushels per acre, as the most likely to occur. In this interval the user enters a score of 100. From there, the user moves to adjacent intervals and asks, "if the 'anchor' interval occurred 100 times, how often would each of the other intervals occur?" Other intervals are evaluated in a similar manner. These numbers are re-indexed to give a discrete pdf that is graphed for the user. Users may then go back and re-examine their conviction scores. ELICIT stores the discrete pdf, CDF, mean, and standard deviation in an "American Standard Code for Information Interchange" (ASCII) text file named by the user.

Pease et al. (1990) described the conviction scores method of elicitation in greater detail. They concluded growers were very interested in this activity. Producers with very little understanding of probabilities, could use the conviction scores quite successfully. The following equations show how ELICIT works. Suppose a decision-maker indicated the following values (in brackets) for the five bushel increments in soybean yield: 15-19.9bu [5], 20-24.9bu [10], 25-29.9bu [20], 30-34.9bu [40], 35-39.9bu [100], 40-44.9bu [40], 45-49.9bu [20], 50-54.9bu [5]. The numbers in brackets are summed. An adjustment ratio is calculated as the desired total value of 1 divided by the summed amount. For this example the bracketed terms sum to 230. Multiplying each bracketed number by $1/230$ and rounding to the nearest hundredth, the discrete pdf is: 15-19.9bu [.02], 20-24.9bu [.04], 25-29.9bu [.08], 30-34.9bu [.17], 35-39.9bu [.42], 40-44.9bu [.17], 45-49.9bu [.08], 50-54.9bu

[.02], 55-59.9bu [2.5]. These values are displayed in a histogram by the ELICIT software. Users are permitted numerous revisions.

Unfortunately there are very few other methods of what Pease et al. (1990) called "measuring alternative events." Detrended local yield distributions would be useful, but are subject to detrending method error, aggregation error, possible measurement error, perhaps limited observations, but more important, potential problems of availability.

Another way of representing yield uncertainty is through parametric distributions, rather than the discrete pdf's and CDF's formed by ELICIT. Parametric distributions could be triangular, normal or log-normal, since these three functions are easier to represent than most others. These functional forms could be fit to discrete data or perhaps elicited directly from producers. The advantage of the triangular function is it's flexibility, and the simple data to describe it (high, low, and mode). The disadvantage is that much error can occur in the tails of the distribution, when continuous distributions are represented by a triangular distribution. Anderson et al. (1977) demonstrated use of triangular distributions.

The biggest advantage of subjective yield elicitation is that farmers can do it. Producers may have errors, but they can make the data available. Conditional normativists would say that whether their opinions are close to the "truth", they represent what the decision-maker feels is truth, and they make decisions based on these subjective probabilities (see Anderson et al.;1977)². In time they will likely get better at evaluating probabilities, (as learning takes place). However, conclusive evidence to this regard was not discovered.

² p. ix (Preface)

2.3 Representing Distributions

There are two basic methods for representing uncertain variables (distributions). The first is the direct method, using the functional form of "well behaved" (parametric) distribution(s). In this method, basic principles of probability theory are used to add, subtract or multiply the equations to get a CDF for the performance ($\bar{x}$ for this research). Often, normal distributions are used to represent these functions, because normals are common in nature and they are easy to work with from a statistical standpoint. Unfortunately, with two or three important distributions and their relationships (correlations), the process of using functions directly becomes very difficult. Anderson et al. (1977) gave an example of calculating the variance of gross revenue resulting from uncertain quantity times uncertain price. When non-parametric distributions are part of the problem, the direct method can not be used. Since individual producer yields are not expected to be well-behaved or parametric, the direct method is only useful for more simple problems.

The second way of representing uncertain variables is to create a large number of observations on each distribution in the problem, in such a manner that the CDF of the large number of observations is like the CDF of the discrete or continuous functional form. These observations are constructed using a zero-one random number generator and the CDF of each uncertain variable. Each continuous zero-one random number maps into a unique value of the CDF, since the CDF is a non-decreasing function. That is $p_i = \text{CDF}(x_i)$ for all i , and $0 \leq p_i \leq 1$. These observations can then be used in computations to find the CDF of the performance distribution. This second method is called Monte Carlo representation. Non-parametric distributions such as those created by ELICIT, can be represented by

Monte Carlo methods and the CDF transformation method, as well (Manetsch and Park;1988).

King(1979) presents methods for dealing with correlations among uncertain variables (distributions). Fackler and King (1988) made further improvements on this process by suggesting use of fractile correlations rather than typical "mean-based" correlations. Distributions that are uncorrelated to all the others can be generated independently. If there are non-zero elements in correlation matrix between the uncertain variables, then the variables are multivariate and each distribution is referred to as a marginal distribution.

2.4 Market Efficiency

Forecasts of price distributions (f and b) are necessary, when developing a pre-harvest risk management commodity marketing program. There is a simple way to forecast prices, if the item is traded in an efficient forward market. A forward market is one where price can be set today for a good to be delivered at a specified future time. The item to be traded could be stocks, bonds, stock options, commodities, futures on commodities and options on futures. Any item that is traded in a public market, with grades and standards, with many traders and highly visible prices is a candidate for being efficient. If a market is efficient, the unbiased forecast of the price of an item in the future period, is its current market price.

The Dictionary of Modern Economics (Pearce, 1983) summarized the Efficient Market Hypothesis as:

The title given to a view about the stock market that the prices of shares are good, or, the best available estimates of their real value because of the highly efficient pricing mechanism inherent in the stock market. There are three levels of efficiency. First, the market is held to be "weak-form efficient" if share price changes are independent of past price changes. Second, semi-strong form efficiency is present if share prices fully reflect all publicly available information. Third, strong-form efficiency will imply share prices will have taken full account of all information whether publicly available or not.

Leuthold et al. (1989) discussed each form of efficiency and appropriate tests.

These same efficiencies can be applied to commodity futures markets, as well as a stock market. The three efficiency classes were first described by Fama (1953).

Leuthold et al. (1989) concluded that "none of these developments (research) have shown an alternative marketing mechanism that provides prices of any less biased nature than the futures market. No one has devised a more efficient marketing alternative."³

Semi-strong market efficiency implies that today's futures price for November soybeans is the best predictor (currently available) of the closing price of that contract on the day it will expire. Market efficiency also implies that speculative attempts to arbitrage the market cannot result in long-run profits. This latter position is particularly true for farmers, since their transactions costs and information costs (per bushel) are higher than large commercial firms that trade futures. The efficient market also means that necessary data is minimal; only the currently traded price is important.

The principle of the efficient market, is that numerous persons are processing market information, and "voting" with dollars if they believe an arbitrage exists. Such opportunities might be across time or distance. The standards involved with a futures contract make this process easier. While some market participants are exposed

³ p. 116.

(taking risks), others use tactics of selling one product and buying a slightly different product, with a belief that the spread between the two is mis-priced. With enough market liquidity, the current price for November Soybeans at the "Chicago Board of Trade" (CBOT) is a composite forecast of all of the market participants. Note that persons who do not participate in the market, by abstention, signal that the price is too low (if they hold grain to be sold), or too high if they will need grain in the future. In this way, even producers and commercial buyers who are not currently trading in the market, are helping form the price.

Thompson et al.(1988) surveyed farmers and grain merchandisers regarding subjective mean and standard deviation of harvest-time commodity prices. The individuals seemed to use closing futures price for expected price, but underestimated volatility implied by the BOPM. Producers also failed to adjust prices for transactions cost. This implies that letting producers subjectively enter price distributions for analysis might be an inferior method.

The antithesis of the efficient market is the idea that the market is mis-priced or biased. If this case were true, some system or formula or person, should be able to profit from such a situation. Tinker et al.(1989) outlined seven different forecasting methods including VAR, ARIMA, and technical trading systems, for the soybean complex (beans, oil and meal), for three and six month periods. They concluded that "No model exhibited significant market timing value for soybean oil prices.", and only one of seven were significant for soybeans (a six month ARIMA model). Their research excluded execution costs which Greer and Brorsen (1989) summarize as significant and variable across commodities. In addition, brokerage costs were excluded in the Tinker et al. (1989) research. These are understandable omissions

since Tinker et al. (1989) were trying to find efficiency in the way Fama (1953) had defined it. Unfortunately, producers and users of futures must pay brokerage and execution costs, which likely void most opportunities for arbitrage, making the futures market at least weakly efficient (especially from the producer's viewpoint).

2.5 Generating Price Distributions

The next two subsections further discuss sources and measurement for the marginal distributions of futures (f) and basis (b). These are presented separately because futures prices are centrally determined in large markets and represent a large portion of the total price. Basis is a local indication of demand, as well as distance to major terminals where futures are delivered and received. Only a small portion of futures contracts are ever delivered upon, or delivered from these major terminals, but they serve as reference points to the cash market.

2.5.1 Futures Price Distributions

Black (1976) developed a model relating market volatility to the premium on an options contract. Cox et al. (1979) expanded on this model with their own binomial pricing model. Under continuous market assumptions the models converge, as shown by Cox et al. (1979). In either case, computer programs like the one Labuszewski (1983) developed, can be used to solve for the implied market volatility. Such programs are used by traders in options pits, as well as other speculators, spreaders and traders. These general equilibrium models have basically two unknowns, (1) the premium of the option and (2) the futures market volatility. By fixing one of the two variables it is possible to solve for the other. For forecasting

price distributions, the current premium is assumed to be efficiently formed in the market and the model is solved for the "Implied Volatility (IV)." There is a third unknown to the equation; a functional form of the distribution is usually assumed in the model.

Fackler and King (1988) developed a non-parametric approach to building the CDF for futures prices. Their approach involved a conversion of put option premiums at all of the actively traded strike prices, into a discrete pdf. There are assumptions about tails of the distribution that must be made, but their method makes no assumptions about a functional form for the price distribution. One disadvantage of their model is that distant trading months have thinly traded options at only a few strike prices. When option contracts are in distant months only a few of the strike prices will be traded. With only a few strike prices trading, assumptions about the tails of a distribution become more critical. Their model does incorporate non-parametric factors such as commodity loans, to the extent that the market has already considered them. This is a big advantage in the Fackler and King (1988) approach.

"Black's (1976) Option Pricing Model" (BOPM) is a general equilibrium model based upon the capital asset pricing model. Development of the BOPM is fully detailed in Black (1976), Cox and Rubenstein (1985), Ingersoll (1987), Elton and Gruber (1987) and Labuszewski (1983). Labuszewski proceeds to show a program written in BASIC. Using his notation and article, the BOPM value for a call premium is:

$$C = e^{-rt} [UN(d_1) - EN(d_2)]$$

Where: $d_1 = [\ln(U/E) + (\sigma^2 t)/2] / \sigma(t^{1/2})$ (2.4)

$$d_2 = [\ln(U/E) - (\sigma^2 t)/2] / \sigma(t^{1/2})$$

And:

C = Fair value call premium (\$/bu.)

U = Current underlying commodity price (\$/bu.)

E = Exercise price (\$/bu.)

r = short term annual interest rates (with continuous compounding)

t = years until option expiration

σ = standard deviation of annualized returns

N = normal cumulative probability distribution

e = the base of natural logarithms, approx. 2.71828

ln = the natural logarithm

The expected price ratio of U/E is 1.0, with some standard deviation for the distribution. Both of these measures are unitless since the ratio of prices removes units. If the options market is efficient, option premiums (especially those close to the money) can be inserted into the BOPM to solve for σ . The σ (implied volatility) or IV that results is an indicator of potential price movement. More precisely σ is the annualized standard deviation in percent of the expected price ratio.

If the IV is .12 or 12 percent, it implies that annualized returns over the period will vary and 67 percent of the time the price ratio will be within 12 percent of the expected price ratio (1.0), (95% of the time within 24%). If we assume that prices are normally distributed, the IV is equivalent to the "Coefficient of Variation" (CV). The CV is the ratio of the standard deviation of a distribution divided by its mean. The CV is very much like the IV, except for important distributional assumptions. Both are unitless.

The issue of a "best" functional form for ending period marginal distributions for futures is not simple. Black (1976), assumed log-normally distributed price changes, implying that the underlying futures price distribution would be log normal. His

assumptions, allowed cleaner analytical solutions than normally distributed futures prices. Originally, he and Scholes had worked on a stock option pricing model published in 1973. Since that time other researchers have re-examined normally distributed futures. Hudson et al. (1986) examined soybeans, wheat and live cattle and concluded "the results of the study suggest that options pricing formulae which rely on the assumptions of normality will do an accurate job in predicting true option premiums."⁴

Forecasting price distributions under the efficient market assumptions, really means selection of a distributional form and forecasting the variance. Another method of measuring futures price variance, is to believe that percentage changes in historical prices from today's date to the ending date, will be the same this year, as in some previous year(s). The CV's could be compiled for weeks or months (prior to harvest). This method would be especially useful if there was strong evidence to believe that this year is like some other year or group of years. One disadvantage of this method is the requirement that a very large database be maintained. On the other hand, this historical data could be compiled and summarized. No previous research on this historical method or the next method has been located to date.

A final method for forecasting futures price distributions is to use today's futures price as the expected futures price in the ending period, and the market's historical volatility for the past few days or weeks. The assumption with this method is that the market volatility will continue as it has. Naturally, this is a rather naive assumption. However, such a simple model could also be used in conjunction with other forecasts. In addition, the IV and the historical variance follow one another very

⁴ p. 2

closely, but neither are stationary when examining CBOT charts for 1990 corn, soybeans, and wheat.

2.5.2 Basis Distributions

Like the previous two distributions, basis could be represented as parametric, (e.g. normal) or it could be entered in a discrete manner similar to the ELICIT program used earlier for subjective yield distributions. Since there is no way to arbitrage basis volatility, small error in the volatility of the basis distribution should minimally affect marketing strategies. Bias in the expected value of the basis, however, could be arbitrated and is critical. In either case, error in estimating the basis distribution will probably have a small effect on the marketing equation, compared to errors in forecasting the futures price distribution, since futures are the major portion of price.

If basis records have been kept, they should be helpful in forming subjective basis distributions. If there are no records, grain elevators or possibly commodity brokers might have them.

Miller and Kahl (1987) used an E-V framework to compare forward contracting to futures hedging. The difference between these methods in a non-dynamic analysis is the basis. They concluded from their research: (1) Basis uncertainty does not explain why producers prefer forward contracting. (2) The use of aggregated data to represent individual decision-makers is not advised. (3) The effects of basis on hedging decisions is very small.

2.6 Eliciting Risk Attitudes

The preceding sections discussed the uncertain distributions on the right hand side of the marketing function. In the next several sections, the topics focus on how to decide (left side of the equation).

If accurate utility curves can be gleaned from producers, then they could be used to find solutions in the manner that Bernoulli (1738) suggested. There are two key words in the previous sentence that make this section necessary. They are "accurate" and "gleaned." The easiest part is gleaned. We can discuss hypothetical situations, present real opportunities, or observe producer behavior. Each of these are discussed in the sections that follow. The more difficult part is, how do you know when you have subjective attitudes measured most accurately? There is lack of consensus in the literature.

2.6.1 Methods

Employing "Expected Utility Theory" (EUT), researchers are able to study decision-maker preferences in risky situations to determine the nature of their risk utility functions. The three general methods for accomplishing this are known as (1) "Observed Economic Behavior" (OEB), (2) "Direct Elicitation of Utility" (DEU) and (3) experimental methods. Regardless of the general method, the researcher has little a priori knowledge of the functional form of utility or which moments of a risky decision are important to the decision-maker. Only with repeated decisions at known probabilities and known income levels, is it possible to solve for risk preferences and approximate a utility function in the neighborhood of the problem.

Using Observed Economic Behavior (OEB), such as actual farm plans for farmers, assumes the researcher knows all constraints affecting this decision and the decision-maker has formed subjective probabilities similar to the more objective ones the researcher might use. Linear programming methods like MOTAD (discussed later) are used to find risk efficient farm plans, and then measures of the difference between efficient farm plans and the current farm plan are made (not in terms of $R(X)$, but changes in allocation). The difference between the two farm plans (allocations) is attributed to risk. Of course all error from each of the plans are contained in each of the solution, along with risk affects. Musser et al. (1986) showed that incomplete constraint sets may overstate the benefits of risk aversion in firm decisions. Many researchers refrain from using OEB and instead rely on direct elicitation, because of difficulties in measuring expected probabilities and assuring a complete constraint set.

Brink and McCarl (1978), and Moscardi and de Janvry (1977) are examples of research that utilized OEB. Brink and McCarl noted difficulties in their model and concluded in the summary that, "although it appears desirable that risk studies be done using actual farmer behavior rather than hypothetical behavior, the difficulties encountered here with price expectations, for example, may indicate why gaming approaches have been preferred".⁵

Binswanger (1980) used experimental methods with real payoffs for 240 peasant farmers in India. Gambles were simple with the lowest payoff being zero. Local income rates and high currency exchange rates (dollars to rupees) helped make the project affordable while evaluating payoffs that were at times greater than the monthly income of the subjects. He also repeated these gambles without payoffs

⁵ p. 262

(direct elicitation) to examine the difference in the two methods. He found that direct elicitation was inconsistent with the experimental methods of elicitation (using actual payoffs). One criticism of experimental methods is that some persons may have moral objections or preferences to the act of gambling. Such biases might be accentuated by the fact that the gamble is carried out and transactions are actually made. With hypothetical gambles (no payoff), the moral objection or preference might be diminished by describing the gamble as a realistic business decision.

An additional problem is that with actual and sizable lotteries, the wealth of the individual is not held constant over the observations. One would expect if decision-makers are not CARA, then their ARA coefficient would change throughout the elicitation process, even if the set of lotteries remained the same.

The conclusion of Binswanger (1980) regarding the superiority of experimental methods is disturbing; because, while they may be more accurate, they have extreme limitations. It would be difficult to find willing subjects for an experiment in which several of the outcomes might be losses of the size that decision-makers often encounter. Each person will have unique risk attitudes (see 2.6.2), so results of one experiment could not be applied to another set of decision-makers. If Binswanger is correct, aiding a decision-maker through a risky decision (using experimental methods) requires them to first make an equivalent risky decision with an actual payoff.

For helping decision-makers through more complex risky decisions there is no practical choice but to interview them to establish their risk preferences, prior to the "real-world" decision. Young (1979), in his summary of empirical risk measurement methods, called this "direct elicitation of utility (DEU)." Unlike experimental methods,

the DEU involves no real payoffs, and therein lies its biggest criticism. Without real risks, decision-makers behave differently than with the experimental and/or observed economic behavior methods. For this reason Musser and Musser (1984) noted that "In contrast to standard procedure, the attitude literature suggests that utility functions for analysis of specific management decisions should be elicited in the context of the particular decision".⁶

In experimental methods and DEU, there are several ways that gambles can be presented. The von Neumann-Morgenstern (1944), (vN-M) method requires the decision-maker to choose certainty outcomes which are equivalent to specified gambles. So that..

$$U(A) = p*U(B) + (1-p)*U(C) \quad (2.5)$$

where A, B, and C are outcomes, and p is the probability ($0 \geq p \geq 1$) of outcome B. The decision-maker chooses a value for A to satisfy the equality. Outcomes B and C remain fixed while the researcher varies the value of p. The monetary value of A is the certainty equivalent for the decision-maker, and can be plotted in income-utility space, as shown in Figure 2.3. The values for U(B) and U(C) are arbitrarily valued on the utility scale. If $U(B) = 0$ and $U(C) = 1$, then the coordinates on the utility curve are $(A_i, E[p_i*0 + (1-p_i)*1])$, with the i subscript denoting the ith observations. The resulting coordinates are data for a utility regression, with a functional form for utility provided by the researcher.

One weakness of the vN-M method is evidence that decision-makers have more difficulty dealing with changing probabilities than with changing outcomes (see

⁶ p. 85

Officer and Halter, 1968; Anderson et al., 1977).⁷ Further, persons may systematically underbid the problem due to the bidding process. Since any bid would be accepted they enter a low bid. Other persons may systematically overbid in a desire to get rid of all risk, regardless of lottery values.

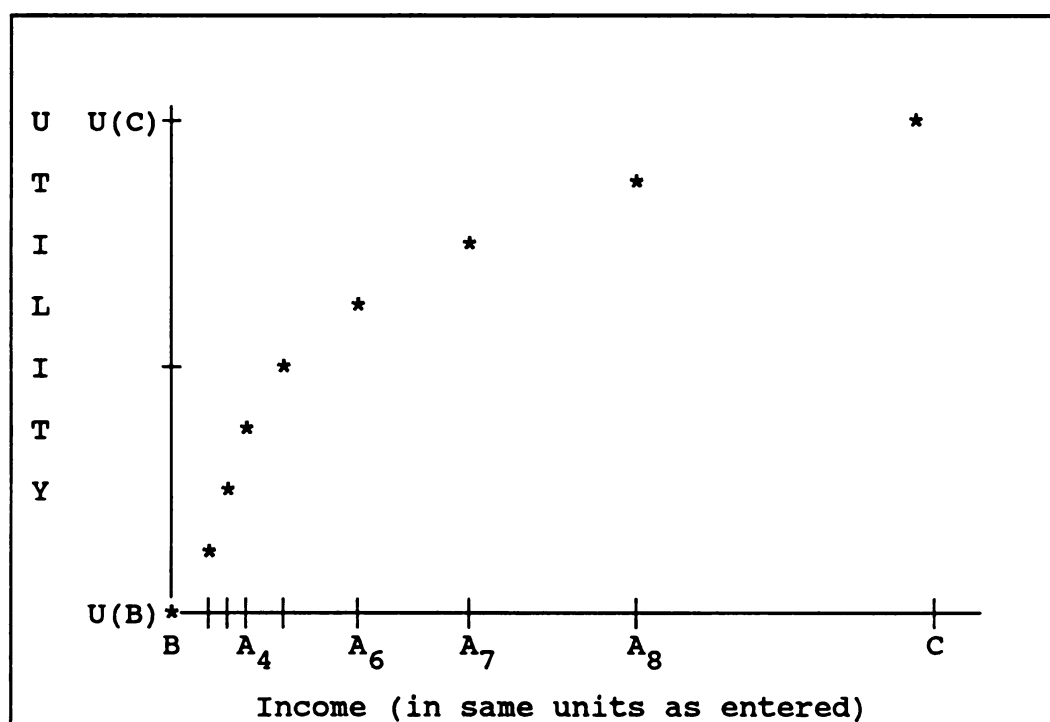


Figure 2.3 Plotting Bernoullian Utility Curves

The second method of DEU is the modified vN-M method which involves the same equality of equation 2.5, but p is fixed (usually 0.5) and values of B and C are varied. This method allows decision-makers to analyze situations with familiar (and constant) probabilities, overcoming one of the objections to the vN-M method. Biases from moral objections to gambling are still present. Methods for approximating the

⁷p. 69

utility function are an adaptation of the vN-M method described above. Systematic over or under bidding could still occur.

The Ramsey (1931) method of DEU involved the following equation..

$$p*U(A) + (1-p)*U(B) = p*U(C) + (1-p)*U(?) \quad (2.6)$$

The value of p is fixed by the researcher (often 0.5) and $A > B > C$ are outcomes, also set by the researcher. If the value of p is set to .5 the method is usually referred to as an "Equally Likely Risky Outcome" (ELRO) method. The value of "?" to satisfy the equality is provided by the respondent, or alternatively, varied by the researcher until the respondent is indifferent between the gamble on the left of the equation and the one on the right. Officer and Halter (1968) presented a method for establishing new values for A , B , and C for the purpose of subsequent elicitations. For each value of "?" which makes the decision-maker indifferent between the two sides of equation 2.6, then $U(B) - U(A) = U(?) - U(C)$. Repeated tests provide additional interval values on the utility scale.

Proponents of the Ramsey (1931) method point out that because the respondent is choosing between two risky situations, biases due to morality of gambling are diminished. This should especially be true if the choices are described as business decisions rather than monetary lotteries. Like other DEU methods, the Ramsey (1931) method involves a game with only hypothetical gains or losses. Because of this important abstraction, Binswanger (1980), as well as Newbery and Stiglitz; 1985) have faulted its realism.

King (1979) and King and Robison (1981) developed an elicitation procedure called an "interval approach" to risk measurement. King felt that other elicitation

procedures over-simplified the decision domain by presenting simple gambles and solving for precise risk preferences and utility functions. Skeptics of EUT also point out that decision-makers may be indifferent about some range of risky alternatives. If this is true, then maximizing expected utility and presenting the decision-maker with only one optimal solution would be an over-simplification of his or her preferences.

As the name implies, the interval approach finds interval values of local risk preferences. The decision-maker is asked to choose between two hypothetical risky alternatives, each with similar mean income values. Each alternative has six possible outcomes and each outcome has equal probability (1/6). The example in Table 2.2 is from King (1979).^a

Table 2.2 Interval Approach Choice Format

Compare distributions 5 and 20 and indicate which one you prefer.			
	Dist 5	Dist 20	
	-----	-----	
	9400	9250	
	9850	9300	Outcomes under each distribution have equal (1/6) chance of occurrence.
	9900	9600	
	9900	10300	
	10050	10400	
	10150	10600	
	-----	-----	
Ave.	9875	9909	These bottom four values are for summary and are not shown to the decision-maker.
St.Dv.	258	595	

^a p. 219

If the decision-maker chooses the riskier distribution (20), he must prefer more risk than the "safer" distribution (5) offers. Alternatively, if 5 is chosen, the decision-maker must prefer less risk, than distribution 20. If the decision-maker chooses distribution 5, elicitation would proceed with two new distributions, both located about the same expected income and less risky than distribution 20. If the decision-maker chooses 20, elicitation would continue with two different distributions that would be more risky than Distribution 5. The elicitation proceeds though one more branch of choices, until risk attitudes are narrowed down to a small interval.

Comparing three such pairs of distributions is all that is needed to solve for one of 8 interval values of the ARA coefficient at a single expected income level. Since the ARA coefficient is local and the form of the global utility function is unknown, the process must be repeated at other income levels that are likely to be experienced by the decision-maker. Locally the ARA is solved by assuming utility is as follows.

$$\begin{aligned}
 U(X) &= -e^{(-RX)} && \text{if } R(X) > 0 \\
 U(X) &= X && \text{if } R(X) = 0 \\
 U(X) &= e^{(-RX)} && \text{if } R(X) < 0
 \end{aligned}
 \tag{2.7}$$

The risky distributions offered to the respondent are closely clustered about similar means resulting in small variances. The coefficient of variation (standard deviation as a percent of the mean) for the distributions used in King's (1979) work were in the range of .024 to .085 percent (for non zero expected income levels).

Thomas (1987) used the interval approach to measure risk attitudes in a survey of Kansas farmers. He noted that surveyed farmers often commented that they really did not see much difference in the two distributions offered to them.

The interval approach to risk measurement is extremely flexible. The researcher or decision analyst can choose several income levels to be elicited, as well as the size of the intervals. Once elicitation is complete, the decision analyst has observations of risk preference at various income levels without any assumption of a particular functional form for utility. Income levels can be negative and positive. It is relatively simple to check consistency of responses by incorporating one or two additional pairs of risk alternatives at each income level. (Wilson and Eidman, 1983; and Tauer, 1986).

The interval approach is not without some limitations. The fact that a utility function is not solved gives added flexibility and increases computational problems. Meyer (1977a) developed a method of using interval approach measurements called "Stochastic Dominance With Respect to a Function" (SDWRF). SDWRF uses optimal control techniques to find efficient alternatives that reflect the decision-maker's interval preferences for risk, but are independent of a particular utility function. SDWRF is usually more selective than a decision criteria called second order stochastic dominance (defined in section 2.7.2) since individual risk preferences are incorporated. King (1979) demonstrated the selectiveness of SDWRF compared to other criteria. The stochastic dominance methods he examined (first and second order), are not usually very discriminatory, while utility maximization finds the single optimal solution. SDWRF has intermediate discriminatory power that varies according to the income distributions and the individual's interval measures.



The decision analyst can determine how narrow or wide the risk intervals will be, the number of possible outcomes in each gamble presented, how many income levels will be tested and the number of consistency checks to be made at each income level, all of which will alter the results of elicitation and the SDWRF efficient set. In addition, the researcher can choose to keep skewness at zero for all distributions offered to the decision-maker or may vary skewness either systematically or randomly. Skewness is likely an important part of risk preferences that is not fixed by the other DEU methods described (Alderfer and Bierman; 1970).

The flexibility of the interval approach makes it important for the researcher to perform consistency checks. King (1979), Love (1982) and Thomas (1987) pretested their interval surveys, but did not perform consistency checks at each income level for all respondents. Wilson and Eidman (1983) and Tauer (1986) did performed consistency checks on each person surveyed, with differing success. In the case of Tauer's work, less than half of the respondents were consistent enough that their results could be used in analysis. Tauer (1986) did show that as a group, choices between the intervals presented were far from being random, indicating that substantial consistency existed compared to random selection. Wilson and Eidman (1983) showed fewer inconsistencies, perhaps due to a different set of intervals and a different method of consistency checking than Tauer (1986).

In addition to interval measures of risk aversion, there is magnitude estimation. Patrick et al. (1981) reviewed elicitation methods and described magnitude estimation. Magnitude estimation, like interval measurement, does not result in a utility function. Instead, it gives an ordinal measure of attitudes based on the importance of risk related goals of the respondent. Magnitude estimation is similar to attitude indices

developed in social sciences. For example, Hughes (1971) describes the Likert (date unknown) scale of attitudes.

The attitudes expressed regarding risk related goals were not stated as a function of some income level in the Patrick et al. (1981) research. Magnitude estimation may be useful for correlation of risk attitudes to socio-economic variables, but Patrick et al.(1981) had low r^2 values (correlation coefficient) and concluded that risk attitudes are quite varied across subgroups. Since the measured preferences are not a function of an income level, magnitude estimation cannot give a utility function, nor an ARA coefficient; making its use for decision assistance very limited.

2.6.2 Results of Risk Elicitation

Officer and Halter (1968) tested all three DEU methods described, and found the vN-M method inferior to the modified vN-M and ELRO methods. Ramaratnam et al. (1986) and Lin et al. (1974) used the ELRO method with the respondent choosing a value of "?" to balance equation 2.6. Ramaratnam et al. (1986) also tested four functional forms of utility for goodness of fit, and for their sample, found that the negative exponential had the best r^2 , and the most desirable economic properties. Dillon and Scandizzo (1978) used the modified vN-M method, to find that most Brazilian farmers and land-owners were risk averse. Reviews of other efforts to survey decision-maker's preferences can be found in Young (1979), Robison et al. (1984), and Love (1982).

Table 2.3 Results of Previous Attitude Measurements

	<u>Percent of Risk Attitudes</u>			<u>Sample</u>
	<u>Averse</u>	<u>Neutral</u>	<u>Prefer</u>	<u>Size</u>
<u>United States</u>				
Brink & McCarl *	66	34	0	38
Love (1984) **	35	15	50	23
Tauer (1986) +	34	39	26	72
Thomas (1987) ++	73	DNA	27	30
Wilson & Eidman (1983)+	44	34	22	47

* Observed Economic Behavior

** Average of 2 years elicitation at group mean income. + Each producer attitude measured near expected income. ++ Average of all income levels (group mean income not given)

Most surveys show that farmers are in general risk averse or risk neutral, with a minority of individuals showing preferences for risk at high positive levels of income, and also at very low income levels. Young (1979) summarizes earlier work in risk preferences. Table 2.3 focuses on more recent work concerning U.S. farmers.

Many of the researchers combined risk elicitation with cross-sectional analysis of producer characteristics such as age, education, financial measures, and other factors. These have often been regressed on the ARA coefficients to examine their associations and related statistical significance. For examples of these efforts, see Love (1982), Tauer(1986), Wilson and Eidman (1983), Patrick et al. (1985) and Branch and Olson (1987). In nearly all cases, the r^2 values were low (often less than .20). Because each research group regresses a different set of independent variables, it is difficult to summarize their findings on related socioeconomic characteristics. There does seem to be positive correlation between the ARA coefficient and both the age (or farming tenure) of the operator and financial debt of the operation. This generally

indicates that older farmers are more risk averse (*ceteris paribus*). As expected, farms with higher (but probably manageable) debt levels were also more risk averse. When debt is burdensome some managers will likely become risk preferring, much like the long "bomb" at the end of a football game (see Robison, 1986).

2.6.3 Problems with Previous Research

Anderson et al. (1977) felt the realism of hypothetical losses or gains is increased when elicitation is couched in terms of net worth rather than income. This directly contradicts the findings of von Winterfeldt and Edwards (1986). They argued convincingly that decision-makers do not often know their asset position and are more comfortable dealing with cash flows (income). They also observed that decision-makers learn to write off the sunk costs. Other supporters of this later view are Newbery and Stiglitz (1985). Previous elicitation research has involved gross income, net income, after-tax net income and net worth. As noted by Raskin and Cochran, these changes in units of measure for X (income), affect the $R(X)$ (the ARA function) and diminish the comparability of the research results, except when the negative exponential utility function is used.

Regardless of how preferences are queried, there will always be critics of EUT and the methods of elicitation. Simon (1986) and others have argued decision-makers exhibit "satisficing" rather than utility optimizing behavior. King and Robison (1981) felt the decisions faced in DEU "games" are too simplistic and not representative of the choices decision-makers face. G. A. Miller (1956) found that human cognition is limited to simultaneous analysis of "seven, plus or minus two" factors. Most interval approach work has been performed with two columns of six

numbers each, thus giving the producer no summary information and twelve data points to consider.

Solving for a utility function requires some assumption of the functional form. With limited data points and reasonable responses, several different forms may have r^2 values exceeding .95 (see Officer and Halter, 1968; Ramaratnam et al., 1986 for examples). Individual decision-makers can be expected to vary in both form and coefficients, of their utility functions. Management prescriptions (or suggestions) arising from errors in fitting a utility function could themselves be in error.

Another error not mentioned in the literature is related to wealth effects of the gambles presented. Was the survey respondent to view the gambles being offered in elicitation as supplements to their "real-world" next period income distributions, or as replacements of such distributions? In decision assistance the analyst is usually trying to seek attitudes about a "real-world" situation and would like the decision-maker to replace that situation with the hypothetical ones presented. The research presented has indicated that preferences can be elicited and that some response consistency beyond random selection is present (Tauer;1986 and others). What is not clear, is whether the survey respondents always understood the wealth effects of the hypothetical gambles. Even if respondents fully understood these wealth effects, could they mentally substitute hypothetical income distributions for real ones?

There are limitations with the interval approach to elicitation. The interval approach asks for responses with various expected income levels and small "coefficient(s) of variation"(CV's). As a result, producers must indicate preferences at income levels other than the expected, which exclude any possibility of realizing the expected level of income. This diminishes the realism of the gambles and could

contribute to respondent misunderstanding. An example of this misunderstanding is reported by Love (1982). He stated:

Farmers may have been willing to take added risk at the \$0 income level due to the relatively small magnitude of the absolute dollar amounts and variability of the paired distributions. It was noted from farmer comments that while they make decisions involving a wide range of dollar values, many put little time and effort into decisions involving dollar amounts in the \$0 - \$50 range.⁹

Statements like those from Love indicate added potential misunderstanding. The survey dollars were suppose to represent whole farm annual income. The frequency with which farmers make \$50 decisions should have almost no bearing on their desire for \$25 or \$50 of annual income. This means that the respondents (and possibly researcher) may have forgotten that annual income preferences were being measured.

Another possible misunderstanding of most approaches is that respondents may forget that survey games are to be "played" at the same frequency as the real decision. That is, annual problems need values that are understood to be annual. Farmers may spend little time on real-world small gambles, because they are played quite often compared to gambles of \$30,000 or more (annual).

The variance of the total outcome of a gamble is diminished as the activity is increasingly subdivided (if each sub activity is independent). An example is the adage of not putting all the eggs in one basket, or not betting all of your money on a single horse in a single race. Of course with some activities, splitting them creates two perfectly correlated activities, and no loss in variance occurs, due to a covariance term. An example of this later situation is dividing a corn field into two equal parts

⁹ p. 91

and growing an identical corn crop in each half of the field. In this case, no risk reduction can occur, because both parts of the subdivision are perfectly correlated.

The point is, if a risk attitude survey is to represent annual income, then the respondent must keep in mind that the hypothetical gamble will be played only once per year. This would surely be aided by keeping the variance of elicitation in the neighborhood of realistic annual income variance.

The above discussion points out a difficulty of comparing results of the interval method of elicitation to other methods. ELRO methods examine $U(X)$ in the neighborhood of the problem considered. The interval method looks at very small intervals of income and does not attempt to build a utility curve. One expects that these safer subdivisions or intervals of the problem would understate the variance of the problem allowing producers to be more risk averse over a small domain. This does not indicate errors in the interval method, especially since it uses stochastic dominance with respect to a function (rather than form a utility function). It does mean that the interval method local ARA coefficients should not be averaged to imply a global ARA coefficient.

Finding the answers to questions of wealth effects and other potential misunderstandings are not easy. An initial reaction is that if decision-makers are unable to consider risky synthetic gambles as substitutes for real distributions, then decision analysts have no way to assist decision-makers except through static analysis. There is little doubt that decision-makers must be presented with realistic gambles and that the wealth effect of the gambles is fully understood before elicitation takes place.

Throughout the discussion, utility has been a non-decreasing function of money (dollars, net income, gross margin, wealth, or some financial measure). Other factors besides measures of income affect utility, or at the very least, decisions. People take vacations, serve on civic committees, attend church, and spend time with the children and grandchildren. Decision-makers have knowledge constraints, time constraints, and financial limitations. These factors have not been included in an examination of utility and maximizing expected utility. This is also true of decision rules and criteria, portfolio analysis, E-V analysis (see section 2.7.3).

2.7 Decision Rules and Efficiency Criteria

There are several methods for analyzing risky situations and helping decision-makers reach workable solutions. What follows in this section is an overview of the more commonly used decision rule concepts and efficiency criteria from decision theory, examples of research using the methods described, and a discussion of the strengths and weaknesses of the various methods.

A decision rule is a framework for analyzing alternative actions in a risky environment. Decision rules reflect the decision-maker's risk attitude by establishing procedures for analyzing alternatives. Decision rules make strong assumptions about utility functions and generally result in the selection of only one optimum course of action. Examples of decision rules are safety first rules, maximize expected outcome, maximize the minimum outcome, and maximize expected utility.

Risk efficient criteria are a more general tool in decision theory. A risk efficient criteria is a method or standard for dividing decision-maker alternatives into efficient and non-efficient classes, with only general assumptions placed on decision-maker

utility functions and/or the pdf's they face. An example of a risk efficient criteria is the E-V model, where producers maximize expected income while minimizing income variance. Risk efficient criteria can be adapted for individual use when more specific risk preferences of the decision-maker are known. Because risk efficient criteria make few assumptions regarding the preferences of individuals, the efficient or dominant set of solutions can be quite large.

2.7.1 Maximize Expected Utility

Previous sections discussed methods for measuring decision-maker utility functions. If such functions can be accurately measured, then optimal decisions will be those that maximize expected utility. In the case of risky decisions, optimal solutions will also depend on probabilities of the various outcomes (either subjective or subjectively modified from objective information). Mathematically this is simply

$$U_i = \sum_{j=1}^n (p_{i,j} * U(X_{i,j})) \quad \text{st. } \sum_{j=1}^n p_{i,j} = 1 \quad (\text{for all } i) \quad (2.8)$$

where j indicates the number of possible outcomes for each i decision alternative. If probability is continuous, the probability density function must be known, or for numerical solutions the process can be made discrete by choosing small intervals in probability.

When maximizing expected utility, the underlying performance criteria (i.e., net income, wealth) must be of the same form and unit of measure as was used in utility elicitation (see section 2.3.2).

Utility elicitation and the subsequent fitting of the utility function, took place in some definite interval of X . Maximization of expected utility can involve decision alternatives that result in outcomes outside the elicited range. The extent that this occurs should be minimized. This could be done by designing the elicitation around the context of the problem, and its related alternatives. Assuming the functional form and coefficients of the utility function elicited over a definite interval, will hold globally, further adds to errors in decision assistance.

Maximizing expected utility is the most flexible decision rule, since it is possible to deal with decision-makers having any type of utility function, regardless of whether they are risk averse, neutral or preferring. Not only is the method flexible, but if the utility function can be accurately formulated, and probabilities are known with confidence, then it is possible to solve for a single decision alternative. The price for such flexibility and power is moderately high.

The big criticism of maximizing expected utility is that errors in forming vN-M utility functions and subjective probability are likely sizable, not often measurable and usually ignored in the final optimal solution (see King and Robison, 1984). A second shortcoming is efficient programming algorithms. Most cases of directly solving expected utility involve optimization of a non-linear problem, requiring numerical search algorithms. Exceptions to this are when assumptions regarding utility and/or probabilities are made.

Two proponents of maximizing expected utility are decision analysts von Winterfeldt and Edwards (1986). They felt that persons can not only express preferences, but also strength of preferences. They pointed out that while persons are

sometimes inconsistent in preferences (cognitive illusions), persons are seldom indifferent to two alternatives. Perhaps their most pointed statement was as follows ..

We find the preceding argument so convincing a demonstration that you can indeed judge strengths of preference, and we are so well aware of the simplifications that such judgments produce in obtaining measures of utility, that we are compelled to ask why many deeply respected theorists either deny the possibility of such judgments or refuse to use them in decision analytic procedures.¹⁰

2.7.2 Stochastic Dominance

"First degree stochastic dominance" (FSD) is the simplest risk efficient criteria and requires minimal assumptions of decision-maker preferences. If income (X) is a continuous random variable with values x , and if there are two different CDF's called $F(x)$ and $G(x)$, then $F(x)$ is first degree stochastic dominant (FSD) over $G(x)$ if everywhere $F(x)$ is less than or equal to $G(x)$, and for at least one x , $F(x)$ is absolutely less than $G(x)$. More simply, the graph for $F(x)$ will never cross the graph of $G(x)$, and must never lie to the left of $G(x)$ (see Figure 2.3). FSD (and stochastic dominance of any degree) also applies to discrete distributions. For discussion of discrete stochastic dominance see Robison and Barry (1987), Anderson et al. (1977), or Elton and Gruber (1987). The principles are the same for the discrete case as the continuous, except that summations replace integrals ($F(X)$ and $G(X)$).

¹⁰ p. 210

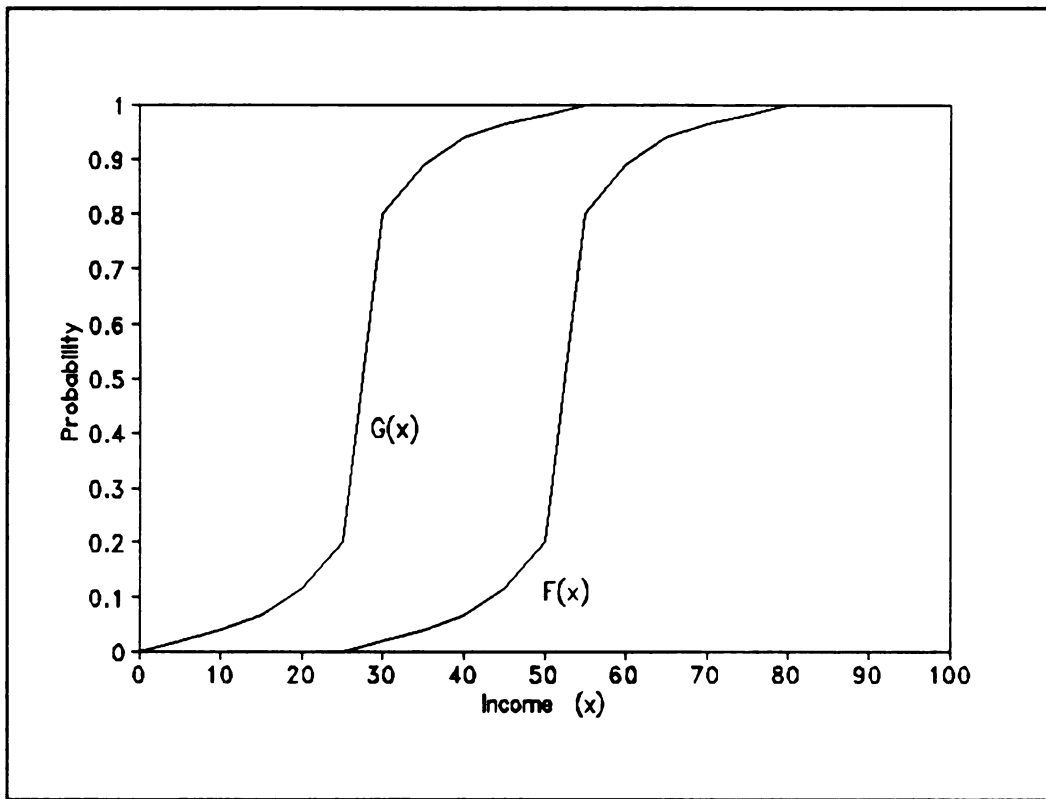


Figure 2.4 First Degree Stochastic Dominance (FSD)

FSD applies to all decision-makers who prefer more to less ($U'(X) > 0$). They may be risk averse or risk preferring. With such broad application, it should seem little surprise that FSD eliminates few decision alternatives in a practical setting (King and Robison, 1984; Anderson et al., 1977). Alternatives that are not dominated by any other decision alternative are said to be first degree stochastic efficient, or members of the FSD efficient set. Transitivity is a property of FSD (and higher order stochastic dominance) so that if $F(x)$ is FSD over $G(x)$, and $G(x)$ is FSD over $H(x)$, then $F(x)$ is FSD over $H(x)$.

FSD and stochastic dominance of any degree have a strength that is often overlooked. No restriction is placed on the types of probability distributions the

decision-maker faces. $F(x)$ and $G(x)$ may be parametric or non parametric, skewed or symmetric, discrete or continuous.

"Second degree stochastic dominance" (SSD) requires added assumptions on decision-maker utility, but not on the type of probability distributions to which it can be applied. SSD compares the area under two CDF's taken from minus infinity to values of x . Using subscripts to denote integrals, so that ...

$$\int_{-\infty}^{x_1} f(x)dx \equiv F(x) \equiv F_1(x) \equiv d(F_2(x))/dx \quad (2.9)$$

The CDF is $F_1(x)$, but the CDF subscript will usually be omitted (as are the constants of integration).

With two different CDF's called $F(x)$ and $H(x)$, then $F(x)$ is SSD over $H(x)$ if everywhere $F_2(x)$ is less than or equal to $H_2(x)$ for all possible values of x , with at least one value of x having a strict inequality. In other words, the area under $F(x)$ is less than the area under $H(x)$ at every point. The two CDF's may cross as in Figure 2.4 creating differences indicated by the letters A and B. In essence, SSD says we prefer $F(x)$ to $H(x)$ because more of $F(x)$ lies to the right of $H(x)$. In Figure 2.4 this condition is true if the area of A is greater than B. If $F(x)$ and $H(x)$ are normally distributed then SSD is equivalent to mean-variance analysis.

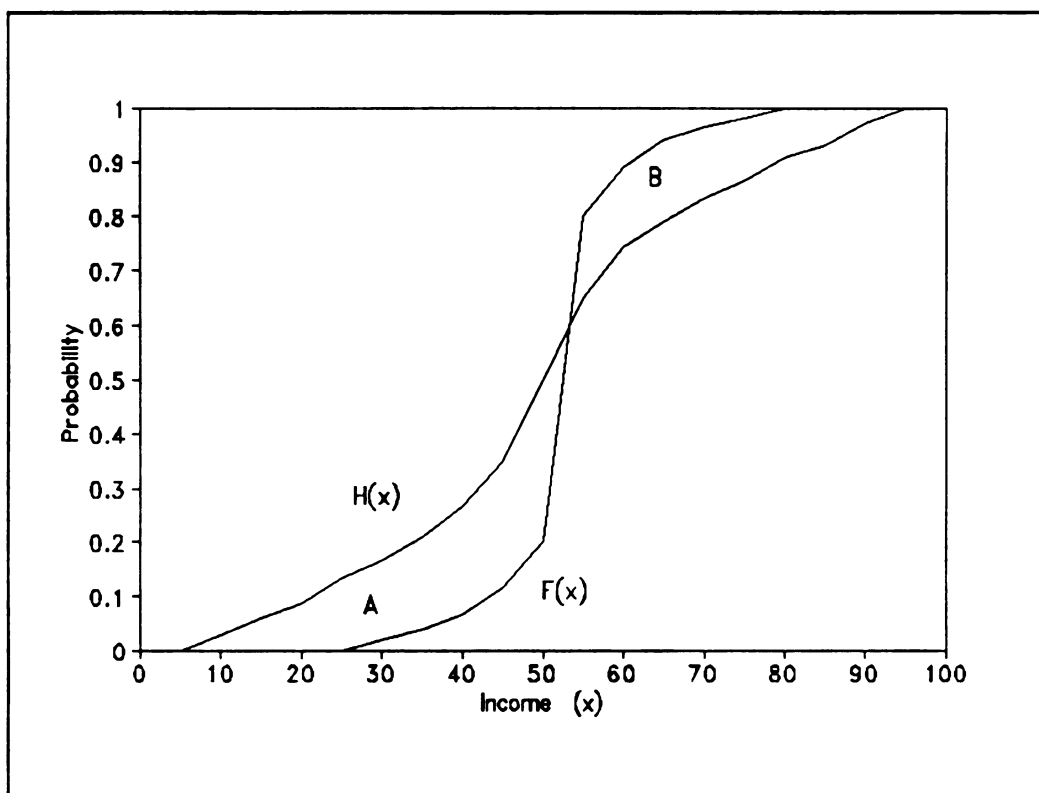


Figure 2.5 Second Degree Stochastic Dominance (SSD)

SSD assumes that decision-makers prefer more to less, as with FSD ($U'(X) > 0$), and that they are risk averse in the area of the values of X being evaluated ($U''(X) < 0$). This latter assumption is a reasonable one for many, but not all decision-makers. Evidence of individual producers showing preference for risks (that is, the ARA coefficient is negative) can be found in Thomas (1987) and Love (1982). King (1979) indicated that most (14 of 17) farmers exhibited local preferences for risk in at least one of four queried income levels. All of these researchers were using the interval method of risk elicitation, however. Often such preferences for risks occur at negative income levels. Broader findings previously discussed in section 2.4.2 showed that in general, producers are risk averse.

SSD involves narrower assumptions regarding decision-maker behavior and its discriminatory powers are larger than FSD (Anderson et al., 1977), but for some decision domains, may not be selective enough (King, 1979; King and Robison, 1981). If the distributions being faced by the decision-maker are normal, then the means and variances sufficiently describe the opportunity set. In this situation, the SSD set, will also be the mean-variance efficient set (further discussed in the next section).

"Third degree stochastic dominance" (TSD) begins with the same decision-maker utility assumptions as SSD, and also assumes that $U'''(X) > 0$. This implies that $R'(X)$ is negative, or that decision-makers are DARA. This assumption is usually considered empirically reasonable. Findings discussed in 2.6.2 support the assumption for surveyed decision-makers in aggregate, but should be questioned for prescriptive work with individual decision-makers.

The definition of TSD is a logical extension of SSD involving integrals of the SSD cumulative function. Anderson et al. (1977) presented a more complete discussion of TSD. With increased decision-maker assumptions and computational complexity, TSD is not as commonly used as SSD. In addition, when distributions are symmetric, SSD sets and TSD sets should be identical.

Asymmetry is measured by skewness. Rational producers should prefer negatively skewed distributions over alternatives that are symmetric, but with the same mean and variance. Negative [positive] skewness implies the median is above [below] the mean, and a thinner tail appears on the left [right] of the pdf. Work by Alderfer and Bierman (1970) suggested that skewness is important in decision-making. For situations where distributions are clearly not symmetric, TSD should

have increased discriminatory power over SSD. An example of such a situation would be an insurance scheme.

Stochastic dominance is an important benchmark in risk analysis. While its assumptions may not hold for certain individuals, decision analysts should seek prescriptions which are part of the stochastic efficient set, using a level of stochastic dominance appropriate for the individual. If an individual is known to be risk averse (through elicitation or behavior), then prescriptions sought through other decision criteria should be a subset of the SSD set.

Stochastic dominance is not without weakness. Because no restrictions or assumptions are made regarding the probability distributions, computation can be quite intensive. Anderson et al. (1977) developed a Fortran program for stochastic dominance. The program makes pairwise comparisons of CDF's (or for appropriate orders of stochastic dominance the related integrals of the CDF), beginning at the bottom of the distribution. The routine requires all distributions to be bounded, uses numerical integration and represents continuous distributions as uniformly divided into small discrete sections. The authors admitted that because the algorithm begins at the lower part of the distribution, it is particularly sensitive to errors in the lower tail of the pdf. Anderson et al. (1977) presented a comparison of TSD results to an E-V efficient set, for a case problem. Because of asymmetry in the pdf of the problem, TSD rejects several alternatives which were E-V efficient. This demonstrates a problem with E-V efficiency when used with asymmetric distributions, more than a weakness of TSD. TSD is never less selective than SSD, but when distributions are symmetric, TSD offers little added selectivity. The decision to use SSD vs. TSD can

also be justified by knowledge of pdf symmetry or asymmetry. Anderson (1975) further discussed risk efficient Monte Carlo programming and TSD.

2.7.3 E-V, MOTAD, M-SD, and Semi-Variance

So far in section 2.7, no assumptions have been made about the probability distributions that decision-makers confront, except that the decision-maker (and analyst) can represent the entire distribution with a known continuous functional form, and/or the distribution can be approximated by converting it to small discrete segments. With the mean-variance efficiency criteria, also called "Expected value - Variance" (E-V), the subject is assumed to examine only the mean and variance of each pdf in evaluating alternatives. This simplifies data requirements as well as analytical solutions, thereby explaining the popularity of E-V models.

Probably no single risk efficiency criteria is more widely used and documented in risk research than the E-V model. Elton and Gruber (1987), Ingersoll (1987), Robison and Barry (1987), Barry (1984), and numerous other texts and articles in the last 30 years, have presented extensive discussion of E-V and its application.

E-V is consistent with EUT when decision-maker utility is quadratic or when decision-makers are CARA and the distributions they face are normal (Fishburn, 1977; Selley, 1984; King and Robison, 1984 and others). More generally, the income distributions need not be normal, but they must be identical except with respect to location and scale (Meyer, 1987; Robison and Meyer, 1988). This broader criteria expands the applicability of E-V.

Meyer (1987) made use of "mean-standard deviation" (E-SD), because the convex preference set requirement applies to a larger number of utility functions and

distributions than when variance is used as a measure of risk. E-SD also allows the units of measure to be retained in an understandable manner. If decision-makers exhibit constant absolute risk aversion CARA and distributions are identical except with respect to location and scale, then E-V and E-SD are equivalent (and consistent with EUT).

The E-V decision rule has a number of advantages in addition to those previously mentioned. Many investment pdf's can be approximated by normal distributions, especially investments whose daily price movement can be characterized as a random walk. This is the expected result of the central limit theorem. With some income distributions this may not be the case. Pre-harvest crop income is a function of three stochastic income factors: basis price, yield, and futures price. Each of the marginal distributions that make up uncertain crop income may or may not be normally distributed for the individual producer. Day (1965) and Gallagher (1986) make cases for non-normal yield distributions in cotton and corn respectively. Even if the individual pdf's (marginal distributions) are not normal, it is still possible to estimate the mean and variance of the resulting crop income distribution (Anderson et al., 1977).

A second disadvantage of E-V is that solutions are often sensitive to changes in values of the variance/covariance matrix of all the marginals. This data is not available in many cases, especially for individual farmers. Even if historical correlations were available, they may not include effects of commodity programs and insurance payments.

"Quadratic Programming" (QP) is often used in applied risk analysis to solve for E-V efficiency when proper conditions are satisfied (or assumed to be). QP is

computationally efficient relative to many risk programming alternatives, and requires the analyst to input the vector of means for decision alternatives available, as well as the related variance/covariance matrix. Section 2.8.2 documents several efforts in analyzing marketing alternatives through E-V criteria. Quadratic programming is documented in Hazell and Norton (1986) and in Taha (1987). Algorithms for quadratic programming are presented in Kuester and Mize (1973) and Scales (1985). To solve for the entire E-V efficient set using QP, requires repeated analysis with varied levels of expected income (a QP constraint).

Hazell and Norton (1986) presented a method called "Minimization Of Total Absolute Deviations" (MOTAD), which is related to E-V analysis. MOTAD is a linear programming algorithm that maximizes expected returns from various alternatives, while minimizing the absolute deviations from the mean. To solve for the entire efficient set using MOTAD requires several successive runs, with changing values of the expected income parameter (similar to the changing QP expected income constraint for E-V). MOTAD implicitly handles covariances between decision alternatives. Tauer (1983) showed that MOTAD results are not necessarily SSD.

The biggest disadvantage of E-V, E-SD and MOTAD is that good outcomes (above the mean) are weighed the same as bad outcomes (below the mean) if their distances to the mean are the same. Thus skewness and preference for skewness are ignored by these decision rule concepts. Holthausen (1981) and Fishburn (1977) argued that decision-makers more likely view risk as deviations from some common point across all distributions, rather than as deviations from the various means. The alternatives they proposed are later presented.

In response to some criticisms, it is possible to use semivariance. The semivariance is measured like the variance, except only deviations below the mean are squared. The result is a measure of risk involving only bad outcomes (those below the mean), and ignoring favorable ones. If the pdf's the decision-maker faces are normal (or more generally symmetric), the E-V solution is equivalent to the "Expected value - SemiVariance" (E-SV). This is because with symmetric distributions the minimization of deviations below the mean also minimizes those deviations above the mean (since the two are equal). E-SV has strong intuitive appeal for skewed distributions (see Markowitz, 1959).¹¹ It has not been extensively used in applied efforts, probably owing to lack of a mathematical programming method, the difficulty of calculating semivariance, and the complexities of using it in analytical models. If decision-makers view risk as deviations from some common target or threshold, then E-SV would be inappropriate, just as E-V, E-SD and MOTAD. The commonality that these four efficiency criteria possess are that (1) all of them measure risk as deviations from the mean of each pdf and (2) they are only consistent with SSD under specific conditions.

2.7.4 Target MOTAD and Lower Partial Moments

Section 2.1.1 discussed moments of probability distributions taken about the origin and the mean. The "Lower Partial Moment" (LPM) is a probability distribution measurement that quantifies outcomes below some level. The semi-variance is a special case of a lower partial moment for a probability distribution. More generally lower partial moments are noted as.

¹¹ See page 200.

$$\text{LPM}(a,t) = \int_{-\infty}^t (t-x)^a f(x)dx \quad (2.10)$$

where $a \geq 0$ (and constant), t is some target or reference level of income, and $f(x)$ is the pdf. $\text{LPM}(2,E[X])$ is the semi-variance. $\text{LPM}(1,E[X])$ is equivalent to the absolute value of deviations below the mean. Porter (1974) proposed the use of $\text{LPM}(2,t)$ where t is a constant level of income across all decision-maker pdf's. He called this the fixed reference point semi-variance. Fishburn (1977) generalized Porter's more special case to give the definition of equation 2.11. Fishburn (1977) also proved that if $a \geq 1$, then examining alternatives in a mean- $\text{LPM}(a,t)$ framework, would give efficient solutions that were a SSD subset.

Tauer (1983) presented a linear programming method for analyzing mean- $\text{LPM}(1,t < \text{mean})$ that he called Target MOTAD. While all Target MOTAD solutions are members of the SSD set, Target MOTAD may not find all members of the SSD set. Tauer believed that by repeated analysis using different values of t , it should be possible to find all members of the SSD set. At a given target, numerous levels of the risk parameter (allowable deviations below the target) must be analyzed to find the efficient mean- $\text{LPM}(1,t < \text{mean})$ set for the given t . Thus to find as many members of the SSD set as possible, requires $N \cdot M$ Target-MOTAD solutions, where N is the number of target level values and M the number of risk parameter values to be considered.

Target-MOTAD strengths are the ability to model using linear programming algorithms and its relation to SSD. Where MOTAD has a single parameter that needs changing, Target-MOTAD has two. The first Target-MOTAD disadvantage is additional

computation. The extent of this added effort is likely problem dependant. It is also a disadvantage that most Target-MOTAD proponents discount. In some situations, it may be more expedient to use numerical methods for SSD (Anderson et al, 1977) rather than Target-MOTAD. This suggestion is not addressed in the Target-MOTAD literature.

A second disadvantage is that, like SSD, Target-MOTAD may not provide enough discriminatory power for some problem situations. The exception would be when the decision-maker knows what target level is most important and is only interested in solutions related to that target. This would reduce the computations, and the solution set. It would also eliminate some SSD solutions, possibly including those in the neighborhood of the decision-maker's optima.

Atwood (1985) utilized LPM's to improve Tchebyshev-type inequalities for safety first criteria. Previously, these inequalities were too conservative when the mean and variance were used to solve the inequality. This usually resulted in selection of overly conservative management alternatives. Atwood et al.(1988) and Berbel (1988) developed math programming methods for solution of other LPM-type analyses which are useful in safety-first analysis (see section 2.3.5).

In addition to Target-MOTAD and mean-LPM efficiency, Holthausen (1981) proposed replacing mean as a measure of desirable outcomes. Instead of the mean, he proposed an upper partial moment (UPM). The UPM is similar to LPM, but taken from the same target to positive infinity. Holthausen (1981) labeled the LPM "risk" and the UPM "return." The two criteria model from Holthausen (1981) is ..

$$LPM(a,t) = \int_{-\infty}^t (t-x)^a f(x) dx \quad (2.11)$$

$$UPM(a,t) = \int_t^{\infty} (x-t)^b f(x) dx \quad (2.12)$$

$a, b > 0$, and independent

The two measures can be used to solve related efficient alternatives as done in Hauser and Eales (1987a, 1987b).

With the Fishburn (1977) mean-LPM model, decision-maker utility is linear or risk neutral for outcomes above the target, since they are not part of the risk measure. With the Holthausen model the decision-maker is risk averse, (risk neutral) (risk preferring) below the target if $a > 1$ ($a = 1$) ($0 < a < 1$). The value of b is independent of a , so a decision-maker can be risk averse above the target and risk preferring below. When $t=0$, such behavior is observed in much empirical work and supported by Kahneman and Tversky (1979). For values above t , the decision-maker is risk averse (risk neutral) (risk preferring) if $0 < b < 1$ ($b = 0$) ($b > 1$).

Holthausen (1981) showed how to solve the utility function described by his model using the standard vN-M elicitation method (section 2.6.1). As previously discussed, the standard vN-M method involves selection of probabilities which lead to indifference between a certain gamble and an uncertain one. Section 2.6.1 documents the shortcomings of this method. The Ramsey (1931) method of DEU does not incorporate utility functions like the ones proposed by Holthausen (1981), but could easily be modified toward that effort.

One advantage of Holthausen's (1981) utility function is its flexibility to represent nearly any decision-maker preferences. It is consistent with FSD, SSD, and TSD for particular values of a , b , and t . The flexibility becomes a disadvantage in estimating the function because additional parameters reduce the degrees of freedom. Also, ordinary least squares cannot be used to estimate the non-linear function.

2.7.5 Safety First Decision Rules

There are three types of "Safety First Rules" (SFR) that may be used for decision analysis. The first rule, developed by Telser (1955-56), assumed that a decision-maker maximizes expected returns $E[X]$ subject to the constraint that the probability of a return, less than or equal to a specific amount (EMIN), does not exceed a stipulated probability (SP). Telser's SFR is to maximize $E[X]$ subject to $p(X \leq \text{EMIN}) \leq \text{SP}$. Each SFR is well illustrated in Elton and Gruber (1987).¹²

The decision-maker first determines a threshold level of income (EMIN) and the probability with which incomes must exceed this level (SP). These values are the key indicators of risk attitudes under Telser's SFR. This same decision rule is outlined in Elton and Gruber (1987).

The second safety first decision rule was developed by Kataoka (1963). Kataoka's SFR chooses a plan that maximizes the lower confidence "level of income" (INCL) subject to the constraint that the probability of income (X) being less than or equal to the lower limit, does not exceed a specified value, "Plimit." In effect, this rule maximizes the return along a fixed lower confidence Plimit.

Kataoka's SFR is: maximize INCL subject to $p(X < \text{INCL}) \leq \text{Plimit}$.

¹² Chapter Nine

Roy's (1952) SFR is the third and final rule. Roy's (1952) SFR chooses the plan with the smallest probability of yielding a return (X) below some specified income level (INCL). The objective function is: Minimize $p(X < \text{INCL})$.

If a solution exists, and income is normally distributed, then all SFR's return solutions on the E-SD frontier (Elton and Gruber;1987). SFR's can be incorporated into linear programming methods (e.g. see Atwood et al., 1988). The Tchebyshev inequality can be used to approximate the probabilities in the SFR's regardless of the form of the pdf for income. Unfortunately, the Tchebyshev inequality gives conservative probabilities that result in "overly-safe" solutions. Atwood et al. (1988) used linear LPM's of the pdf to solve for Telser's and Kataoka's SFR in a linear programming framework. These methods resulted in less conservative solutions than mean-absolute deviation methods like those presented in Anderson et al. (1977).

These expansions of SFR's through LPM's extend the usefulness of linear programming in risk analysis. Previously, the decision-maker's action could not alter the income distributions. This stipulation was satisfied for only simple problems such as selecting pricing alternatives for a known (deterministic) number of bushels. These new developments help apply SFR's to chance-constrained programming problems, as well as problems where the events are stochastic.

2.8 Previous Efforts

Early computer applications in risk management and analysis were written for university mini-computers and mainframes. Generally, these efforts were aimed at a group of producers typical of the area. The most common application has been selection of risk efficient enterprise mixes, where efficiency was either E-V, MOTAD or

mean-LPM (e.g. Target-MOTAD). In nearly all of these early studies individual producer behavior was assumed to be globally risk averse ($R(X) > 0$) and constant ($R(X)' = 0$). These computer models were not intended for direct use by individual producers and are, therefore, termed "research-oriented efficiency studies."

With the advent of more powerful micro-computers, some risk management analysis can be done by the producer without use of large computers. This category of micro-computer risk management applications is in early development stages, as witnessed by the small number of completed applications. The following sections discuss in more detail, research-oriented efficiency studies and micro-computer based simulation efforts.

2.8.1 Risk Efficiency Studies - Research Oriented

Barry (1984), Anderson et al. (1977), Tauer (1983) and Hazell (1971) developed models for risk analysis and management through enterprise selection. This section overlooks efforts similar to those in order to more closely focus on efficiency studies which include risk management through alternative marketing strategies. Table 2.4 summarizes research efforts to find risk efficient producer alternatives for marketing. The efforts by Musser et al. (1986) and Watts et al. (1984) are included because they compared two types of efficiency criteria across the same problem set.

Research models employing static yield assumptions might be appropriate for post-harvest risk management, or production enterprises where output uncertainty is minimal. These models restrict pre-harvest marketing commitments to some percentage of the expected crop. Curtis et al. (1987a, 1987b) limited pre-harvest contracts to 60 percent of expected production. For many Midwestern producers, this

Table 2.4 Previous studies in Marketing Risk Management for Farmers

RISK EFFICIENT MANAGEMENT STUDIES								
Author	Method	Prices	Yields	# of Price Tools	# of Farm Entpr.	Option Hedge Avail.	Perf. Variable	Other
Alexander, et al. (1986)	E-V	St.Ave Month	St.Ave An.	3	2	No	Gross Revenue	B,E,PY
Anaman & Bogess (1986)	SDWRF	1970-84	Crop Model	4	4	Yes	Net Income	B,E,Z
Curtis, et al. (1985)	Target MOTAD	St.Ave Month	Static	4	1 soybeans	No	\$/bu	B,I
Hauser & Eales (1987)	Risk/Return	Futures Only	Static	3	1 beef	Yes	\$/cwt	F,H
Hudson, et al. (1985)	SDWRF & E-V	St.Ave Wkly D	Static	5	1 beef	Yes	\$/cwt	B,PY
Mapp, et al. (1979)	MOTAD & Sim.	St.Ave An. D	AES Plots D	2	8	No	Gross Margin	B,I
Musser, et al. (1986)	MOTAD & QP	An.Ave Cash D	Multi-Co An.Av D	1 (cash)	6	No	Gross Margin	I,N
Rowell & Kenyon (1988)	Target MOTAD	Terminal Prices	Static	4	1 swine	Yes	Gross Margin	B,I
Watts, et al. (1984)	T-MOT& MOTAD	Co.Ave An. D	Co.Ave An. D	1 (cash)	5	No	Gross Margin	I,N

B - Basis was historical & included D - Discounted prices or Detrended yield
 E - Enterprise covariances were used F - Fixed basis assumed zero (cash = futures)
 I - Covariances are implicit in MOTAD N - No futures prices were included
 PY - Cov(Price,Yield) were incorporated Z - Cov(Price, Yield) = Zero

Prices are indicated as annual (An.), monthly (Month), weekly (Wkly) averages (Av or Ave). Prices usually refer to futures and cash. Yields were state (St.), county (Co.) or regional (Reg.) averages. Gross margin is gross revenue minus variable production costs. Net income is gross margin minus fixed costs. All performance variables were net after marketing costs.

simplification for a drought year could result in over-contracting. When price is the only income risk (yield is static), there is no danger of "over-contracting." Clearly, these assumptions simplify the model, but lead producers to pre-harvest prescriptions that ignore unlikely, but not inconsequential outcomes.

Sources of yield, futures, and basis data are important for the usefulness of the individual research effort and its applicability to producers. In examining prescriptions from the research models, those that use highly aggregated yields and prices have likely understated the variances and overstated covariances of yield and price (in absolute terms), compared to an individual producer. If one is considering adapting a research model to use as individual decision support software, the data used in the research model must be replaced by individual data. Producers could substitute data relevant for their own farms, providing such data is available.

The use of SDWRF in research models (Anaman and Bogess, 1986; Hudson et al., 1985) is an effort to apply a newer portion of risk theory to a group of producers. Unfortunately, SDWRF cannot easily be applied to groups without some assumption of the underlying forms of the utility function. Anaman and Bogess (1986), as well as Hudson et al. (1985), implicitly assume producer utility functions are negative exponential (CARA) by using only one interval of $R(X)$ to describe each producer group. In Meyer (1977a), $R(X)$ is a function rather than a constant. Replacement of the function with constant numerical values of $R(X)$ implicitly requires the utility function to be CARA for all producers. The SDWRF research models may be more suited to adaptation for individual producers than for use to characterize risk attitudes of groups of producers.

Research models using MOTAD and Target-MOTAD require observations of historical yields and prices to be recomputed into deviations and entered into the linear programming matrix as they jointly occurred. Alternatively, Monte Carlo methods and simulation solutions, could be converted to observations in the MOTAD matrix. In either case numerous solutions to the matrix, with changing values of

lambda (the right hand side constraint for income) are needed to identify an efficient set of marketing plans. Producers might have no way of knowing where they should be on the efficient set.

Chance-constrained programming is a safety first linear programming model which has seldom been used in solve marketing problems. Taylor and Zuhair (1986) solved a simple peanut contracting problem with chance-constrained programming. Adapting the Taylor and Zuhair model to incorporate several marketing alternatives with stochastic yields and prices would be very difficult. Linear programming models such as chance-constrained programming, MOTAD and target-MOTAD, must be carefully constructed when building decision support components for use by producers. Without care, the user may receive a message regarding an unbounded solution, or an infeasible one.

Research models have several distinct advantages compared to software decision aids developed for individual producers. One advantage is that researchers have access to historical prices, yields, variances and covariances that producers may not have available and may not understand. A second advantage is that research models can be run on larger and faster computers, not easily accessed by farmers. Some research models may exceed the capacity of farm micro-computers, or may utilize software development tools not readily available for micro-computers. A final advantage is that researchers control the program assumptions and interpretation of the output. This reduces programming and development time and guarantees data quality. The disadvantages of research models will be discussed in the next section.

2.8.2 Micro-Computer Based Simulations

Unlike the research-oriented efficiency studies, micro-computer efforts at farm risk management are difficult to generalize, except that all have been simulation based. None have attempted to search for risk efficient solutions. This leaves the task of finding superior alternatives for risk management to the producer, who then must use trial and error to find efficient solutions. Experienced simulation users may be able to form heuristics to more quickly locate "good" solutions.

Knight et al. (1987) and Alderfer (1988) reviewed extension oriented risk management software in some detail. What follows is a brief overview of four of the software packages reviewed by Alderfer. Not summarized are a crop insurance evaluation program developed at Virginia Polytechnic Institute and a package regarding the government feed grain program developed at Texas A. and M. Both of these were reviewed by Knight et al. (1987).

Agricultural Risk Management Software (ARMS) was developed by King, Benson and Black (1987). ARMS allows yields and/or prices to be entered non-parametrically, or as normal distributions. ARMS was primarily developed to look at the question of participation in federal all-risk crop insurance. ARMS can look at forward contracting versus fall cash sales, but does not incorporate basis uncertainty, futures hedging or options hedging. Three risk scenarios can be analyzed side-by-side (with both graphics and table output) for comparison. Correlation coefficients are entered for yields and prices within and across enterprises. ARMS uses Monte Carlo techniques for simulation. ARMS is a stand-alone program available for MS-DOS™ computers.

The "Whole Farm Risk Rating Model" (WFRRM) was developed by Anderson and Ikerd (1984, 1985). All pdf's are entered using triangular distributions (low, mode, high). The "entered" mode is used to approximate the mean. The distance between the high and low possible outcomes is assumed to be twice the standard deviation of the distribution. Elicited yield distributions are assumed to be normal and price distributions log normal. The product of yield times price distributions is approximated as a normal distribution of expected income for each enterprise. Calculations employ the use of appropriate correlation coefficients. Up to nine farm enterprises may be modeled for a single farm.

WFRRM incorporates stochastic yield, basis and futures. Crop production costs are not stochastic, but some livestock production costs are. WFRRM was developed in BASIC for the MS-DOS™ and TRS-80™ micro-computers. The output to the producer is expected income, optimistic (expected plus one standard deviation) and pessimistic (expected minus one standard deviation) income for any combination of enterprises, or for the entire farm. The four marketing alternatives available include futures hedging, basis contract, forward contract and cash sales.

Budgeting Enterprises and Analyzing Risk (BEAR) is a Lotus template developed at Guelph University (see Bates et al., 1987). BEAR followed the pattern established by its predecessor, WFRRM. BEAR allows no analysis of pricing alternatives, variances within enterprises are fixed, and covariances between enterprises were forced to be zero. These factors may have been updated in a more recent version. BEAR requires the user to own LOTUS, and the manual suggested larger more powerful micro-computers to speed computations.

Baldwin and Dayton (1988) developed a Lotus spreadsheet template similar to BEAR but theirs focuses on grain marketing. The template, called "Grain Marketing Risk Management" (GMRM) uses a fixed coefficient of variation on all crop yields of 20 percent. GMRM incorporates price variance, but those variances are entered by extension specialists, and are not intended to be varied by the producer.

The micro-computer based simulation software discussed are quite different. WFRM and BEAR are concerned with trying to analyze all farm enterprises, whereas ARMS and GMRM are more concerned with crop enterprises. All of the simulation models, except for ARMS, make very restrictive assumptions about the pdf's for yields and prices. All of the packages require numerous runs to analyze different alternatives, and contain no incorporation of decision rules or efficiency criteria to assist the user.

2.9 Summary

This chapter began with principles in risk, probability, and utility theory that established a foundation for the remainder of the chapter. A marketing decision model was presented to show how the problem could be described (the right hand side). Of particular emphasis was representing distributions for the stochastic factors of basis, futures, and yield.

Methods of describing the probability distributions on the right hand side included historical data, option pricing models for futures, and subjective probability elicitation. Candidates for representing uncertainty include triangular functions, discrete functions, and smooth parametric functions like the normal and lognormal.

Subsequent to the right hand side discussion of how to describe or represent the problem, the focus became how to decide the problem. Decision Rules and other supportive methods that are candidates for use as Decision Support System Tools, for problems with significant economic risks were reviewed. The list of methods was not exhaustive, but rather an attempt to identify and briefly describe appropriate alternatives. The later portion of the chapter focused on risk efficient research models versus micro-computer based simulation software.

The risk efficient research models are quite different than the micro-computer based simulation software. The research models tend to make restrictive assumptions about risk behavior. For producers whose risk attitudes are accurately represented, the risk efficient research models could be adapted for individual use for decision support. This would eliminate repeated simulations that would be needed to find similar results using micro-computer based software. Unfortunately, producer risk attitudes are not simple (see section 2.6.2), and are probably not stable over time, due to changes in wealth, age, and other factors.

To increase the value of information to the producer regarding marketing and risk management, more processing is needed than what is provided in the micro-computer based simulation models discussed. The mainframe research models provide some help in this area, but are not designed as DSS components for individual users. The method selected, was to elicit risk attitudes of producers (Bernoullian utility) and incorporate those attitudes into the DSS. The utility curves will be used along with simulation and optimization to find superior marketing alternatives in the neighborhood of the optimum.

In Chapter 3 this proposed solution will be further defined.

CHAPTER THREE

THE FIRM MODEL

3.1 FIRM Model Overview	94
3.2 The Audience	96
3.3 Generating Yield Distributions (ELICIT)	97
3.4 Generating Price Distributions	100
3.5 Adjusting Monte Carlo Observations	103
3.6 GENRINC	104
3.7 Measuring Risk Attitudes (ELRISK)	106
3.8 Marketing Simulation - The Objective Function	114
3.9 Finding Superior Marketing Plans (MKTOPT)	121
3.10 Post-Optimal Solutions	126
3.11 Issues	128
3.12 Future Improvements to FIRM	131
3.13 Summary	134

Farm Income Risk Management (FIRM) is detailed in this chapter. Several topics related to FIRM have been presented in Chapter 2, but their relationship to the model should be more completely understood following this chapter. A research model of FIRM was developed, as opposed to a finished end-user package. A hypothetical producer of 250 acres is used to demonstrate FIRM. The producer should not be misunderstood to be representative, average or typical, but instead merely a case farm.

The chapter begins with a brief overview of the FIRM model, followed by a description of the appropriate target audience for the research. Beyond this are major sections that discuss each of the FIRM components. The chapter concludes with a short discussion of FIRM's strengths and weaknesses, a section for future improvements, and a summary section.

3.1 FIRM Model Overview

FIRM is a set of DSS components that allow a commercial grain producer to analyze pre-harvest risk management through commodity marketing. FIRM requires input on market prices, and distributions of prices and yields expected in the future. FIRM measures farmer yield predications and risk attitudes and finds a portfolio of pricing alternatives that maximize expected utility. Other portfolios near the optimal one are also outputted for comparisons. Following optimization, the manager can enter custom marketing plans and compare them to the best plan.

FIRM uses option premiums to generate an ending period "Cumulative Distribution Function" (CDF) for futures prices. CDF's are also formed for basis and yield using historical values (if they exist) and subjective modification. Monte Carlo

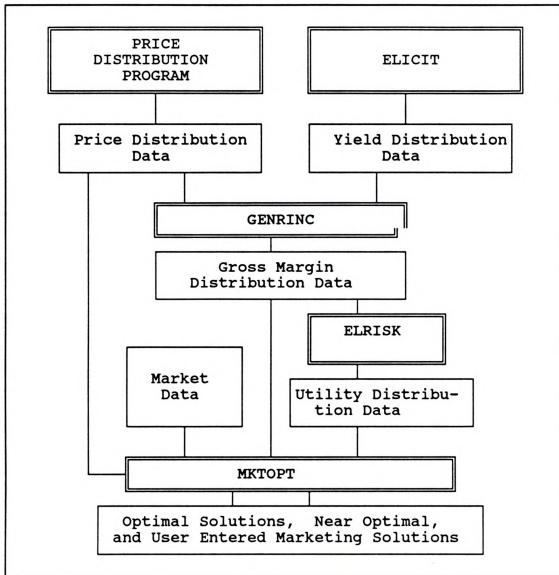


Figure 3.1 Components of FIRM and their linkages

observations on the distributions are generated. FIRM first simulates the "all cash" marketing plan to determine the expected gross margin for a single commodity and its standard deviation. These two values are inputs to seed an expert system that measures producer risk attitudes for the gross margin distribution of the crop. Next, non-linear optimization searches for mixtures of pricing alternatives that maximize

expected utility. FIRM is a single crop, non-dynamic, stochastic simulation and non-linear optimization program. Figure 3.1 shows how FIRM is organized.

There may be important correlations between crop yields, futures, and basis for the crops produced on a farm. This would especially be true if more than one crop were examined simultaneously. It was decided early in development to focus on a single crop marketing model (particularly soybeans). If a single crop model could be developed, then perhaps a two crop model could follow.

The following sections examine each of the major components of FIRM.

3.2 The Audience

The target audience for this research is commercial grain producers with above-average understanding of marketing and management. Farm size is not a selection criteria for the target audience and neither is financial condition, age, education, or computer experience. These later factors were not considered important because of the heterogeneous characteristics of farmers. The farm factors just mentioned might indirectly affect solutions, but many types of farmers are welcome in this "target-audience."

Above-average management skills and marketing knowledge are needed to complete the input data and interpret the solutions. It is possible that marketing consultants and advisors could use the model to provide a service for producers with a weaker understanding of commodity pricing tools.

3.3 Generating Yield Distributions (ELICIT)

FIRM was designed to be run at any time through the growing season. Yield uncertainty can be quite high at planting time. As the season progresses, more information is revealed and the yield typically becomes more certain. A mid-season forecast of a yield distribution should include all the crop development to date, plus the uncertainties related to the remainder of the season. To capture this process with historical data would be nearly impossible, since farm records on mid-season yield forecasts have probably not been kept. Plant growth models were a possibility mentioned in Chapter two, but a suitable candidate was not available. The only reasonable sources in this situation are objective professionals or farmers themselves.

As discussed in Chapter 2, ELICIT was used with the conviction scoring method. ELICIT is used in the Agricultural Risk Management Simulator (ARMS) Version 3.x. as one method of establishing yield pdf's for analysis of Federal All-Risk Crop Insurance.

ELICIT results in a discrete pdf like the one in Figure 3.2. for the case farm. ELICIT stores values for pdf, CDF, sample mean, and sample standard deviation in an ASCII text file named by the user. The file is automatically given a ".PRB" extension. A portion of this file is shown in Table 3.1 for the case farm pdf in Figure 3.2.

In FIRM, yields are elicited in this manner and a list of the CDF paired values are formed. One vector in the table is the CDF(x) and the other is x; where x is the upper end of a range of equal interval yields. The CDF(x) is bounded by zero and

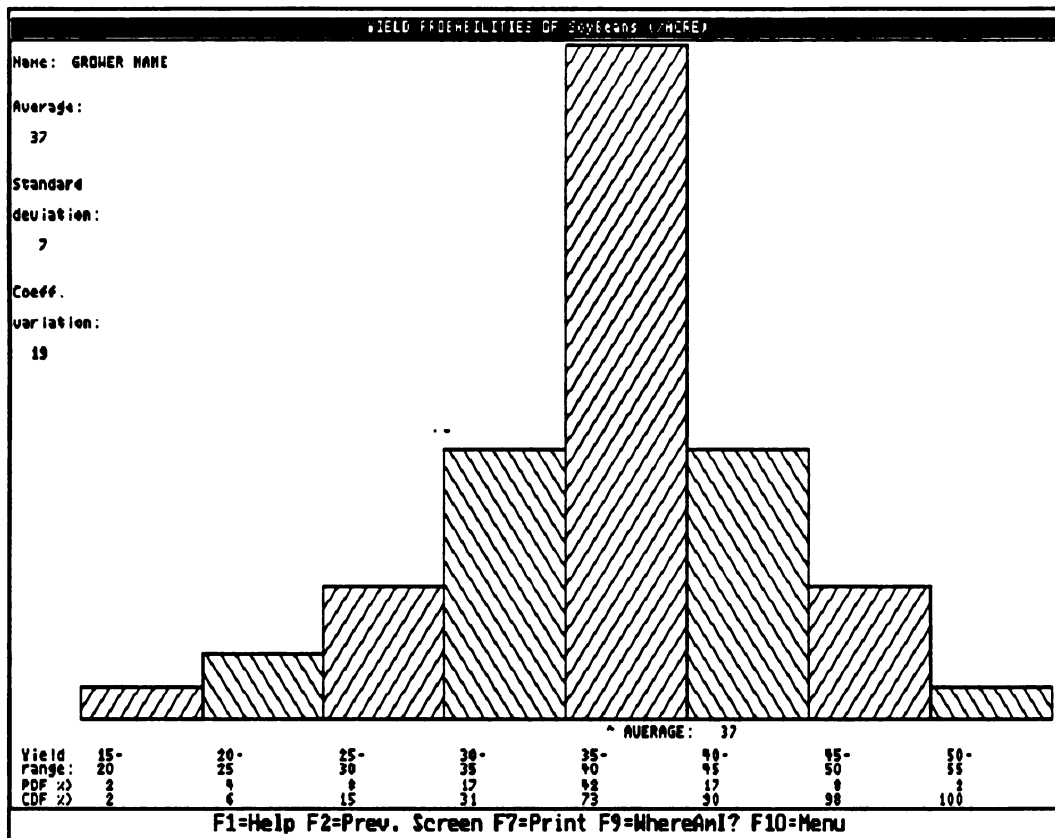


Figure 3.2 The Case Farm Yield Distribution (pdf)

one. Numerous UNIFORM(0,1)¹ observations are created with a random number generator (FIRM uses a default number of 200 Monte Carlo observations). The default can be increased or decreased. The random numbers are some proportion between two CDF values. To demonstrate, the mode (.5 CDF) for the case farm, falls between .3125 and .7292 in the CDF values that correspond to 34.99 bu/ac. and 39.99 bu/ac, respectfully. One half (.5) is 55 percent of the distance between the two CDF values (above .3125). Fifty-five percent of the way from 34.99 to 39.99 is 37.74 bushels per acre.

¹ A specific uniform distribution is usually denoted by its name, followed by the two boundaries.

Table 3.1 Portion of ELICIT Output

A Portion of an Output File from
ELICIT for the case farm

Yield	Range	Input	pdf	CDF*100
0.00	4.99	0.00	0.00	0.00
5.00	9.99	0.00	0.00	0.00
10.00	14.99	0.00	0.00	0.00
15.00	19.99	5.00	0.02	2.08
20.00	24.99	10.00	0.04	6.25
25.00	29.99	20.00	0.08	14.58
30.00	34.99	40.00	0.17	31.25
35.00	39.99	100.00	0.42	72.92
40.00	44.99	40.00	0.17	89.58
45.00	49.99	20.00	0.08	97.92
50.00	54.99	5.00	0.02	100.00
55.00	59.99	0.00	0.00	100.00
60.00	64.99	0.00	0.00	100.00
65.00	69.99	0.00	0.00	100.00
70.00	74.99	0.00	0.00	100.00

E[yld.] = 36.77 bu/ac
St.Dev. = 6.85 bu/ac

This linear mapping between the CDF and its values changes 200 random numbers into observations of yield whose PDF and CDF, look like the ones the farmer suggested in ELICIT. The net result is that a discrete yield distribution has been converted to 200 samples of the yield distribution.

Pease et al. (1990) concluded from their experience in using ELICIT, that "The authors have not figured out good methods for elicitation in the absence of a 'professional' performing the elicitation. The interaction between the grower and the

individual performing the elicitation has been important in our studies and in Extension meetings." (draft, unnumbered)

This is to be expected with any user of new software. Computer software learners naturally learn well with "hands-on" training of new software. The student - teacher interaction is also expected to be valuable. However, it should be possible to train in a workshop setting and expect the producer to later be able to use the knowledge and software on his or her own farm.

Justifying the selection of ELICIT to be part of the FIRM model is not difficult, since there was almost no other available method to measure mid-season yield distributions. A distant second choice would have been to elicit a triangular yield distribution directly from the producer. This second choice would have been a shorter subjective procedure, but errors in the distribution tails might have been substantial. Empirical research comparing the elicitation of triangular distributions to output from ELICIT was not available.

3.4 Generating Price Distributions

FIRM used manual entry of the mean and standard deviation of both futures and basis, and assumed that both were normally distributed and uncorrelated. The correlation is actually a user input, but all analysis in this research were run with the correlation set to zero. The current futures price and basis levels implied the expectation of the ending period distribution, if markets are efficient. Thus, today's futures price is equal to the mean of the ending period futures price distribution. For example: the case farmer called the elevator for fall soybean prices. CBOT November soybean futures were trading at \$6.1825 per bushel, and the forward contract for

delivery in mid-October was \$6.08, with \$-.1025 equal to the basis (ignoring transactions costs on futures). The \$6.1825 and \$-.1025 are the desired means for the ending distribution of futures and basis, if markets are efficient.

With normal distribution and a mean, only the volatility is needed to completely describe a futures or basis distribution. Hilker and Black developed software to examine two different option pricing models. They examine the "Black Option Pricing Model" (BOPM) with a conversion to normality. They also examined a model like the one used in ARMS 3.0 (King, Black and Benson;1987). Values from their software generated futures price volatility estimates that were entered by hand into the file called PRICE.DAT. Fackler and King (1990) have continued research in this area. They support evidence found in other research (Mann and Heifer;1976, Hudson et al.;1986) rejecting the hypothesis that futures prices should be log normally distributed. Hudson et al. (1986) summarized:

These results have implications for option pricing. Black's option pricing formula assumes log-normality and constant variance. The recent move toward normality in commodity price changes suggest that such formulas may adequately represent the actual value of the commodity traded on option markets. Also, hedgers who rely on the portfolio theory of hedging typically maximize revenue given risk (variance). These results suggest that the variance exists and is finite, allowing portfolio models to be used optimally.²

The choice of a particular "Options Pricing Model" (OPM) has not taken place for an end-user version of FIRM. The availability of a reasonably good OPM facilitated testing FIRM. Further research in this area is needed. It should be noted that using the BOPM or other no-arbitrage based models should still be better than eliciting subjective price distributions from farmers (as done for yield). Thompson et al. (1988)

² p. 14

found in their survey that farmers underestimated market variance compared to the variance implied by BOPM.

An improved version of the Fackler and King (1988) non-parametric model discussed in section 2.5.1 does exist, has been viewed, but was not available for evaluation. An added alternative is the coupling of two or three OPM's into a composite forecast. Such a model could use volatility measures that are historical (e.g. prior 20 trading days volatility) or implied by one or more of the OPM's. As new research makes improvements in volatility forecasting, this portion of FIRM should be updated.

With efficient markets (see section 2.4), the futures market provides an unbiased forecast of the ending period mean price. Additionally, if options markets are efficient, they give the best estimate of the volatility being implied by the market through option pricing models such as Black (1976) (also Cox and Rubinstein;1985). Occasionally during a trading day a particular option premium will have both a BID and ASK price. This evidence of illiquidity and non-existence of a risk neutral value, violates assumptions of the BOPM as well as Cox and Rubinstein (1985) model. The OPM by King and Fackler (1985) assumes no particular distribution, but depends on thinly traded option premiums and assumptions about the tails of the distribution. OPM's are the best currently available tool for forecasting the futures distribution. The OPM's are surely an improvement on subjective price elicitation, but are they good enough? An answer is not expected, but may come through extensive future research.

An added concern is the distribution functional form for the probability density function. If it is "properly defined", the result is the market's implied pdf for futures

contracts. Of course a major research issue is the best functional form (normal, log normal, other) to best describe the total pdf implied by the options markets. This issue is addressed in Chapter Five.

3.5 Adjusting Monte Carlo Observations

With efficient markets, the price generator needed to generate prices with average values the same as expected price. Otherwise, false arbitrage opportunities could have existed in the data. If the ending period price distribution has an average value of \$6.01/bushel, but today's forward contract price for that period is only \$6.00/bushel, there is opportunity to make (on average) one cent per bushel. Monte Carlo methods have difficulty creating distributions with means precisely equal to the desired value, except with extremely large samples which increase computational costs and time. One vector of 200 prices may have a mean slightly below the desired mean, and the next vector computed may be above the mean.

Adjusting the mean of the Monte Carlo vector for prices is a simple matter of moving all observations by a distance of E/n , where E is the error in the two means and n is the number of elements in the vector (200). Suppose the market price for futures is \$6.18, but the 200 observations on ending period futures have a mean price of \$6.17. The error of \$.01 is divided by 200 observations, and all elements of the vector are increased by \$.01/200.

A similar process is used to adjust observations of symmetric distributions to give exact desired sample standard deviations. These later changes are based on a ratio of "desired total sum of squared deviations" (DSSD), divided by the "sample sum of squared deviations" (SSSD) for the 200 Monte Carlo observations. X_i is each

sample observation and i is all integers from 1 to 200, denoting elements in the vector. $\bar{X}$ is the desired mean, and each X_i was compared to $\bar{X}$ (see equation 3.1).

If the $X_i > \bar{X}$ then:

$$X_i = \bar{X} + \text{SQR}(((X_i - \bar{X})^2 \cdot (\text{DSSD}/\text{SSSD}))) \quad (3.1)$$

If the $X_i < \bar{X}$ then:

$$X_i = \bar{X} - \text{SQR}(((X_i - \bar{X})^2 \cdot (\text{DSSD}/\text{SSSD})))$$

Of course if $X_i = \bar{X}$ it doesn't need to be adjusted.

3.6 GENRINC

The purpose of GENRINC is to compute a mean and variance, of the ending period gross margin distribution, when the Monte Carlo production (yield times acres) is sold on the uncertain cash market (futures (f) plus basis (b), using the notation in Chapter two). They are used as measures of the magnitude and range of gross margin.

GENRINC is listed in Appendix G; its output file "BUANDINC.DAT" is in Table 3.2." It requires the producer to enter the number of acres of the crop (soybeans), the variable costs per acre for production, as well as the remaining variable costs that are yield dependant. Examples of these later expenses include harvesting, trucking, drying etc., and are not to be double counted with the per-acre costs. Producer crop acreage is calculated according to rental arrangements. Acres that are owned and cash rented for the crop in question are added to the producer's proportion of share-

rented acres for that crop. Summing these gives the effective production acreage.

The producer must also enter the name of the data file from ELICIT.

GENRINC reads the data file from ELICIT to capture the CDF values for yield. GENRINC also opens the "F&BDIST2".DAT file, where 200 independent observations of futures price and basis are stored. Zero-one uniform random variables are created using the Microsoft QuickBASIC™ function, RND. These values are converted into 200 observations of yields as discussed in section 3.3.

All of the Monte Carlo values are stored to disk and summarized with sample means and standard deviations.

$$GM_i = (f_i + b_i - c) \cdot a \cdot y_i - C \cdot a \quad (\text{for } i = 1 \text{ to } n) \quad \text{Where:} \quad (3.2)$$

- GM_i = the i th observation on gross margin (all cash sales)
- f_i = the i th observation on futures prices
- b_i = the i th observation on basis
- y_i = the i th observation on yield
- a = effective acreage
- C = per acre costs (seed, chem, fuel etc.)
- c = per bu. costs (harvesting, drying, trucking)
- n = number of Monte Carlo observations (usually 200)

GENRINC was used to compute an expected gross margin, standard deviation of gross margin, total costs, and gross income. All of the gross margin Monte Carlo values were stored on a disk and summarized. The output file for GENRINC is called BUANDINC.DAT. That file consisted of a brief heading, four columns of numbers, and a footer. The BUANDINC.DAT file for the case farm is shown in Table 3.3.

The top line of the file shows the number of Monte Carlo observations to be listed, the number of acres of production (250), variable costs per acre (\$57/ac.), and variable costs related to yield (\$.3/bu) (from left to right, respectively). The remainder

Table 3.2 BUANDINC.DAT file created by GENRINC

```

200, 250, 57, .3, footer has moments
Total bu.  Gross inc.  Total costs  Net inc.
8923.971,  45425.75,  16927.19,  28498.56
11984.88,  73775.27,  17845.46,  55929.81
7211.078,  47274.95,  16413.32,  30861.63

      (195 more lines here)

9175.797,  65904.46,  17002.74,  48901.72
7158.459,  50047.78,  16397.54,  33650.24

Var.      Average  St.Dev.      Skewness      Kurtosis
Bu. Prod. 9081.563, 1748.188, 5.691607E-04, -3.000179
Net Inc   38122.09, 11280.13, 8.820823E-05, -3.000014

```

of Table 3.3 is labeled. As GENRINC is run it also presents a screen image of the summary information, for the user to view.

The important results from GENRINC are the expected or mean gross margin (\$38,122.09) and the standard deviation of gross margin (\$11,280.13). These two numbers are entered into the next program to give a starting place for eliciting risk attitudes.

3.7 Measuring Risk Attitudes (ELRISK)

At this point, it might help to re-examine Figure 3.1 (diagram of FIRM) to examine what has been covered in FIRM, and what remains. All of the distributions have been created, and all of the static information has been entered into the model. The first simulation (GENRINC) has been done to compute the mean and standard deviation of the gross margin, if the producer sells all grain at the spot price in the fall.

Software presented in this section will measure producer's risk attitudes in the neighborhood of the gross margin distribution that the producer will confront.

ELRISK is an expert system based on an "Equally Likely Risky Outcome" model. Expected gross margin and the standard deviation (values from GENRINC) seed elicitation values in ELRISK. Using the values of mean and standard deviation is not an admission that gross margins are normal, nor that producers only consider the first two moments. Instead, they are starting values that ensure the utility curve elicited is in the neighborhood of the income distribution.

As suggested by Musser and Musser (1984), the elicited preferences are described in the context of the problem the producer actually faces. For this reason, ELRISK uses terms like "situation" rather than "game" and "marketing plan" rather than "lottery." ELRISK also stresses that marketing plans presented in each situation that they face (not "play"), are based upon their individual gross margin distribution.

ELRISK sequentially presents the producer with two marketing plans to be analyzed. Each plan has two possible outcomes of equal probability. The producer is reminded that these outcomes should be considered gross margins for the crop analyzed, and for the same time period (annual). Three of the four possible outcomes in the first two plans are a function of the mean and standard deviation of gross margin. A risk-neutral value for the fourth outcome, giving equal expected outcomes for the two plans, is suggested to the user for revision. ELRISK seeks a revised fourth outcome, which makes the user indifferent between plan A and B. Expert system rules ensure that one plan does not dominate the other, and they establish new situations. Elicitation continues until utilities have been elicited for incomes that are approximately two standard deviations above and below the expected income. The

logic and expert system rules of ELRISK have been written in a standard programming language (FORTRAN) for added flexibility.

Halter and Mason (1978) used a similar method for establishing only five points on a utility function. ELRISK uses a modification of the Halter and Mason (1978) method to elicit 10 to 14 points. The expert system logic in ELRISK rounds the distribution mean and standard deviation input, establishes new situations and checks for errors and consistency. No specific form of the utility function is assumed.

Situation 1			Situation 2		
PROB	Marketing Plans A B		PROB	Marketing Plans A B	
.5 Bad Year	Mean - Stand. Dev.	?	.5 Bad Year	? from Game 1	??
.5 Good Year	Mean + Stand. Dev.	Mean + 1/2 * StDev.	.5 Good Year	Mean + Stand. Dev.	Mean + 1/2 * StDev.

Figure 3.3 Structure of Situations 1 and 2 in ELRISK

Figure 3.3 shows an example of situations one and two. Every situation is shown to the producer on a separate computer screen in ELRISK. In Figure 3.5 this is not the case because we are focusing on the theory of the game. In situation one, the decision maker must enter an income level in the quadrant marketed by "?", that makes him or her indifferent between marketing plans A and B. In subsequent situations, the values of the other quadrants are varied and a new indifference level is sought.

Halter and Mason showed that if the response to the second situation (indicated by "??") is arbitrarily given a utility of 200, and the mean minus one standard deviation is given a utility of zero, then the response to situation one (indicated by "?") must have a utility of 100. To demonstrate why:

$$\begin{aligned}\text{Game 1: } & .5(0) + .5U(k_1) = .5U(?) + .5U(k_2) \\ \text{Game 2: } & .5U(?) + .5U(k_1) = .5(200) + .5U(k_2)\end{aligned}\tag{3.3}$$

Since all probabilities are equal in Equation 3.3..

$$\begin{aligned}\text{Game 1. } & 0 + U(k_1) = U(?) + U(k_2) \\ \text{Game 2. } & U(?) + U(k_1) = 200 + U(k_2)\end{aligned}\tag{3.4}$$

Solving for $U(k_1)$ in game 2 of equation 3.4,

$$U(k_1) = 200 + U(k_2) - U(?) \quad \text{subbing this into } U(k_1) \text{ of game 1 equation 3.3}$$

$$0 + 200 + U(k_2) - U(?) = U(?) + U(k_2) \quad \text{combining terms gives...}$$

$$200 = 2U(?) \quad \{ ? = \text{response to first game in \$} \}$$

$$U(?) = 100$$

The previous condition holds, if the respondent's behavior satisfies the principle axioms of expected utility theory. After the first 2 games there are dollar values for three utility levels. These three levels 0, 100, 200, can be used to sequentially build the remaining situations. If plan A is a choice between $U(\$) = 100$ and $U(\$) = 200$, while plan B is a choice between $U(\$) = 0$ and a response field, the user response, in dollars will be the dollar value for $U(\$) = 300$. This is true to satisfy principal EUT axioms. This process continues upward until the last point surpasses the mean plus two standard deviations. The process can be reversed with the dollars for $U = (0, 100)$ in plan A, and plan B is $U = (?, 200)$. The user response to ? in this case is $U = (-100)$.

The risk attitudes generated are specific for an individual, at a particular wealth level, regarding a particular commodity to be produced and marketed. ELRISK can be used in other contexts besides commodity marketing, but it is still sensitive to the context in which it was elicited. Context dependence makes the situations presented more "real" to the decision maker, but limits any other contexts in which the utility function could be applied.

Previous risk attitude measurement research (summarized by Young, 1979) has included (1) experimental games with real payoffs, (2) games with no payoff, and (3) observed economic behavior (OEB). Each of these three classes of risk measurement have disadvantages (see section 2.6.1).

ELRISK is similar to direct elicitation of utility methods with no payoffs, except producers are reminded that income levels used in ELRISK are theirs. Also, their risk attitudes reflected from ELRISK will affect marketing recommendations that are found in the utility optimization model following ELRISK. Thus, ELRISK is context sensitive, so that producers and users have strong incentives to carefully consider their response, if they know it will impact their solution.

The first choice when operating ELRISK, is to choose between using the mean and standard deviation, or a triangular distribution to describe the probability density function (pdf) of the gross margin. Recalling the mean and standard deviation were \$38,122.09 and \$11280.13, respectively, these numbers were entered by the manager of the case farm. ELRISK uses a complex set of rules to round the input values. These rules can be found in the code for ELRISK in Appendix H. The case farm input values were rounded to \$40,000 and \$12,000 for the mean and standard deviation.

Situation 1			Situation 2		
PROB	Marketing Plans		PROB	Marketing Plans	
	A	B		A	B
.5 Bad Year	\$28,000	? (\$34K)	.5 Bad Year	? from Game 1 \$31K	\$35 K ?? (\$37K)
.5 Good Year	\$52,000	\$46,000	.5 Good Year	\$52,000	\$46,000
Average	\$40,000	\$40,000	Average	\$41,500	\$41,500
Values in parenthesis are risk neutral computer suggestions.					

Figure 3.4 Case Farm ELRISK Situations 1 and 2

Figure 3.4 shows the basic method for seeding the risk elicitation. The case farm manager was asked in Situation 1 which marketing plan (gross margin for soybeans) was preferred (A or B) when the \$34,000 was inserted for the "?" value. In this situation both plans had the same mean return, but a substantial difference in variability. The farmer said that marketing plan B was his choice (because it is less risky). ELRISK responded with a message that "if plan B was preferred, the manager must lower the value in the cell marked "?" until he or she became indifferent between plan A and the revised plan B." The case farm entered the value of \$31,000 in the upper right corner of situation 1 (marked by the single question mark in Figure 3.4). Queried amounts can be revised numerous times. Each time they are revised, a new average for Plan B is recalculated and the screen is updated. When the producer is satisfied with a situation, function key 10, <F-10> is pressed and ELRISK moves to the next screen and a new situation.

Situation 2 depends upon the "?" response given by the producer in situation 1. In Situation 2 the bottom values were unchanged. Risk neutral values (equal average incomes) were suggested, and the producer was asked whether he preferred A or B. Again, plan B was safer, he preferred it, and the computer reminded him to lower the value in the upper right-hand corner of Situation 2. The case farm manager entered \$35,000.

During the development of ELRISK, it was discovered that many decision makers wanted to find the risk neutral situation if it was not given to them. This is called anchoring (von Winterfeldt and Edwards;1986)³. From this reference point or anchor, they would proceed to revise. For this reason, ELRISK starts the producer with plan A and plan B each having the same average gross margin. After deciding which plan they prefer (A or B), the software rules suggest whether the value to be elicited should be moved up or down.

Using Figure 3.4 and the expected utility, theory in Chapter 2 the case farm has identified the following preferences $U(\$35,000) = 200$, $U(\$31,000) = 100$ and $U(\$28,000) = 0$. The process continues using the known values. If plan A is $U(.5(U=100)/.5(U=200))$, and plan B is $U(.5(U=0)/.5(???))$, then the producer response for $U(???) = 300$. This process is repeated both upward, and downward, according to stopping rules. The slashes are used here to represent differing outcomes, and probabilities proceed the known dollar values.

There is a consistency check for $U(\$) = 200$. If the dollar values for $U(\$) = 200$ differ by more than 5 percent, the user can (1) back up and replay that situations, (2) average the two dollar values, or (3) take the previous dollar value and

³ p. 541

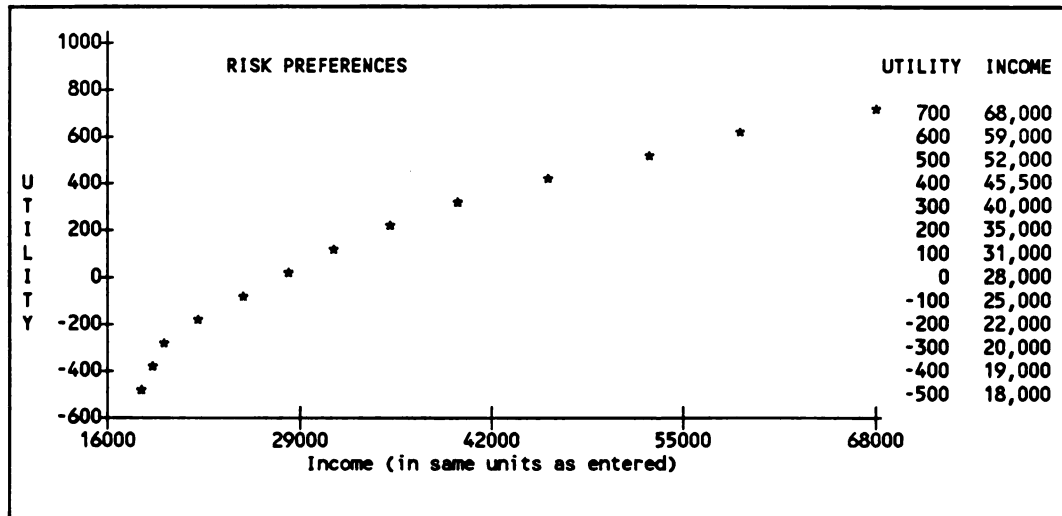


Figure 3.5 Output from ELRISK

proceed. The first alternative (to back up) is best when the answers differ substantially. The second alternative (averaging) is fine when the two values are moderately close, and the third (use previous value) is used when the two values are very close, but not within 5 percent. For example of the third case, suppose a gross margin distribution goes from \$ 0 to \$ 10,000 and $U(\$150) = 200$ and the consistency check shows $U(\$140) = 200$. In this situation the percentage differences are more than 5 percent, but not really significant because of the comparative size of the distribution.

Figure 3.5 shows the ELRISK results for the case farm. The values of utility on the Y axis are cardinal; like the measure of temperature. Any linear transformation of the scale results in new utility values, but the same shape of curve and the same optimal risk solutions. Curvature is more important than the absolute value of utility.

If a producer has two marketing plans with expected utilities of 200 and 201, how much is that difference in tangible terms? The answer is to convert the $U(\$) =$

201 and $U(\$) = 200$. These dollar values are called certainty equivalents. Subtracting one certainty equivalent from the other gives a risk premium between the two utility values. The risk premium is in dollars and for FIRM the dollars are gross margin.

The ELRISK utility function is used in a table-lookup function like the one described to ELICIT yields. ELICIT uses probability on one axis of the CDF(x) and yield (X) on the horizontal axis, while ELRISK examines income (x) versus its utility. Both result in paired vectors of non-decreasing elements. One difference, between them is that the CDF of yield is bounded by zero and one, while utility and income for the marketing problem are not bounded. Both paired vectors are evaluated with the same table look-up subroutine that extrapolates linearly between two elements, and beyond ending elements if necessary.

From previous research (Love, 1982; Ramaratnam et al., 1986), it was demonstrated that utility functions for farmers were quite varied. Rational producers could be risk preferring at some income levels and risk averse at others. Measuring utility with DEU offered behavioral flexibility not offered by most decision criteria. Maximizing utility is not only flexible, but offers higher levels of discrimination than decision criteria. Naturally, if utility is measured inaccurately, the solution will be erroneous.

3.8 Marketing Simulation - The Objective Function

To find optimal marketing strategies that maximize expected utility...

$$E[U(\bar{x})]_{\max} = \sum_{j=1}^n U_j \left[\frac{\sum_{i=1}^m N_i \cdot G_{i,j} - (C \cdot a) - c \cdot (a \cdot y_j)}{n} \right] \quad (3.5)$$

$$\text{st. } \sum_{i=1}^m N_i \leq E[y] \cdot a \cdot 3 \quad \text{and } 0 \leq N_i \leq z_i$$

Where:

- $E[\]$ = the Expectations operator
- n = number of Monte Carlo (MC) observations (usually 200)
- y_j = MC observations on yield
- $G_{i,j}$ = marketing revenue or marketing method ($i = 1$ to 6)
- N_i = Number of bu. marketed in the G_i way
- C = direct costs per acre (vary only with intended yield)
- c = costs which vary according to actual production (i.e. trucking, drying etc.)
- $U[\]$ = utility function or table lookup values for utility conversion
- z_i = default for z is $(3/2) \cdot a \cdot E[y]$ for cash market contracts ($i = 1, 4$),
otherwise default for z is $(2 \cdot a \cdot E[y])$ ($i = 2, 3, 5$)
- m = the number of marketing alternatives available (including spot sales)

For FIRM, n (the number of Monte Carlo observations) is usually 200 and m (the number of marketing methods) is 6. Spot harvest sales are one marketing method, but the N_6 for spot sales is a residual, since production is stochastic. The y vector is created from the producers subjective yield distribution. The research model has independent yield, basis, and futures. Bivariate basis and futures were possible, but that correlation was kept at zero throughout the research for consistency. The correlations for yield to basis and futures vectors were also zero. This allowed the researchers to set up all the price data and the distributions on the evening before, resulting in a shorter workshop on the following day and common price distribution for all producers at a particular workshop. While some producers may have significant non-zero correlations between the three stochastic variables, the logical base plan for research is independence.

FUNKSHUN is the marketing simulation that is being optimized in MKTOPT.

The entire FUNKSHUN subroutine is listed in Appendix I. The value returned by FUNKSHUN is expected utility of a particular marketing plan. FUNKSHUN calculates the like equations which follow.

The marketing simulation can be subdivided into each of its 6 ways of marketing (each $G_{1,j}$) for $i = (1 \text{ to } 6)$. The six ways are ordered in the same sequence that MKTOPT outputs them to the screen or printer, with forward contract (the left most column) being $G_{1,j}$. Production and transportation costs are considered elsewhere in the marketing functions, so the only costs in this section are pricing costs. $G_{1,j}$ represents gross revenue for forward contracting as shown below.

$$G_{1,j} = N_1 \cdot FCP_0 \quad \text{for all } j \text{ Monte Carlo observations} \quad (3.6)$$

Where: $G_{1,j}$ = gross revenue from forward contracting (non-stochastic)
 N_1 = bushels forward contracted (control variable)
 FCP_0 = forward contract price in time 0

The other cash market contract is a basis contract in column four of the MKTOPT output. $G_{4,j}$ is stochastic basis contracting income, and N_4 is number of bushels to basis contract. Bushels yet to sell in the cash market ($N_{6,j}$) are reduced by N_4 and N_1 . $G_{6,j}$ is remaining cash bushels to sell (or buy if over-contracted). $N_{6,j}$ is bushels to sell in the uncertain cash market, and is a residual variable (not a control variable). Gross revenue from basis contracting and cash sales are equations 3.7 - 3.10.

$$G_{4,j} = N_4 \cdot (BC_0 + f_j) \quad (3.7)$$

$$Q_j = (a \cdot Y_j) - N_4 - N_1 = N_{6,j} \quad (3.8)$$

$$\text{IF } Q_j \geq 0 \text{ THEN } G_{6,j} = Q_j \cdot (f_j + b_1) \quad \dots \text{selling the residual.} \quad (3.9)$$

$$\text{IF } Q_j < 0 \text{ THEN } G_{6,j} = Q_j \cdot (f_j + b_j + \text{ASK-BID}) \text{ ...buying grain} \quad (3.10)$$

Where:

- $N_{6,j}$ = Quantity remaining to be sold in the i th Monte Carlo
- $(a \cdot y_j)$ = acreage times the i th Monte Carlo of yield (production)
- ASK-BID = elevator "spread" if buying grain to meet contracts (can be zero)
- $G_{4,j}$ = a stochastic revenue from basis contracting
- $G_{6,j}$ = a stochastic revenue from cash sales (could be negative)
- BC_0 = basis contract level in time zero

The ASK-BID is a cash spread or any type of penalty for not delivering all the bushels in a cash contract. The ASK-BID is a user input and can be set to zero, if there are no penalties for not filling a contract. If equation 3.10 is true, then the revenue for cash sales ($G_{6,j}$) is negative, since $N_{6,j}$ is negative. At this point, all cash grain in the simulation is disposed. Hedging does not require offsetting by a precise number of bushels. The remaining marketing functions are futures hedge ($G_{2,j}$), put hedge ($G_{3,j}$) and a speculative call position ($G_{5,j}$). For futures hedging:

$$G_{2,j} = N_2 \cdot [(f_0 - f_j) - I \cdot t \cdot (AMf + TC_2) - TC_2] \text{ Where..} \quad (3.11)$$

- AMf = average margin deposit per bushel (for futures)
- t = time in months that margin money remains on account
- f_0 = the futures quote at the time the hedge was initiated
- TC_2 = round trip per bushel brokerage commission
- N_2 = number of bushels to futures hedge
- $G_{2,j}$ = a stochastic revenue from futures hedging
- I = Annual interest/1200
- f_j = ending period futures price (stochastic)

The formula for $G_{2,j}$ uses a constant margin requirement (AMf) and interest rate. Persons who routinely hedge may use U.S. Treasury Bills as security in their margin account so that the opportunity cost (interest) is zero, since the Treasury Bills still grows in value while in the account. Persons who fear margin calls while hedging

can commit extra margin deposits at the start. This makes futures hedging more costly and less attractive than the cash market instruments.

The two remaining plans involve options, but a few new variables are needed. The "Put Premium" (PP_j) is a function of the ending period futures price (f_j). PP_0 is the beginning premium at the time of purchase, and the "Call Premium" is CP_j ; with CP_0 equal to the purchased call in time zero. The "Strike Price of a Put" option (SPP), and the "Strike Price of a Call" option (SPC), are set at purchase time and remain a constant number of dollars per bushel. TC_1 is one-way per bushel transactions costs for options, and t is the number of months from the time options are purchased until a few days before they expire. The ending time period is chosen to eliminate most of the time value of an option, leaving only intrinsic value. Also, the last day that an option trades can be more volatile than normal. This is due in part to the dwindling liquidity as more traders move to the next contract month.

The formula for returns from put hedging ($G_{3,j}$) is ..

$$PP_j = \text{the larger of } (0, SPP - f_j) \quad (3.12)$$

$$\begin{aligned} \text{IF } PP_j \leq TC_1 \quad \text{THEN} \\ G_{3,j} = N_3 \cdot [PP_j - (1+I \cdot t)(PP_0 + TC_1 + AMO) + AMO] \end{aligned} \quad (3.13)$$

$$\begin{aligned} \text{IF } PP_j > TC_1 \quad \text{THEN} \\ G_{3,j} = N_3 \cdot [PP_j - (1+I \cdot t)(PP_0 + TC_1 + AMO) + AMO - TC_1] \end{aligned} \quad (3.14)$$

Where:

- I = (Annual interest)/1200
- t = time in months that margin money remains on account
- AMO = average margin deposit per bushel (for options)
- PP_0 = the put premium at the time the hedge was initiated
- TC_1 = one-way, per bushel brokerage commission for options
- N_3 = number of bushels to put hedge
- $G_{3,j}$ = a stochastic revenue from put hedging
- SPP = the strike price of the put
- PP_1 = ending period put premium

j = subscript for Monte Carlo observations
 f_j = ending period futures price (stochastic)

The speculative call position is exactly as it sounds. Almost like the calculations for puts, the one for calls ($G_{5,j}$) is ...

$$CP_j = \text{the larger of } (0, f_j - SPC) \quad (3.15)$$

$$\begin{aligned} \text{IF } CP_j \leq TC_1 \quad \text{THEN} \\ G_{5,j} = N_5 \cdot [CP_j - (1 + I \cdot t)(CP_0 + TC_1 + AMo) + AMo] \end{aligned} \quad (3.16)$$

$$\begin{aligned} \text{IF } CP_j > TC_1 \quad \text{THEN} \\ G_{5,j} = N_5 \cdot [CP_j - (1 + I \cdot t)(CP_0 + TC_1 + AMo) + AMo - TC_1] \end{aligned} \quad (3.17)$$

Where:

I = (Annual interest)/1200
 t = time in months that margin money remains on account
 AMo = average margin deposit per bushel (for options in \$/bu)
 CP_0 = the call premium at the time the call was initiated
 TC_1 = one-way per bushel brokerage commission for options
 N_5 = number of bushels to speculative call position
 $G_{5,j}$ = a stochastic revenue from speculative calls
 SPC = the strike price of the call
 CP_j = ending period call premium
 f_j = ending period futures price (stochastic)

Combining the previous 6 portions into the larger objective function gives...

$$E[U(\bar{X})] = \sum_{j=1}^n U_j \left[\frac{\sum_{i=1}^m N_i \cdot G_{i,j}(Y_j, f_j, b_j, t, S) - C \cdot a - c \cdot (a \cdot Y_j)}{n} \right] \quad (3.18)$$

$$\text{st. } \sum_{i=1}^m N_i \leq E[Y] \cdot a \cdot 3$$

st. a user adjustable constraint z_1 , so that $0 \leq N_i \leq (z_1)$

$E[]$ = the Expectations operator
 n = number of Monte Carlo (MC) observations

y_j	= MC observations on yield
$G_{i,j}$	= marketing revenue or marketing method ($i = 1$ to 6)
N_i	= Number of bu. marketed in the G_i way
S	= Static market data such as interest rates, costs, today's bids, option premiums and strikes, transactions costs, time and more
f_i	= Stochastic futures
b_i	= Stochastic basis
a	= effective acreage (portions share rented plus all cash rent and owned)
C	= direct costs per acre (vary only with intended yield)
c	= costs which vary according to actual production (i.e. trucking, drying etc.)
$U[]$	= utility function or table lookup values for utility conversion
z	= default for z is $(3/2)aE[y]$ for cash market contracts ($i = 1, 4$), otherwise default for z is $(2 \cdot a \cdot E[y])$ ($i = 2, 3, 5$)
t	= time (in portions of a year) from beginning period to ending
m	= the number of marketing alternatives available (including spot sales)

By examining equations 3.4 through 3.17 it is easy to observe that the strength of simulation is its ability to completely represent the problem. This strength is directly related to its biggest weakness. With even a modest problem, the situation may become complex enough that the modeling process is not tractable, and becomes a black box to the reader. Error trapping is an added concern with simulation. Programming errors can go undetected causing incorrect results. There is also a problem that user input could create a run-time error (e.g. dividing by zero). In spite of all the possible problems, when simulation works correctly, the analyst has an opportunity to examine factors like transactions costs that simpler models may not incorporate. Simulation can also be used to handle government commodity programs.

Using simulation creates a need for optimization, but methods needed may exceed the limitations of linear programming. With non-parametric utility functions. Non-parametric yields, quadratic programming, and many math programming methods might be less efficient than using the simulation directly in a search algorithm. This is unfortunate since these methods are relatively fast, and if Kuhn-

Tucker conditions are met they will have a single global optima. As previously mentioned, a disadvantage of most math programming methods for risk is that one or more parameters, must be varied to solve for an efficient set. Such an efficient set for a marketing problem with extremely divisible solutions would do little to help producers, and requiring numerous program runs, would reduce the speed advantage.

Producers need more than an efficient set. The reason for this, is that they might not know where in the efficient set they should operate. They need some small number of reasonable solutions near an optima based on their individual risk attitudes. They also need post-optimality analysis to measure the tradeoffs of other potential solutions. The most discriminatory method available is to elicit producer utility functions, use those functions in a simulation model to measure uncertain income with various marketing plans, and seek a marketing plan that maximizes expected utility. No other method allows for such high degree of selectivity, and a highly representative marketing model.

3.9 Finding Superior Marketing Plans (MKTOPT)

Kuester and Mize (1973) presented a simple version of Box's Complex in FORTRAN. Complex operates by evaluating the objective function at a best guess, and K-1 other randomly chosen vertices in the solution space. K is the number of vertices to simulate in the solution space. The number of vertices is usually 2 to 3 times the number of search (control) variables (N). The notation for Complex follows the notation of Kuester and Mize (1973). The objective function is inserted into a subroutine. Values of the control variables (a vertex) are passed to the objective

function subroutine and the value of the objective function at the vertex is returned to Complex.

Complex can handle explicit constraints on the control variables, as well as implicit constraints. An example of an implicit constraint is when the sum of all control variables must be less than some fixed value. If a vertex in the search space violates any of the explicit constraints, it is moved a small distance (δ) inside the constraint and re-evaluated for feasibility. Feasibility not only involves meeting the explicit constraints, but also the implicit ones. If the objective function values of all vertices are within "Beta" of one another, the search stops and results are printed. "Beta" is a convergence parameter with the same units of measure as the objective function.

Until convergence is reached, the vertex with the lowest objective function value is selected, and a centroid of the other vertices is computed. The "worst" vertex is moved toward the centroid of the other vertices a distance of "Alpha" times the distance of the vertex to the centroid (on a straight line when the solution space is 2 or 3 dimensions). Alpha is usually 1.3 so that some intentional "overshooting" of the centroid occurs. Larger alpha (1.6) increases robustness and computing time, while smaller alpha are less robust in finding the true optimum, but are less likely to get "stuck" in the search process. Smaller alpha lead to an averaging process.

Figure 3.6 shows principle components of Box's Complex with 2 control variables. A is the lowest valued vertex in the solution space. The large C is the centroid of all the other points. A is moved in the direction of the centroid by a factor Alpha times the centroid to A distance. If the new point (the black square named B) is still the "worst" it is moved half way back toward the centroid. If it violates any explicit constraints, the new point is moved " δ " (a very small distance) inside of the

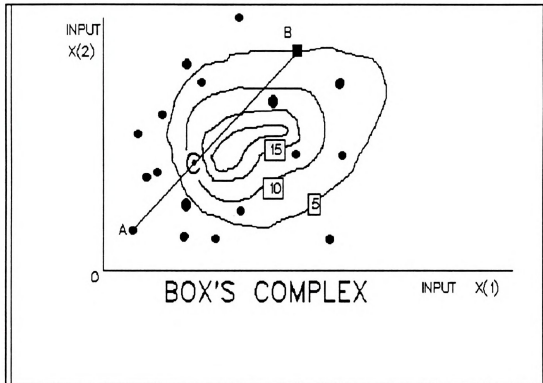


Figure 3.6 Schematic of Complex

constraints to satisfy the constraints. If the new box (b) is not the "worst" point, a new "worst" point (lowest objective function value of all vertices) is selected, a new centroid is computed, and (in the same way) the new worst point is moved toward the new centroid. As mentioned, convergence occurs when all objective function values for all the vertices are within "Beta" of one another.

The routine used to optimize expected utility for FIRM is a modified version of Box's Complex. Some of the modifications are from Manetsch and Park (1988) and many from the author. Manetsch and Park wrote an M-OPTSIM (1986) version in BASIC that included a variable value of Alpha. Early in the convergence process Alpha is 1.6 to increase robustness, and as convergence proceeds Alpha is reduced

to 1.3 and progressively to lower values. This gives all the robustness of a large alpha, followed by the desirable faster convergence of a smaller alpha.

Other improvements for FIRM (to Complex), were to completely rewrite the code in a structured format using a compiled version of BASIC (MicroSoft's QuickBASIC™. The version of Complex used in FIRM differs also because the 15 best vertices (marketing plans) are printed as part of the solution. Rather than choosing a single best guess for a vertex to seed the search, MKTOPT (the FIRM version of Complex) uses 5 "best guesses" (vertices 1-5). Best guesses in MKTOPT use only one of the five marketing methods at a level of half the expected production, (while the other four marketing methods are set to a level of zero. Thus..

Vertex - k -	N ₁	N ₂	N ₃	N ₄	N ₅
1 =	Z _{1,1}	0	0	0	0
2 =	0	Z _{2,2}	0	0	0
3 =	0	0	Z _{3,3}	0	0
4 =	0	0	0	Z _{4,4}	0
5 =	0	0	0	0	Z _{5,5}
6-15 =	r _{k,1}	r _{k,2}	r _{k,3}	r _{k,4}	r _{k,5}

$$\text{s.t. } 0 \leq r_{k,i} \leq UC_i \quad \text{for all } i = 1, 2, \dots, 6 \\ \text{and for all } k = 1, 2, \dots, 15$$

$$\text{s.t. } 0 \leq Z_{k,i} \leq \text{the lesser of } (UC_i, .5E[y-a])$$

Where:

N ₁	= number of bushels to forward contract
N ₂	= number of bushels to futures hedge
N ₃	= number of bushels to put hedge
N ₄	= number of bushels to basis contract
N ₅	= number of bushels for speculative call
r _{k,i}	= random number of bushels
E[y,a]	= expected production
UC _i	= upper constraint (user adjustable)
k	= the number of vertices
Z _{k,i}	= best guess marketings

The objective function for FIRM is ...

$$\text{Max } E[U_j(G_{i,j}(N_1...))] \quad (3.20)$$

$$\text{s.t. } 0 \leq N_i \leq UC_i \quad i = (1, 2, 3, 4, 5, 6)$$

$$N_6 = N_1 + N_2 + N_3 + N_4 + N_5$$

Where:

- $G_{i,j}$ = Previous marketing functions (see section 3.8)
- $E[]$ = Expectations operator
- N_i = Bushels to sell the i th way (for $i = 1, 2, 3, 4, 5$)
- N_6 = Total marketings ($UC_6 = 3 \cdot E[\text{production}]$)
- UC_i = Upper Constraints (defaults are user adjustable)
- U_j = Utility of gross margin for a marketing plan

The numbers for each pricing alternatives relate directly to the subscript i in the marketing function. Remaining production is also sold, but is not a control variable.

In fact, if negative bushels remain, the producer may have to buy back the cash commodity at a potential premium.

Utility (U_j) is computed from H_j , where $H_j = \sum G_{i,j} \quad (i = 1, 2, 3, 4, 5, 6)$, based upon the Monte Carlo observations of yield, basis, and futures. All U_j are summed and divided by the number of Monte Carlo observations to get expected utility. Each set of gross margins at a particular Monte Carlo observation (numerator in equation 3.18) is converted into utility through a table-lookup function from ELRISK data. From ELRISK each producer had a utility curve where the rounded expected gross margin minus the rounded standard deviation of gross margin was equal to a utility of 0. This is true because of the way that ELRISK was seeded. This means that large farms and small farms are indexing their gross margin distributions via their utility functions. This conversion into utility doesn't precisely standardize the expected utility (the performance criteria), but it does bring all producer's answers into a relative neighborhood. This is a big advantage for non-linear optimization, since the beta

convergence parameter can be set in advance. Most producers who run ELRISK will have expected utilities of 100 to 400 regardless of farm size. Beta is set at a default of 1.00 internally, but the default can be changed by the producer.

Penalties on undesirable outcomes can also be incorporated in Complex, but were not utilized if FIRM. MKTOPT source code in MicroSoft QuickBASIC™ is listed in Appendix I.

3.10 Post-Optimal Solutions

Figure 3.7 is the output from MKTOPT. The last three lines are custom plans entered by the producer following the first 15 provided in optimization. Custom plans allow exploration by the producer, and overcome the difficulties of contract lumpiness.

- - - - - BUSHEL TO - - - - -									
Plan	Forw. Cont.	Futures Hedge	Put Hedge	Basis Cont.	Spec Call	Expect SpotBu	Exp. Util	Risk Prem	
1	4541	0	0	0	0	4542	205.1	0.0	
2	3324	52	0	420	38	5338	204.9	11.2	
3	3949	0	30	950	125	4188	204.8	14.9	
4	3724	23	44	188	65	5170	204.8	15.7	
5	3388	0	88	0	2	5693	204.7	17.9	
6	4355	0	39	0	110	4727	204.7	19.7	
7	3327	28	44	225	63	5529	204.6	22.8	
8	5204	16	39	391	92	3511	204.5	28.2	
9	3622	0	156	0	52	5459	204.5	31.0	
10	3100	156	0	0	68	5982	204.5	31.3	
11	3170	15	23	162	89	5749	204.4	31.8	
12	3166	46	19	0	84	5916	204.4	32.4	
13	5247	12	74	159	85	3691	204.4	32.6	
14	2888	0	51	0	0	6194	204.4	35.7	
15	3013	0	11	0	75	6069	204.3	36.7	
16	0	0	0	0	0	9082	197.0	372.6	
17	5000	0	0	0	0	4088	205.0	4.8	
18	5000	2000	0	0	0	4088	201.4	186.0	

Figure 3.7 Part of the Sample Farm Output

The value in the expected utility column has little meaning to producers, since it is unitless. This is much like the idea that a temperature of 38 degrees could be

Celsius, Fahrenheit, or Kelvin. Note that the 15 alternatives have been sorted from highest to lowest expected utility. On the far right of the output is a column called risk premium. Suppose each expected utility value in Figure 3.7 was converted to dollars via the producers utility graph in Figure 3.5. The result is called a "certainty equivalent." These values were not listed in the output, but if they were, the certainty equivalent could be thought of as a selling price for the risky proposition of the expected utility it represents. The difference between the certainty equivalent of one plan, and that of another, is the risk premium. In ELRISK, the risk premium listed is the difference between the certainty equivalent of the best plan listed (plan 1), and the certainty equivalent of each of the rest of the plans. Plan 16 shows that if the producer does no marketing between now and harvest, then by his or her risk preferences this is \$372.60 worse than the best plan in "certain" terms. In other words, doing no advanced marketing has a risk "cost" of \$372.60 compared to plan 1 for the sample producer. This \$372.60 risk cost is referred to as the "Risk Premium Above Doing No Marketing" (RPANM) in the remaining chapters.

Users of FIRM (e.g. researchers, farmers, extension agents) may enter up to five post-optimal plans to compare to the above 15. These plans can address problems of "lumpy contract values", where futures and options are only available in fixed contract sizes. Post-optimal testing allows the elimination of some marketing alternatives by setting the quantities to zero.

Figure 3.8 shows additional output from MKTOPT for analysis of means, standard deviations, and four different percentiles. This data was computed from FUNK2 a subroutine in MKTOPT that works just like the objective function (marketing simulation), except that the 200 observations are sorted to give percentiles of the

Plan	Expected		SDev.	PERCENTILES			
	Util.	\$Rev.		5th	10th	20th	80th
1	205.1	38112	10328	17864	24016	30298	45347
2	204.9	38108	10487	17631	23156	30491	45705
3	204.8	38093	10401	17736	23404	30272	45493
4	204.8	38099	10427	17668	23384	30309	45556
5	204.7	38102	10475	17601	23239	30452	45751
6	204.7	38093	10349	17772	23796	30254	45305
7	204.6	38100	10488	17591	23151	30508	45687
8	204.5	38092	10265	17970	23718	30245	45226
9	204.5	38086	10435	17604	23406	30330	45594
10	204.5	38101	10510	17556	23144	30421	45655
11	204.4	38100	10521	17548	23130	30464	45670
12	204.4	38100	10517	17544	23145	30437	45670
13	204.4	38088	10259	17957	23692	30262	45238
14	204.4	38109	10565	17692	23259	30422	45816
15	204.3	38104	10552	17641	23219	30434	45773
16	197.0	38122	11280	18431	21783	29203	47126
17	205.0	38111	10283	17958	23937	30244	45322
18	201.4	38037	10209	18169	23507	30600	44471

Figure 3.8 Additional MKTOPT output

gross margins. This additional data in Figure 3.8 is occasionally needed to help understand the differences in two distributions listed on the previous screen (Figure 3.7). Note that Plan 16 offers the highest expected income, but its standard deviation is substantially higher than the best plan. Since distributions are non-parametric, it may be necessary to examine percentiles when comparing two close distributions.

3.11 Issues

Choosing the appropriate mix of pricing alternatives and the number of bushels to commit to each alternative is an ill-structured task during the pre-harvest time period. The decision-maker must consider the uncertainties of yield, basis, and futures, plus factors related to the producer's ability (or desire) to accept risk. It is not yet clear whether producers can accurately do this. Some would argue that they

already implicitly do this in marketing, but how accurately can producer risk attitudes and subjective yields be "known" by producers and elicited? Such a question could be studied by behavioral analysts, but the process of extracting information from humans will always contain some misunderstanding and mis-information (error), however small.

There are numerous pricing alternatives available for producers, but only six basic methods were considered in the research. This is several more pricing methods than most research projects have handled simultaneously. Other pricing strategies were not considered in the research because they are extremely close substitutes for the six pricing alternatives listed above. One example of these is the hedge-to-arrive contract. In this contract the grain elevator is a "substitute" for a broker, and offers a cash contract covering only the futures portion of the price, for specified quantity, location, and time. Non-linear optimization is very difficult when nearly perfect substitutes are available. In such situations there is usually not a single optima, but a "ridge" formed between the two substitutes. One answer is to reduce substitutes in the model, but realize they might exist at the time the grain is priced. There may be "non-pricing" reasons to use hedge-to arrive contracts rather than futures hedging (e.g. margin calls).

Time is an additional consideration for the problem environment, but it affects the problem in two ways:

1. Marketing is a stochastic, dynamic process, since decisions can be made numerous times during the season. The problem was reduced to a two period (non-dynamic) stochastic one. Period one is any pre-harvest time when acreage is known or intended, but yield is not. Period one is also the day the model is run. Period two

is a post-harvest date when residual cash sales will take place. For convenience in calculating options premium values, period two is a day or two before option expiration. At that point, the time value of the option is minimal, and only the intrinsic value remains (if the premium has value at all). The problem here is that dynamic strategies could be superior. The difficulty of dynamic analysis is one of data (conditional distributions), and computing power at the farm level.

2. The second effect of time is that yield pdf's and static market data will change throughout the growing year as weather and crop information is updated. Although the model is not dynamic, it is expected that producers should be able to market in several different time periods. Producers should be able to price some grain at planting time for harvest delivery, and later in the season, with the help of the model, make commitments on additional sales (perhaps in January for tax purposes). Changes in the yield distribution and static market data affect subsequent marketing decisions. The need for mid-season yield pdf's dictated that yields be subjectively formed from the producer. Mid-season elicitation of yields would likely have a shift in the mean from a planting time elicitation, and would usually be less volatile.

Income in FIRM is measured in terms of gross margins (total income minus direct costs). Two kinds of direct costs are considered. There are "per acre" expenses such as seed and fertilizer, and "per bushel" expenses such as drying and trucking. Some risk research is based on wealth (Robison;1987), some on per bushel income (Rister and Skees;1982), and nearly every measure in between. Raskin and Cochran noted that most studies used net farm after-tax income. von Winterfeldt and



Edwards argue that people do not know their wealth. They also argued that "investors and poker players alike must learn to write off sunk costs."⁴

Most decision theory and management texts would encourage decision makers to examine only the relevant information. Enterprise analysis and partial budgeting are perfect examples of tools to produce useful information for decision making. Risk theory has incorporated wealth into the utility function as an explanatory variable on why wealthier persons seemed to behave differently than less wealthy. The same principles of utility can be used for enterprise risks as well as the whole farm. Doing this, implies that farm wealth does not change during the risky period due to the enterprise risk.

3.12 Future Improvements to FIRM

Quality records are the foundation for sound decision analysis. FIRM needs to know what previous commitments have been made for the crop in question and the amount of deterministic gains or losses to date (if any). Ferris (1985) designed a marketing record system to be kept on paper. This system is the outline for a computerized grain marketing database. The database will record marketing transactions and will contain information about brokerage commissions, storage costs on grain, and other needed price data. The database will employ a dBase IV file format, but entry forms will be supplied to the producer, thereby eliminating the need to purchase and learn Dbase. Database tools are under development in the AIMS project at Michigan State University, Department of Agricultural Economics that will help facilitate building a marketing database.

⁴ p. 377

The most important portion of the marketing database for FIRM is the open position report. The open position report is a summary of marketing commitments yet to be delivered (contracts in the cash market) or offset (futures and options markets). The format for the open position report is shown in Figure 3.9.

OPEN POSITION REPORT								
Date	Crop	Contract Month	Mktg Method	# of Bu.	Prem or \$ /Bu.	Strike \$ /Bu.	Tran ¢ /Bu.	Margin ¢ /Bu.
2-16	Soy	11-89	For. Con.	1000	6.83	0.00	0.0	0.0
3-19	Soy	1-90	Buy Put	5000	.49	6.75	3.0	15.0

Figure 3.9 Report From the Marketing Database

When FIRM is executed, the first action would be to read the open position report and retrieve entries related to the selected crop. FIRM will also need current pricing data and data from the production portion of the database. Important data also includes historical yields for the selected crop, acreage, and leasing arrangements for crop land. This data will come from the field records section of the farm database.

The research model of FIRM has no marketing database. However, needed static default data (e.g. interest rates, current cash, and futures market bids) are stored in ASCII files. All of the default values can be changed when the program is run. Some database material for the research model is entered manually, such as direct costs, per bushel, variable costs, and acreage. Table 3.1 is a listing of database static marketing data for a case farm.

Table 3.3 Static Input to MKTOPT

 PARAMETER VALUES FOR THIS RUN

NS= 5 NC= 6 NV= 15 ITMAX= 100
 ALPHA= 1.35 BETA= 1 GAMMA= 5 DELTA= .0001

The upper constraints for

Forward Contracting = 9081.563

Futures Hedging = 18163.13

Put Hedging = 18163.13

Basis Contract = 9081.563

Speculative Call = 18163.13

Today's month is 1

The contract month is 11

The unbiased Futures price is (\$/bu) 6.1825

The forward contract price is (\$/bu) 6.08

The Price of a basis contract is (\$/bu) -.1

The Call premium is (\$/bu) .44

The Strike for the Call is (\$/bu) 6

The Put premium is (\$/bu) .28

The Strike for the Put is (\$/bu) 6

Round trip trans. costs for futures (cents/bu) = 1.5

ONE-WAY trans. costs for options (cents/bu) = 1.5

Margin costs per bushel on futures (\$/bu) .3

Margin costs per bushel on options (\$/bu) 0

The ANNUAL interest rate is 10.000

The cash elevator spread for ASK - BID is (\$/bu) .05

The ASCII file data includes option premiums, strike prices, the closing futures price for November soybeans, current contract prices, interest rates, and other transactions costs. This data is stored in a file named PRICE.DAT and is read into the FIRM model. The workshop coordinator is able to update the PRICE.DAT file. PRICE.DAT provides default values in the MKTOPT program, which can also be changed by the user when running MKTOPT. (MKTOPT is described later)

The generation of futures and basis required that the Monte Carlo sample mean for futures, had to equal the static futures price in the PRICE.DAT file. All price distributions (futures and basis) were adjusted following their creation. This was not necessary with the yield distribution, since it was not parametric.

In addition to a database, there are improvements needed to the user interface with help messages, screen editing, documentation and more. An end-user version of FIRM should also include an interface to electronically available market data, further reducing data entry.

3.13 Summary

This chapter presented the Farm Income Risk Management (FIRM) model. FIRM is a commodity marketing tool that maximizes decision-specific subjective expected utility, thereby matching pre-harvest price risk with producer's desire or ability to bear risk. FIRM can be operated on a IBM compatible microcomputer. A case farm was presented to improve understanding of the research version of FIRM. Chapter 4 presents two major groups of tests; the first set of tests are validation. Chapter 5 presents a group of tests for correspondence and workability. The final chapter is a summary and presents challenges to further research.

CHAPTER FOUR

MODEL VALIDATION

4.1 The Base Farm for Testing	136
4.2 Test 1 - Effect of Utility Changes on Marketing Plans	138
4.3 Test 2 - Effect of Utility Changes on Pricing Tools	145
4.4 Test 3 - Changing Put Options Premiums and Utility	148
4.5 Test 4 - Changing Price Distribution Forms	149
4.6 Summary	152

Chapter 4 contains tests of FIRM. Most of these tests are performed on a feasible or reasonable situation, with marginal changes in model inputs. Several degrees of risk attitudes are explored, especially negative exponential ones, since they are common in other research (Ramaratnam et al.;1986) and are easily summarized. The tests in this chapter are part of the validation process before field testing.

The number of inputs and parameters to FIRM exceeds 20. If each is tested at 3 levels (high, low, and medium) the total number of combinations would be 3^{20} or more than 3.4 Billion. Fortunately, not all combinations are needed, in order to validate the model. There are, however, several systematic value changes that should be considered and evaluated. The process used, is to formulate a reasonable base situation and begin changing important inputs (one at a time).

4.1 The Base Farm for Testing

The base farm in this chapter is different than the one used to illustrate the model in Chapter 3, although several factors of the base farm are the same. In the previous chapter ELICIT was used to create a non-parametric yield for 250 soybean acres. This distribution is unchanged, as are production costs. In some of the tests in this chapter, transactions costs will be reduced to zero. The reason for no pricing (brokerage) costs was so that $E[\text{basis}] = E[\text{cash price}] - E[\text{futures}]$. Although someone must pay brokerage fees and interest on margin, it is not clear where those costs should enter in the traditional equation of $\text{futures} + \text{basis} = \text{cash price}$.

Upper constraints in MKTOPT were increased on forward contracting and basis contracting in order that any pricing alternative could be done at up to twice the expected production level. Twice the expected production should be high enough

that only speculative positions would be constrained. Options retained their interest on premiums for time "t" (from purchase to just before expiration). Table 4.1 lists static data for this farm.

Table 4.1 Static Input to MKTOPT

PARAMETER VALUES FOR THIS RUN

The upper constraints for
 Forward Contracting = 18163.13
 Futures Hedging = 18163.13
 Put Hedging = 18163.13
 Basis Contract = 18163.13
 Speculative Call = 18163.13

Today's month is 1
 The contract month is 11
 The unbiased Futures price is (\$/bu) 6.1825
 The forward contract price is (\$/bu) 6.08
 The Price of a basis contract is (\$/bu) -.1
 The Call premium is (\$/bu) .44
 The Strike for the Call is (\$/bu) 6
 The Put premium is (\$/bu) .28
 The Strike for the Put is (\$/bu) 6
 Round trip trans. costs for futures (cents/bu) = 0
 ONE-WAY trans. costs for options (cents/bu) = 0
 Margin costs per bushel on futures (\$/bu) = 0
 Margin costs per bushel on options (\$/bu) = 0
 The ANNUAL interest rate is 10.000
 The cash elevator spread for ASK - BID is (\$/bu) .05

Figure 4.1 is a "Cumulative Distribution Function" (CDF) that represents the income distribution with no advanced marketing. This distribution is a function of non-parametric yields, costs, and normally distributed futures and basis. Costs include both per acre costs, as well as, costs that vary with yield. Table 4.1 data also affect

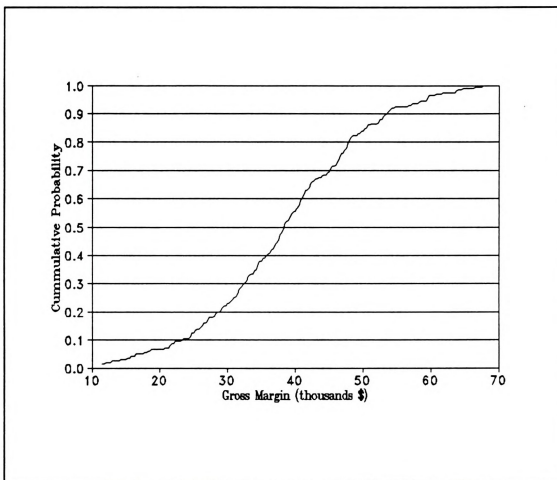


Figure 4.1 Case Farm Gross Margin Distribution

the gross margin distribution in Figure 4.1. Very few gross margin observations occur below \$18,000 and above \$68,000.

4.2 Test 1 - Effect of Utility Changes on Marketing Plans

Figure 4.2 shows 5 negative exponential utility functions. The span which they covered includes roughly 95% of the gross margin observations in Figure 4.1. The utility functions were created with the aid of Borland's Quattro Pro™. A negative exponential function of the form $U(X) = k - a \cdot (\text{EXP}(-b \cdot X))$ where k and a are location and scale parameters and b is the CARA coefficient. There are no "curves" in Figure

4.2, as each "curve" is actually 12 line segments. One point here, is that 13 data points can very closely approximate a curve, even a moderately risky one. Of course, this presumes the points are reasonably well fitted.

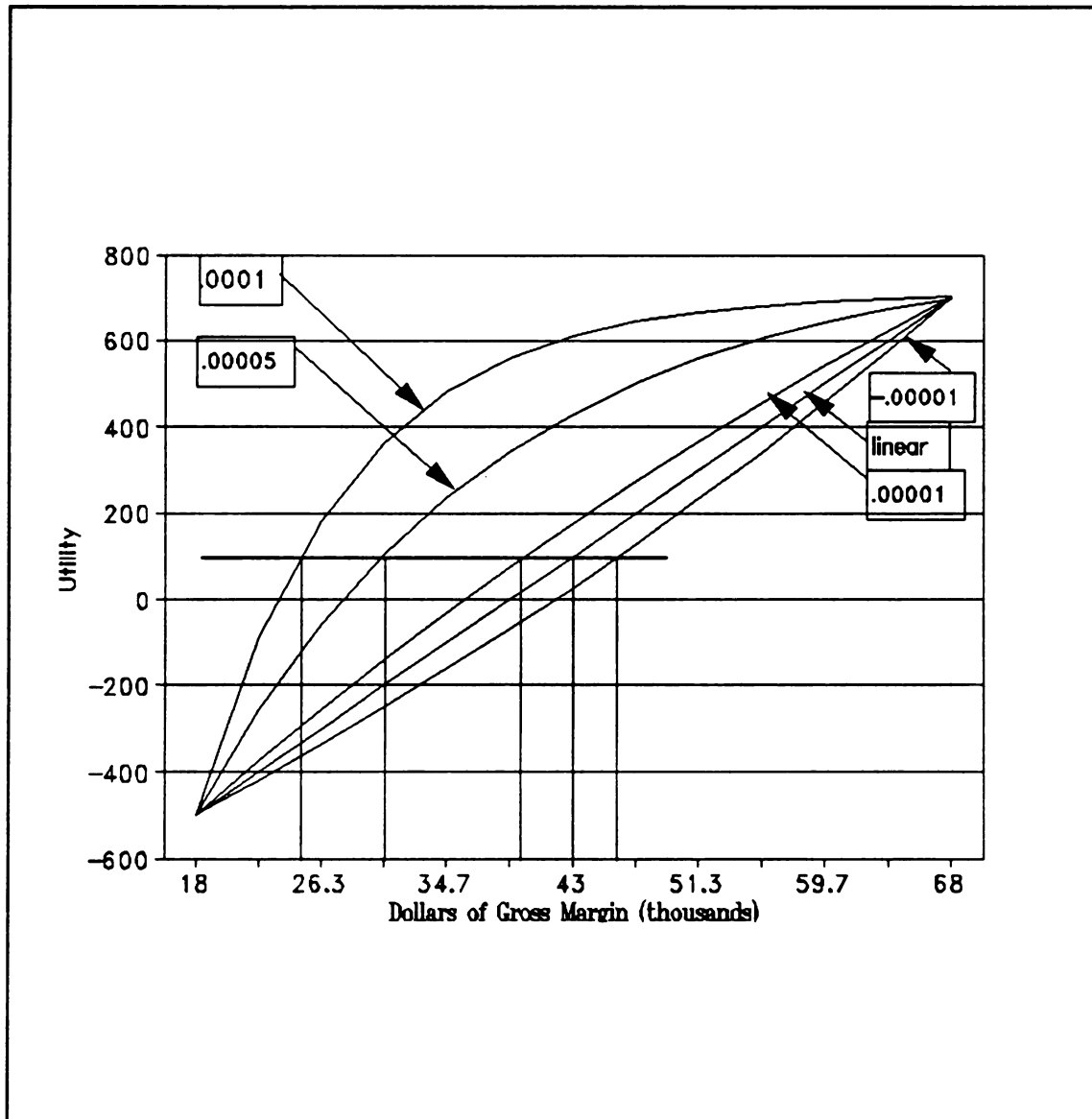


Figure 4.2 Five Negative Exponential Utility Functions

The linear (risk neutral) risk attitude in Figure 4.2 behaves like a profit maximizer. If offered a gamble with a half chance of winning \$18,000 and a half chance of \$68,000, the expected income would be \$43,000, resulting in a utility of 100 for the risk neutral producer. This producer would equally prefer the gamble to its expected outcome. This same situation presented to the producer with .00005 CARA coefficient would bid only \$30,317. The producer with .0001 CARA coefficient would pay \$24,852 (or less). These values are available in Figure 4.2 at the utility level of 100 for various producers. Each of the dollar values are called "certainty equivalents," and the difference between them and the expected outcome (\$43,000) is the "risk premium."

The reason for these values is not due to the utility of 100, but because \$43,000 is the expected value, midway on the line between \$18,000 and \$68,000. The straight line represents not only the risk neutral producer, but a linear gamble set between the two endpoints. The midpoint of the line represents a 50/50 gamble of the two endpoints. This is also where the risk neutral producer has a utility of 100 for \$43,000. The risk neutral producer is willing to pay the expected outcome of the gamble, (\$43,000), and the risk preferring producer will pay extra, above the expected outcome, to play the this 50/50 gamble.

The real issue is not how much producers with different risk preferences would bid for some extremely high variance gamble, but how they would market the grain from a farm that has identical production and common prices. Just as with the gamble above, more risk averse producers should have higher risk premiums (compared to doing no pricing). They should prefer hedging or forward contracting over basis contracting, because basis contracting protects a much smaller portion of the total price. Risk neutral producers are profit maximizers and are indifferent to

variance, they will seek any chance to increase expected income through marketing regardless of the variance. Risk neutral persons help identify arbitrage opportunities. When the best price is the ending period cash price, risk neutral producers will do no advanced marketing. Persons who prefer risk, prefer income and variance, such a person might like to speculate by selling much more than expected production and increasing the variance of gross margins.

The first test in this chapter is to let the five CARA attitudes analyze the same marketing problem. This test also examines behavior of the pricing instruments under different risk attitudes. All of the five utility curves in Figure 4.2 extend over most of the income distribution in Figure 4.1.

In the MKTOPT output 14 other plans are listed with the best plan to give sensitivity analysis in the area of the optima. Boiling down these answers to a single marketing plan results in lost information, since there is no information about tradeoffs near the optima. For many tests in this chapter and the next, it is not possible to list or easily summarize the neighboring solutions. Since this is the case, it is more important that the optimal solution be more tightly converged. All of the optimal marketing plans in this test (and all other tests except where noted) were the result of two passes with MKTOPT. The first pass with MKTOPT was to get in the area of the optimum. The best 15 solutions were examined, the constraints were tightened around the best 15 plans, the convergence parameter to MKTOPT (beta) was further reduced, and MKTOPT was rerun.

Table 4.2 shows the best marketing plan for each of the five negative exponential utility functions. Table 4.2 gives expected results for the three risk averters. Expected utility rises across these producers, as anticipated from looking at

the graph (Figure 4.2). Also "Risk Premiums Above doing No Marketing" (RPANM) increases as the CARA coefficient increases. To compute the RPANM, the optimal plan is compared to a plan with no advanced marketing (just ending period spot sales). Since the optimal plan has a Risk Premium of zero,¹ it is useful to find out how much better the optimal plan is compared to a "do nothing" plan (only spot sales). The higher the RPANM the larger the risk aversion, especially when the "do nothing" plan is the same for all producers (the CDF in Figure 4.1 is the CDF of the "no advanced marketing plan).

Table 4.2 Marketing solutions for 5 Utility Functions.

CARA Coef.	BUSHELs							*
	Forw. Cont.	Futures Hedge	Put Hedge	Basis Cont.	Spec Call	Exp. Spot	Exp. Util	
-.00001	9000	18154	0	0	0	82	-58.2	557.5
Neutral	0	0	0	3913	0	5169	-17.1	0.1
.00001	1963	5237	0	2524	0	4595	43.4	95.4
.00005	370	5601	0	2988	0	5724	257.2	436.7
.0001	2585	3012	0	1327	0	5170	421.4	740.4

*
Risk Premium Above doing NO Marketing

A perfect risk neutral decision-maker (profit-maximizer) would be indifferent between doing nothing and some marketing activity with the same mean (regardless of variance). This is different than the risk preferrer who seeks higher variance. Table 4.2 indicates the risk neutral person would basis contract 3913 bushels and that this person would be happier by 10 cents versus doing no advanced pricing (all spot

¹ MKTOPT always give the best plan a risk premium of zero since it is the base for comparison to the other plans on the output.

sales). This indicates that the ending period basis distribution had a mean that was slightly lower (in fact 10 cents in 3913 bushels or \$.000025/bu) than the current basis contract offer. Basis contracting improved profits slightly for the risk neutral producer, but if production ever fell below 3913 bu (15.6 bu/ac) the \$.05 ASK-BID spread would affect each bushel below 3913. Since the risk neutral producer did not use futures or forward contracting, today's futures price must be below the expected fall futures price.

In Table 4.2 the risk preferrer was suggested to sell all but 82 bushels of expected production by forward contracting, then sell twice his expected production in futures contracts. Total sales by all pricing methods were limited to three times expected production (an implicit constraint on N_s discussed in Chapter 3). Each individual pricing method was limited to twice the expected production (upper explicit constraint). No long futures positions, or option granting (writing) was allowed (lower explicit constraints were zero bushels).

Before leaving Table 4.2 there are other observations to be made. Options failed to enter any of the optimal solutions. One possible reason is that the assumed interest of 10 percent is higher than risk-free short-term interest rates used in the option pricing models that generated the futures price variance. At low enough interest rates and/or lower premiums, options would be expected to come into solution. A second observation from Table 4.2 concerns the difference in the neutral versus .00001 behaviors. If the two curves are considered to be possible measurement error of each other, important conclusions result. The risk premium above doing no marketing (RPANM) only changed by \$95 from risk neutral to the .00001 CARA producer. This infers that measurement errors in elicitation will have

more impact in the neighborhood of a linear function (in terms of marketing solutions, but not in terms of risk premiums).² On the other hand, going from CARA .00001 to the producer with CARA of .00005 is a factor of five and involves a greater visual change on the Figure 4.1 graph. But examining Table 4.2, the change between these two utility curves (.00001 and .00005) is much greater in terms of utility and risk premium, but much less in terms of the marketing plan (compared to the differences in risk neutral versus .00001, that were just discussed).

With no transactions costs and no dynamic factors (across time), forward contracts and futures hedging are nearly perfect substitutes. If forward contract and futures hedging are added together, each of the risk averters had similar levels of forward pricing, but increasing utility and RPANM.

To summarize, increasing the risk aversion (the CARA coefficient), increased the expected utility of the best marketing plan and the Risk Premium Above No Marketing (RPANM). Global risk preference was shown to behave in an unusual manner that can be summarized as a preference for higher variance. It appears that measurement error (perhaps in elicitation) in the neighborhood of risk neutral behavior would result in greater changes in activity levels and less in terms of RPANM when compared to changes in more risk averse utility curves. One important note is that the analysis seemed consistent with expectations. These findings are based upon well defined utility curves (CARA) and the specific pricing circumstances.

² Except for the unusual case of global risk preference. Global risk preference is logical behavior for persons in dire straights. One rule here would be to maximize the maximum outcome. This would lead to unusual behavior as happened in Table 4.2.

4.3 Test 2 - Effect of Utility Changes on Pricing Tools

In this test the base farm remains the same, the brokerage fee is still zero, but each producer will individually examine only one pricing alternative at a time (plus cash sales in the final period). Spot (cash) sales are always available and cannot be turned off. The expectation here is that producers might use a poorer performing pricing alternative, if they have no other choices except all cash sales. Expect the risk averters to price more grain in each individual risk reducing pricing alternative, than when they could choose from all five simultaneously. Basis contracting is not likely to change utility or the risk premium much, since it is a small part of price.

Table 4.3 Pricing Solutions for 5 Utility Functions.

CARA Coef.	Units	ONLY Forw. Cont.	ONLY Futures Hedge	ONLY Put Hedge	ONLY Basis Cont.	ONLY Spec Call
-----	-----	-----	-----	-----	-----	-----
-.00001	Bu.	0	18163	0	0	0
	Util.	-71.0	69.2	-71.0	-71.0	-71.0
	\$ RPANM	0	75.3	0	0	0
Neutral	Bu.	0	0	0	0	0
	Util.	-17.1	-17.1	-17.1	-17.1	-17.1
	\$ RPANM	0	0	0	0	0
.00001	Bu.	5536	7079	0	4541	0
	Util.	43.3	43.4	41.0	41.1	41.1
	\$ RPANM	91.3	93.6	0	2.3	0
.00005	Bu.	6227	6617	0	4541	0
	Util.	257.1	257.1	245.1	245.1	245.1
	\$ RPANM	433.4	433.6	0	10.3	0
.0001	Bu.	5641	5858	2888	4723	0
	Util.	421.4	421.0	403.7	403.2	402.5
	\$ RPANM	738.4	724.8	48.5	25.6	0

The risk neutral producer did no pricing in any of the five alternatives, when each were examined individually. When no pricing is done all sales are spot cash at harvest. This indicates the ending distributions for basis and futures had expectations no higher than current bids. The very small arbitrage using basis contracts (10 cents on 3913 bushels), was discovered earlier in the related search in Table 4.2., but was not found in this test. The slight risk preferrer sold twice his expected production on the futures market. This is a very predictable behavior. Without system constraints it is probable the solution would have been unbounded. Using futures to speculate (beyond production), increases the maximum possible outcome, with almost no change in mean of the price distribution and the forward contract price. Reasons for this are that transactions costs are zero, and market means were fairly unbiased.) Thus, variance could be increased and the mean preserved, by speculating in added short positions in futures.

The three risk averters can be discussed as a group since several patterns appeared. Producers with these attitudes gained most from either forward contracting or futures hedging. None of these persons overhedged in any instrument (more than expected production). Basis contracting did little for risk reduction as indicated by its with very low RPANMs compared to the other instruments.

When no other marketing alternatives were available, the very risk averse producer, did use the nearest out-of-the-money put hedge. The put hedge purchase involves, not just paying the premium, but interest on the premium until expiration. If farmers have higher interest rates than the "risk arbitragers" in the market, then the shift in expected gross margins with options may overshadow its risk reducing benefits. This could explain why options did not come into solution for the less risk

averse producers. Note that the Put hedge for the .0001 risk averter has a RPANM of \$48, while forward contracting and futures hedging had RPANMs of more than \$700 for the same risk averter.

In Table 4.2 the risk neutral producer "basis contracted" 3931 bushels for a \$.10 benefit on an expected \$38,000 in gross margins. This explains why the same solution was not reached between Table 4.2 and 4.3 regarding the risk neutral farmer. In fact, the non-linear search algorithm usually converges before such small differences could be detected. With a risk neutral producer, totally unbiased prices and distributions, then the producer will get the same utility from any plan chosen (including doing nothing). This creates a "flat" optimal area where many equal-utility solutions exist. This is what is seen in Table 4.2 and Table 4.3. The risk neutral behavior (profit maximizer) is very useful for finding arbitrage opportunities.

RPANMs among the risk averters increased, as the risk aversion coefficient increased. The recommendation that the .00001 producer market 4541 bushel when basis contracting was the only pricing alternative, is weakened by its meager RPANM of \$2.3. Users of FIRM should understand that the solution is important, but that the RPANM is like a confidence or conviction factor. The RPANM rises (for risk averters) as the amount of risk reduction increases.

At the beginning of this section it was observed that the tests would also reflect the risk averting strengths of the pricing alternatives. Since speculative calls do not reduce risk they were not selected by any of the producers. Even the slight risk preferrer, chose not to use them. The reason for this is that although the speculative call position could increase variance, the cost of the premiums and interest on them, reduced expected gross margins.

Futures and forward contracting are very similar in their risk reducing capacity. Their pricing levels, utilities and risk premiums were very similar to each other for the three risk averters. Options and basis contracting were less effective in risk reduction as indicated by smaller risk premiums (and smaller utility) than forward contracting and futures hedging. These judgements are based on examining utility values as well as RPNMs across the table for each of the risk averse utility functions.

In this section, 5 CARA utility curves were matched with 5 individual pricing instruments for 25 situations and twice that many runs of MKTOPT. Futures hedging and forward contracting functioned almost identically, since transactions costs are zero. RPNMs and utility increased as risk aversion increased. The basis contract does little to reduce risk for this group of producers. Speculative Calls were not used by any producer. Only the most risk averse producer used put-hedging. This occurred when put hedging and cash sales were the only pricing alternatives available for the .0001 CARA producer.

4.4 Test 3 - Changing Put Options Premiums and Utility

With Put options priced at \$.28, (10 months from harvest) the implied volatility of futures prices from the Hilker and Black OPM was 11.5%, or roughly \$.69 standard deviation, with \$.18 soybeans. This is the same distribution and volatility used previously in this chapter. In Table 4.4 Put premiums were lowered further to examine their acceptance at different risk attitude levels.

Table 4.4 shows that more risk averse producers should be first to Put hedge. With \$.24 put premiums the .00001 CARA attitude, still did not purchase options. Lower put premiums bring increased purchasing, increased utility, and increased risk

reduction as measured by the RPANM. In Table 4.4 all other pricing alternatives were eliminated (except cash sales), in order to focus on option hedging. Table 4.4 and Table 4.3 are similar in the way they were computed; both examined one pricing alternative at a time.

Table 4.4 Changing Put Premiums

CARA Coef.	Put * Prem.	Bushels Put Hdg	Utility	RPANM
-----	-----	-----	-----	-----
.00001	\$.24	0	41.0	0
.00005	.24	1623	245.0	\$2.1
.0001	.24	5843	408.5	232.8
.00001	\$.20	0	41.0	0
.00005	.20	7696	250.2	182.5
.0001	.20	8649	416.9	561.0
.00001	\$.16	18163	48.8	310.8
.00005	.16	14098	262.5	628.3
.0001	.16	11591	427.7	983.3

Put premiums were \$.28 originally. No brokerage fee in these calculations. Annual interest rate on premiums from purchase to liquidation was 10 percent.

When put premiums were lowered to \$.16 they became profitable, and the .00001 risk aversion attitude bought all the Put options possible (2 times expected production). The other more risk averse producers each bought more Puts than expected production, but less the .00001 attitude. This indicates that for the price distribution used, a \$.16 put premium is too inexpensive. Also shown here, is the fact that the decision-makers risk attitude determines whether he or she believes options are fairly priced.

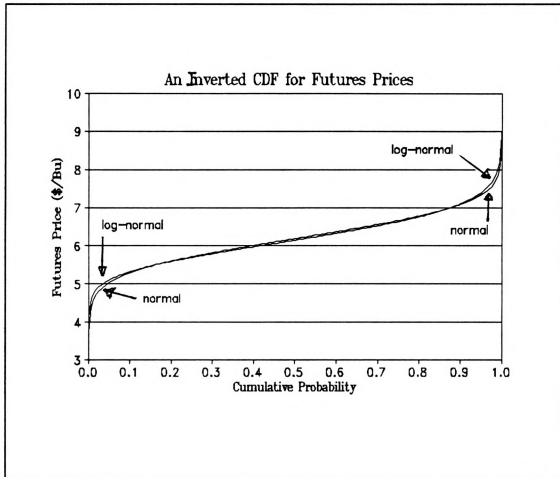


Figure 4.3 Log-Normal versus Normal Prices

4.5 Test 4 - Changing Price Distribution Forms

Fisher Black (1976) developed an "Option Pricing Model" (BOPM) based upon log-normally distributed prices. This research used normal distributions for futures and basis, since some empirical work indicates they are appropriate. This section examines results when prices have three different representations; (1) normal, (2) log-normal, and (3) randomly chosen prices from a normal distribution. Information on how each of these were developed are in Appendix E.

Figure 4.3 shows two distributions of normal and log-normal prices. Values of the two distributions are listed in Appendix E along with the values randomly drawn from a normal distribution. All three distributions are very similar in appearance, but how do they compare in FIRM?

Table 4.5 shows results of tests with transactions costs (i.e. brokerage fees and interest on margin) both included and excluded. In this analysis none of the optimal solutions included option hedging or speculative call positions. The same

Table 4.5 Comparing Price Distribution Functions

Distri- bution	Trans Cost*	ARA Coef.	BUSHEL\$			Utility	PR Above No Mktg (RPNM)
			Forward Contract	Futures Hedge	Basis Contract		
Normal	None	0	0	0	0	-11.2	0
Normal	None	1E-05	2068	6334	1108	49.9	184.5
Normal	None	5E-05	1809	6798	3450	266.4	859.7
Normal	None	.0001	3576	8341	1179	430.6	1404.5
LnNorm	None	0	0	0	0	-11.2	0
LnNorm	None	1E-05	1639	6564	3251	50.0	184.0
LnNorm	None	5E-05	3790	4791	1147	266.6	842.6
LnNorm	None	.0001	619	7957	4129	431.1	1368.8
MCNorm	None	0	0	0	0	-10.0	0
MCNorm	None	1E-05	1648	7747	2998	50.5	205.5
MCNorm	None	5E-05	2301	6460	2664	263.1	796.8
MCNorm	None	.0001	2021	5357	2707	422.5	1045.8
Normal	IM&B	0	0	0	0	-11.2	0
Normal	IM&B	1E-05	6982	0	0	49.6	173.0
Normal	IM&B	5E-05	8068	0	0	265.7	833.4
Normal	IM&B	.0001	7673	0	0	429.5	1362.5
LnNorm	IM&B	0	0	0	0	-11.2	0
LnNorm	IM&B	1E-05	7000	0	0	49.7	172.7
LnNorm	IM&B	5E-05	8221	0	0	265.9	815.7
LnNorm	IM&B	.0001	8040	0	0	429.9	1325.1
MCNorm	IM&B	0	0	0	0	-10.0	0
MCNorm	IM&B	1E-05	7443	0	0	50.0	185.3
MCNorm	IM&B	5E-05	8201	0	0	262.3	769.6
MCNorm	IM&B	.0001	6736	0	0	422.0	1027.1

* "Interest on Margin and Brokerage" were included or not (None).
LnNorm is log normal and MCNorm is Monte Carlo Normal Prices.

CARA risk functions were used, as previously described in this chapter. The basis vector of 200 observations and the yield vectors were unchanged from one price distribution to another. All three futures distributions had means of \$6.1825.

It is easy to see that transactions costs make a bigger change in optimal plans than do changes in the form of the price distributions. With transactions costs included for futures, all optimal plans involve only forward contracting. When transactions costs are excluded futures and forward contracting are similar, except that forward contracting also locks in a basis level and retains a small penalty for over-contracting. Of course these conclusions are based on the pricing relationships used in this test. It should be noted, that from a risk management standpoint, the inclusion or exclusion of transaction costs had minor effects on the utility and the RPANM. Examining Figure 4.4 and Table 4.5 leads to the conclusion that the differences in normal and log-normal price distributions with equal mean (6.1825) and standard deviation (.6983) is very small, and creates only minor differences in optimal solutions in FIRM.

4.6 Summary

In this chapter four tests were performed using different CARA utility functions. Firm performed as expected by showing higher utility and risk premiums for more risk averse utility curves. Tests covered changing price distributions, inclusion and exclusion of transactions costs, changing put premiums, examining all five pricing alternatives as well as each one individually. All tests were done across changing utility functions.

It was shown that the global risk preferrer can be represented by the FIRM model, but that such behavior is not likely to occur. FIRM has nearly 20 data inputs that could be altered to change the model. With the values used in this chapter: (1) more risk averse producers had higher risk premiums above doing no marketing, (2) indicating increased benefit of using FIRM (for more risk averse utility) compared to less risk averse producers. (3) log-normal and normal price distributions gave very similar results as did randomly chosen prices from a normal distribution. All pricing functions worked as expected. Put options came into solution for all producers when premium prices were lowered. When put options and spot sales were the only pricing methods, put options were used by the most risk averse producer. When other pricing methods were available, futures hedging and forward contracting reduced the use of options. This was probably because futures hedging and forward contracting protect the producer from low prices without reducing expected income, as much as options do. Basis contracts offered very little risk reduction compared to futures hedging and forward contracting. This latter observation was expected since basis is such a small part of the total price.

FIRM performed well with well-behaved utility curves. In the next chapter, workshops with soybean producers are summarized and tests are performed with less well behaved utility functions.

CHAPTER FIVE

WORKSHOP RESULTS

5.1	Generating Price Distributions	155
5.2	The Workshop Format	156
5.3	Getting Acquainted	156
5.4	Yields and Probabilities	158
5.5	Estimating Yield Distributions with ELICIT	158
5.6	Crop Costs and Effective Acreage	160
5.7	Running GENRINC	161
5.8	Soybean Outlook and Volatility Forecasting	162
5.9	Estimating Utility Functions with ELRISK	162
5.10	Marketing Solutions	168
5.11	Producer and Presenter Evaluation	171
5.12	Testing Other Utility Curves on a Case Farm	173
5.13	Changing Price Data for the Case Farm	179
5.14	Summary	181

A small group of Michigan Extension Agents, in conjunction with their District Farm Management Agents, were asked to coordinate a local workshop for marketing "new-crop" soybeans. Agents were informed that the workshop was research related and that workshop participants were needed to test microcomputer risk management, marketing software. The target audience of Chapter 3 was described to agents, for agents who wanted to select the audience. At least one of the workshops was open to the general public, because the agent did not want to exclude anyone. Another agent made personal contacts by mail and phone. One workshop was held in August 1989 to examine October 1989 sales, and the other three workshops were held in January and February of 1990 to examine October 1990 pricing alternatives. The title of the workshops was "How to Price Pre-Harvest Soybeans and How Many Bushels to Price In Order to Manage Risk."

5.1 Generating Price Distributions

On the night before each workshop, the coordinators created the random price distributions. The Hilker and Black (1988) Option Pricing Model (OPM) was used to solve for implied volatility of the futures price distribution, and the closing futures price was the expected value of the distribution. November CBOT Option Premiums on the strike closest to being "at-the-money", were assumed to be efficiently priced. The best basis in the area of the workshop was set to the expected value of the basis distribution, and the standard deviation was subjectively estimated to be 10 cents per bushel.

The means and standard deviations were entered into a program called F&BDIST.EXE, that is capable of making bivariate normal distributions for basis and

futures. Correlations for all four workshops were set to zero for consistency. This made basis and futures independent.

Futures and basis prices were created and copied onto each workshop computer. Based on market information and closing prices, the PRICE.DAT file was also updated on the evening before each workshop. PRICE.DAT contains option premiums, strike prices, the closing futures price for November soybeans, current contract prices, interest rates, transactions costs, and other default inputs to the FIRM model. Each of the values in PRICE.DAT can be revised by the workshop participants.

5.2 The Workshop Format

WORKSHOP SCHEDULE

9:00	Coffee and Donuts (get acquainted)
9:15	A Brief Overview of the Program - Steve and Rich
9:30	Presentation on Yields and Probabilities - Rich
	Run ELICIT Software for Soybeans Yields - Jim
	Fill Out Crop Costs Worksheet - Steve
	Generate Income Distributions - Rich
10:30	Ten Minute Break
10:40	Soybean Outlook and Volatility Forecast (including basis forecast) - Jim
11:00	Risk Attitudes (based upon income distributions) - Rich
	Run ELRISK Software
Noon	LUNCH
1:30	Solve Individual Marketing Plans Under Base Assumptions
3:00	Discussion and Evaluation
3:15	Adjourn

5.3 Getting Acquainted

Workshops were advertised to start at 9:00, but attendees did not know that a special "get acquainted" period would begin the meeting. To get acquainted with the 29 workshop attendees, it will be helpful to study Table 5.1. These Michigan

producers were from seven different counties and represented a spectrum of ages, farm types, education levels, and soybean acreage. The 29 farms produced over 10,000 acres of soybeans. The largest soybean acreage was 810 acres and 77 was the smallest.

Table 5.1 Producer Data

Descriptive Farm Data					Descriptive Farm Data				
Code	Age	Yrs farm	Soy Ac.	Soys as % Inc.	Code	Age	Yrs farm	Soy Ac.	Soys as % Inc.
FRA1	47	21	810	40	MON5	37	10	98	20
FRA2	40	22	420	30	MON6	50	30	500	50
FRA3	45	45	85		MON7	36	18	630	35
FRA4	46	26	77	10	MON8	37	19	300	5
FRA5	50	31	300	30	MON9	50	34	575	30
FRA6	52	30	350	20	MON11	49	30	120	18
FRA7	40	18	420	30	MON12	42	20	225	
FRA8	49	27	700	33	MON13	32	20	500	50
CAL2	34	17	320		MON14	26	5	347	45
CAL3	25	6	250	40	SHI1	35	17	629	55
CAL4	44	22	160	45	SHI2	46	28	187	38
MON1	40	18	400	20	SHI3	65	40	162	30
MON2	38	18	480	25	SHI6	63	45	190	40
MON3	38	19	605	29	SHI7	80+		200	
MON4	29	20	350	20					

It should be noted that two of the producers listed in Table 5.1 were actually family teams. Also, one farm couple chose to make their analyses separately and thus represent two producer observations. Acreage and percent of income from soybeans varied substantially among the attendees, as shown in Table 5.1.

Following the "get acquainted" time was an overview of the program and the schedule. The schedule was printed at the start of the three page program. The

entire program is reprinted in Appendix B. The three page program was the outline for the presentation of the overview.

5.4 Yields and Probabilities

Following the overview, was a presentation on yields and probabilities with a very basic introduction to probability density functions (pdf's). All distributions that producers examined were discrete pdf's. It was explained that yields and yield uncertainty were important factors in preharvest marketing. The example of "over-contracting" due to a drought was discussed. There was short discussion of how an uncertain futures, plus and uncertain basis formed an uncertain price, and that the uncertain price could be multiplied by an uncertain yield to give an uncertain income per acre.

Producers were asked to consider that no other marketing had taken place, and that all farmers would be considering harvest-time delivery. This helped place all farms in a more comparable situation. It also reduced the data and calculation requirements for prices commitments in other ending time periods.

5.5 Estimating Yield Distributions with ELICIT

Table 5.2 shows the mean and standard deviations of yield for each producer, as they entered beliefs into ELICIT. Producers were asked to consider a planting time yield forecast, so that all distributions would reflect a similar time period. Producers seemed to understand this. There were few sources to prove any inaccuracy on the part of the producers. Pease (1987) pointed out that using an anchoring method for

elicitation leads to an over-confidence in the mean, and less dispersion than what "really" exists. Workshop attendees were encouraged to examine their graphical pdf solutions, and return to the input section of the software, before exiting ELICIT. This was a useful feature of ELICIT that should have helped managers reconsider yield variability.

Table 5.2 Workshop Summary for GENRINC and ELICIT Results

Code	Soy Ac.	Cost/ acre	Cost/ bush	Mean G.M.	StDev G.M.	E(Yld)	Stdev Yld *
FRA1	810	93.14	0.18	99589	37178	41.0	7.92
FRA2	420	79.21	0.19	65342	24514	44.6	10.10
FRA3	85	74.30	0.11	10632	4723	37.3	9.95
FRA4	77	86.00	0.12	10035	4096	40.7	9.69
FRA5	300	75.00	0.10	41729	17012	40.0	10.07
FRA6	350	57.00	0.10	57698	24999	41.8	12.93
FRA7	420	79.00	0.19	62226	21402	42.5	8.86
FRA8	700	90.00	0.18	88000	38240	41.0	9.76
CAL2	320	75.00	0.23	46180	15451	37.2	6.29
CAL3	250	57.00	0.30	38122	11280	36.8	6.85
CAL4	160	84.00	0.20	27337	8550	43.3	6.90
MON1	400	136.00	0.32	32086	28949	37.7	10.61
MON2	480	66.00	0.48	7532	25943	40.6	7.85
MON3	605	89.00	0.43	81269	31319	39.9	9.11
MON4	350	100.00	0.40	52708	18256	45.0	7.59
MON5	98	53.00	0.45	20146	4280	45.9	5.80
MON6	500	168.00	0.36	44997	27767	44.8	7.80
MON7	630	96.00	0.44	72383	26095	37.5	6.01
MON8	300	114.00	0.48	44054	1345	47.7	6.21
MON9	34	77.00	0.37	107202	36709	44.7	7.71
MON11	120	73.00	0.40	19394	5563	38.9	7.48
MON12	225	91.30	0.40	38934	9737	46.6	4.71
MON13	500	66.00	0.47	81756	25653	40.1	7.43
MON14	347	84.38	0.50	47551	18888	40.0	8.59
SHI1	629	75.00	0.10	76354	30307	35.3	7.14
SHI2	187	68.06	0.18	23666	7486	35.6	6.24
SHI3	162	73.50	0.10	18638	6966	33.5	5.50
SHI6	190	71.85	0.06	22113	8063	33.6	5.41
SHI7	200	95.00	0.10	22140	8004	36.6	4.59

* Expected yield and standard deviation are from ELICIT output.

Workshop coordinators felt that 40 to 60 percent of the producers did back up and make changes in yield intervals. Roughly half of those who re-entered values, made substantive changes affecting the mean and/or standard deviation. These estimates are from workshop coordinators, but they point out the care that producers took in constructing their yield pdf's.

Conditional Normativists would say that regardless of the "truth," these are the beliefs (subjective probabilities) from which decision-makers are acting. That statement is only true if the elicitation method is transparent; that is, having no affect on producer's beliefs. Additionally, producers need some experience to form probabilities and retain confidence in them.

Once each producer had run ELICIT, a **.PRB* file was created and stored to the hard disk in the microcomputer. The *** is the portion of the filename entered by the workshop attendee. A listing of yield pdf's can be found in Appendix D. All workshop participants also printed out their pdf's for soybean yields, revealed through ELICIT. This was the first computer exercise at each workshop and many of the workshop attendees had never used a microcomputer.

5.6 Crop Costs and Effective Acreage

The program contained sample crop budgets for 30 bushel per acre yield goal and 40 bushel per acre yield goal for 1990-91 soybean production (see Appendix B). Per acre items in the budget included seed, fertilizer and lime, chemicals, fuel and repairs, labor and miscellaneous, and interest on the above until harvest. Per bushel variable costs include harvest, transport, drying, and other. Each producer was asked

to create their own budget, based upon the format in the program. A few producers included land rent, but most did not.

Producers were reminded that the costs and gross revenues would create a gross margin value. Such a value will likely be positive, but does not cover all enterprise costs, such as land, operator and family labor, capital investment in machinery, and more. Producers were asked to keep this in mind and to think about goals for the gross margin levels they would reasonably hope to receive.

A short worksheet was built for considering different land rental arrangements. To simplify matters, producers were asked to multiply the number of share-rent acres times the percent of their share, to get effective shared acres. These were added to cash rent and owned land, to get total effective soybean acres (see Appendix B).

5.7 Running GENRINC

The input for GENRINC is rather simple and is listed below:

What filename contains the ELICIT data (Enter only characters left of the decimal)?	SOYS
How many Monte Carlo observations should be run?	200
How many acres are planted to soybeans?	250
Costs PER ACRE that you wish to consider?	\$57
Costs PER BUSHEL you wish to consider?	\$.30

The producer is prompted by the computer to answer five questions shown above. GENRINC outputs a vector of Monte Carlo Observations to a file that is automatically named "BUANDINC.DAT." At the bottom of the file are summary statistics for production and gross margin. The summary statistics for production and gross margins are also printed to the screen after GENRINC is done running. The Monte Carlo values of production and costs, that were stored to file, are used later by

MKTOPT, while the summary statistics seed the starting values for eliciting risk attitudes in ELRISK.

5.8 Soybean Outlook and Volatility Forecasting

This section of the program included a fundamental analysis of USDA supply and demand for new crop soybeans. Following the fundamental analysis was a presentation and discussion of the efficient market hypothesis. Farmers at the workshops conducted were not entirely comfortable with the efficient market hypothesis, but admitted that they had little chance of "beating the market" over an extended period of time. One farmer pointed out that if he could arbitrage the market, he could quit farming and speculate in commodities for a living.

This section ended with a description of how price distributions were formed using an OPM. Producers were told the market location and basis distribution. Since all of these prices were entered onto the workshop computers, there were no calculations for producers, or data to enter in this section. A sample price distribution was sorted (for a CDF) and is listed in Appendix E.

5.9 Estimating Utility Functions with ELRISK

At each workshop, ELRISK was demonstrated with sample farm data, before producers ran their own situations. Extra effort was made to focus on the process, rather than the sample data. The emphasis was on making sure producers first decided which marketing plan (A or B) they preferred. Once they decided which plan they preferred and entered an answer, the software recommended whether they should revise elicitation up or down.

All 29 producers in the workshop were able to operate the ELRISK software (after seeing it demonstrated), but some needed more assistance than others. Initially managers wanted to edit more than one cell, in order to make Plan A and Plan B equally preferred. Perhaps 3 or 4 people had enough difficulty that they started over. None of the producers seemed to have ever used an ELRO method of risk elicitation before. Each producer played 9 to 13 games. Some persons worked faster and more decisively, while other producers carefully pondered each situation. ELRISK stored each keystroke entered, including those when backing up. Some of this information could be analyzed in further behavioral research, but its main purpose was for trouble-shooting problems that users could have had in elicitation.

Data from the 29 discrete utility functions elicited are summarized in Table 5.3 in order of risk attitude, from risk neutral at the top, to most risk averse at the bottom. Following the workshops, data from each individual was fitted to the negative exponential utility function.

The far right column of Table 5.3 (CARA, $R(x)$) was solved using non-linear regression, when solving the negative exponential utility function. The negative exponential function is $U(x) = k - a \cdot \text{EXP}(-b \cdot x)$ where x = income and a, b, c, k are constants of regression. The quadratic function is $U(x) = k + a \cdot x + c \cdot x \cdot x$ and the semi-log is $U(x) = k + a \cdot \text{LN}(x)$ (and x must be greater than 0).

The negative exponential function was fitted using a modified Box's Complex, (non-linear search routine) with an objective function to minimize the sum of squared error between the fitted and the research data. The negative exponential function is commonly used in empirical work as well as theory. One measure of risk is the absolute risk aversion $R(x) = -U''(x)/U'(x)$. For the negative exponential function, this



R(x) value is constant and equal to b in the equation shown in the previous paragraph.

Table 5.3 Function Evaluation in CARA Order

USER	----- r ² values -----				CARA, R(x)
	NEGATIVE EXPONENT	LINEAR	QUAD	SEMILOG	
MON13	NA	<u>1.000</u>	1.000	.931758	0
FRA8	.972151	.980680	<u>.991503</u>	.456601	0.000002
FRA6	.981886	.980501	<u>.982205</u>	.756708	0.000003
MON12	.987494	.987507	<u>.987890</u>	.977658	0.000009
MON3	.989913	.915625	.979585	<u>.995698</u>	0.000017
FRA1	<u>.996183</u>	.865203	.980685	.985124	0.000018
MON1	.961897	.930499	.956556	<u>.974156</u>	0.000024
FRA2	<u>.996954</u>	.908581	.991213	.989488	0.000024
MON4	.993433	.935317	.985698	<u>.997972</u>	0.000024
SHI1	<u>.988731</u>	.868287	.966161	.970580	0.000028
MON2	<u>.981150</u>	.863456	.962666	.950985	0.000031
MON14	.989108	.936740	.982139	<u>.992106</u>	0.000031
MON9	<u>.983787</u>	.871433	.959733	.935131	0.000035
CAL3	<u>.994405</u>	.932073	.988513	.990281	0.000042
MON6	<u>.967589</u>	.840537	.930279	.946161	0.000042
FRA5	<u>.974626</u>	.840972	.942543	.965365	0.000048
MON8	<u>.994565</u>	.900257	.981346	.970757	0.000053
MON7	<u>.976526</u>	.777136	.931139	.885739	0.000057
FRA7	<u>.962971</u>	.810394	.922116	.896759	0.000064
CAL2	<u>.952248</u>	.873173	.932353	.920276	0.000071
CAL4	<u>.989818</u>	.904731	.977411	.977964	0.000071
MON1	<u>.965596</u>	.940867	.958683	.965567	0.000087
SHI6	<u>.973757</u>	.920799	.962540	.970512	0.000095
SHI3	<u>.974707</u>	.922686	.965213	.971865	0.000115
SHI2	<u>.869241</u>	.802432	.854719	.844191	0.000119
MON5	<u>.956746</u>	.922310	.949118	.947446	0.000128
SHI7	<u>.912430</u>	.786505	.910180	.886192	0.000146
FRA4	<u>.983675</u>	.857501	.954866	.953484	0.000267
FRA3	<u>.985868</u>	.703571	.882362	.883265	0.000352

One producer exhibited perfect risk neutral behavior, while three other producers were very nearly risk neutral. This conclusion is based on the observation that linear r^2 values were quite high for the top four producers in Table 5.3. The fifth individual (MON3), showed higher r^2 values in the other functions than in the linear one. The remaining soybean producers show various degrees of risk aversion. They

are listed in order of least risk averse (smallest $R(x)$) to most risk averse (largest $R(x)$). Underlining is used in Table 5.3 to indicate the highest r^* functional form for each producer.

It is difficult to compare the CARA coefficients across different research. While the CARA is independent of the value of the x variable, the x 's must be similar in nature and measured in the same units. This study examined risk attitudes on annual gross margins related to soybeans. Using whole-farm income, per acre measures, or any other x to measure performance, changes the problem since x is not held constant from one project to another. However, since all other empirical work reviewed attempted to summarize and compare producer risk behaviors, it seems only fitting to try.

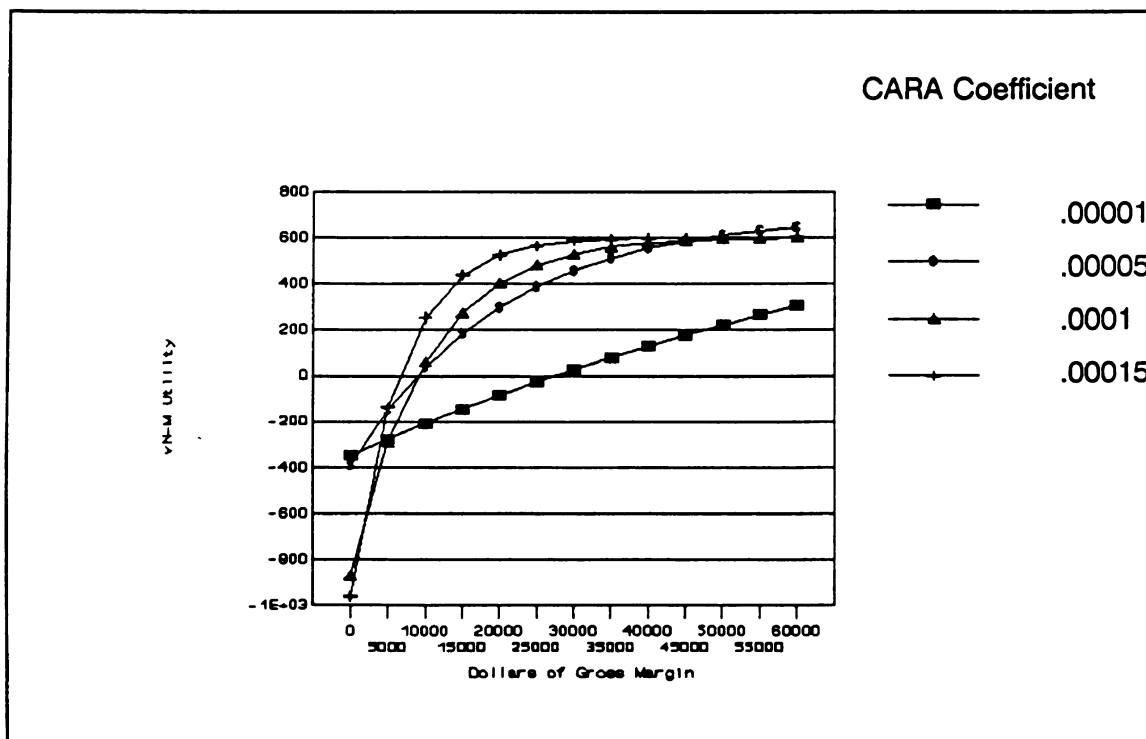


Figure 5.1 Negative Exponential Functions

Studies using the interval approach to elicitation usually categorize risk neutral as having a CARA of -0.0001 to 0.0001 . These include King and Robison (1981), Thomas (1987), Wilson and Eidman (1983), Tauer (1986) and others. Using this range, all but six producers in this study would be risk neutral. In Figure 4.5 there are four negative exponential functions for a situation where the second standard deviations below and above the mean are \$0 and \$60,000. The curve marketed by the small triangles is $R(x) = 0.0001$. It hardly seems risk neutral.

Rister et al. (1984) categorized -0.00001 to 0.00001 as risk neutral when analyzing annual grain storage. These figures more closely match those in this study. Ramaratnam et al. (1986) also found the negative exponential function to be superior in their sample of 23 farmers. In their study, the CARA values ranged from 0.0000026 to 0.0000135 . Because Rister et al. (1984) and Ramaratnam et al. (1986) were dealing with different crops and income measures this limits the degree to which they should be compared. Their measures were less risk averse than most producers in this research.

Based on Figure 5.1, and the values of $R(x)$ in Table 5.3, we can conclude that risk neutral producers (4 of them) were $0 \leq R(x) < 0.00001$, while moderate aversion (23) occurred where $0.00001 \leq R(x) \leq 0.00015$ and two producers were found to be very risk averse.

An added conclusion from Table 5.3 is that the negative exponential function is best, of the functional forms tested, for the 29 producers. Even risk neutral functions that approached linearity had good r^2 values when fitted to the negative exponential function. The only exception is when the utility function is strictly linear. The negative exponential utility function approaches linearity asymptotically, but cannot become

strictly linear and upward sloping at the same time. For this reason, the strictly linear case was not fitted to the negative exponential function.

In examining the data on risk aversion and gross margin, it appeared that a strong negative correlation existed, suggesting that larger farmers were less risk averse than smaller farmers (*ceteris paribus*). One explanation for this is that the standard deviations for large farms are larger, and that only less risk averse producers could accept such large risks. Using Borland's Quattro Pro™, an ordinary least squares regression was performed. The dependent variable was the CARA coefficient of the 29 producers and the independent or explanatory variable was the expected gross margin (EGM). The estimated equation was $CARA = K + (-1.8E-9)EGM$, where K is the y-axis intercept, the standard error was 4.53E-10, and the t-statistic was -3.93 (very significant). Thus larger producers are predicted to have smaller CARA (less risk averse). The r^2 for the equation was .414, which is relatively high for a cross-sectional analysis.

Correlations between gross margin and the CARA coefficient do not indicate that producers are Decreasing Absolute Risk Averse (DARA) in their behavior. Time series data for a particular producer would need to be collected, especially since the performance variable is indirect income from a crop. In the simple linear regression performed, there should be no causation implied. Perhaps less risk averse producers become larger farmers, due to their risk neutrality. Intuition says that an 800 acre soybean farmer would need a nearly risk neutral behavior. Such a large problem would be too risky for a more risk averse producer.

The workshop experience also allowed for evaluation of the model performance. ELRISK was intended to elicit risk attitudes from the second standard



deviation below the mean gross margin up to the second standard deviation above the mean (or beyond). The reason for this, is that points on the utility curve are used in a table-lookup function to convert from gross margin to utility. Monte Carlo gross margin values beyond those in the utility curve were extrapolated (linearly) from the last two endpoints. For MKTOPT to function, it is best to get a utility function that covers as much of the gross margin distribution as is practical.

ELRISK was largely successful at surpassing the second standard deviation above the mean. Only six times were the highest user values below the mean plus two standard deviations. ELRISK did not perform as well on the lower end of the gross margin distribution. Was the expectation unreasonable on the lower end? Are improvements needed in ELRISK or ELRO methods, or is it unreasonable to think that producers should feel the same way (marginally) about incomes that are two standard deviations below the expected?

The methods used gave mixed risk attitudes when examining values in the neighborhood of \$0.00 gross margin. Cochran et al. (1990) noted that when elicitation reaches certain biases areas, such as zero, this can effect the elicitation. One other weakness of the elicitation method used, (common to many elicitations) is serial dependence. This occurs in the ELRO method, when previous answers are used to build new situations. For example: a person may transpose two digits in their response, and not realize their mistake. Such a mistake affects subsequent elicitations. Fortunately, ELRISK allows the decision-maker to back up and revise previous input values.

5.10 Marketing Solutions

There are five groups or types of data, that directly resulted from field testing. The first type of data is the subjective pdf for yields. These were summarized in Table 5.2 and available in Appendix D. The second group of data is results of risk measurements taken with ELRISK. These were discussed in Section 5.9 and are presented in Appendix C. Third are the marketing alternatives that each producer received from running the programs (the farmer results). These are discussed in this section. The fourth and fifth types of data are producer and presenter workshop evaluations (discussed in the next section).

Since the workshops were conducted using microcomputers, each producer's input was stored to disk, reducing the data collection problems. These same data saves were also needed for the model to function correctly. The output for each farmer included the best 15 marketing plans from the MKTOPT program. This output was both printed and stored to file. In fact, several producers ran MKTOPT more than once to change data inputs.

Summarizing the best 15 plans for each of the 29 producers was not simple. When solutions were reduced to a single marketing plan, the sensitivity of the solution was lost. This is particularly true with risk neutral persons and slightly risk averse producers. Due to unintentional biases in measuring market volatility, options seldom came into solution for any producers at significant levels (more than 1% of expected production). Producer solutions were converted from bushels to be marketed, into percentages of expected production. This helped reduce the farm size effect of each marketing plan.

Table 5.4 Summary of Producer MKTOPT Results

Portions of Expected Production								
USER	FORWARD CONTRACT	FUTURES HEDGE	BASIS CONTRACT	CARA R(x)	E[Bu.]	RISK* PREM	ACRES	RP*/ Acre
MON13	.000	0	.053	0	20503	\$ 0	500	\$0
FRA8	.732	0	.209	.0000016	28670	104	700	.15
FRA6	.867	.019	0	.0000032	14653	238	350	.68
MON12	.542	0	0	.0000087	10462	448	225	1.99
MON3	.119	0	0	.0000170	24023	127	605	.21
FRA1	.078	0	0	.0000183	33213	2233	810	2.76
MON1	.756	.323	0	.0000236	14945	758	400	1.90
FRA2	.489	.130	0	.0000238	18737	455	420	1.08
MON4	.852	0	0	.0000239	15427	1709	350	4.88
SHI1	.618	0	.014	.0000284	22039	2873	629	4.57
MON2	.759	0	.013	.0000306	19133	2542	480	5.30
MON14	.554	0	.015	.0000311	13772	382	347	1.10
MON9	.845	.292	0	.0000350	26438	10212	575	17.76
CAL3	.500	0	0	.0000415	9082	373	250	1.49
MON6	.796	0	.034	.0000420	22582	781	500	1.56
FRA5	.331	.463	.134	.0000479	12008	667	300	2.22
MON8	.771	0	0	.0000526	13988	1401	300	4.67
MON7	.570	.016	.026	.0000571	23593	5521	630	8.76
FRA7	.308	.284	0	.0000640	18121	2484	420	5.91
CAL2	.715	0	0	.0000709	11992	1909	320	5.97
CAL4	.807	0	.019	.0000709	6928	668	160	4.18
MON11	.466	0	0	.0000868	4975	443	120	3.68
SHI6	.790	0	.062	.0000947	6321	1858	190	9.78
SHI3	.734	0	0	.000115	5450	923	162	5.70
SHI2	.586	0	0	.000119	6603	140	187	.75
MON5	.371	.058	0	.000128	4506	611	98	6.24
SHI7	.693	0	0	.000146	7336	2198	200	10.99
FRA4	.207	.030	.435	.000267	3133	130	77	1.69
FRA3	.601	.245	.018	.000352	3172	261	85	3.07

* RP is Risk Premium Above doing No Marketing (RPANM).

Table 5.4 shows that forward contracting was the major pricing instrument selected. Forward contracting was very similar to futures hedging in the model, except for two differences. First, the basis was uncertain with futures hedging. Second, when producers over-contracted they had to pay a \$.05/bushel penalty to buy back additional grain to meet contract obligations. This user adjustable value called ASK-BID, was set at \$.05/bushel. The ASK-BID spread could represent any per

bushel penalty for not meeting cash contract obligations. It further separates the characteristics of the two pricing methods. Most farmers at the workshops did not adjust the ASK-BID spread.

There were few pricing patterns among the producers listed in Table 5.4. The producers are listed in reverse order of their risk aversion. Those with the smallest CARA coefficients (least risk averse) are at the top, and the most risk averse are listed at the bottom. Even though price variability was the same for all producers, there was considerable difference in their means and standard deviations of gross margins. There were also differences in yield distributions, acreage, variable costs, and costs per bushel. The smaller the per bushel costs and/or the smaller the yield variance, the less variability in gross margin.

Several producers had sizeable "Risk Premiums Above doing No Marketing" (RPANM), indicated in the seventh column (Table 5.4). Placing these values on a per acre basis, put them in clearer perspective by reducing farm size effects. The monetary value of the workshop to five producers was less than one dollar per acre. For these decision-makers, the workshop had little risk-management benefit, except for educational value. Thirteen producers indicated RPANM of more than \$5 per acre. The workshop was worthwhile to these persons if they followed some of the suggestions presented by the FIRM model, and if they revealed their risk attitudes accurately.

5.11 Producer and Presenter Evaluation

Producers were given an evaluation form at the start of each workshop. Every producer but one completed the form. The results are summarized in Table 5.5.



There was also additional space on the worksheet for open comments. A copy of the evaluation forms are in Appendix B and the unstructured comments offered by twenty of the producers are in Appendix A.

Table 5.5 Producer evaluations

WORKSHOP EVALUATION:	Needs		
	<u>Good</u>	<u>Fair</u>	<u>Improvement</u>
1. Program overview	26	2	0 *
2. ELICIT yield distributions	20	5	1
3. Market outlook & volatility	20	6	1
4. Risk preference elicitation	15	10	2
5. Finding optimal marketing strategies	14	12	1
* Totals across are not 29, because of missing data. Numbers indicate occurrences of each response.			

Most producers indicated the workshop was worthwhile, interesting or gave a positive description (11/20). A number of producers made suggestions for improvements (9/20). One or two suggested making things simpler, while others had more specific suggestions. One workshop attendee expressed doubt about the potential success, but enjoyed the day. One producer felt the day might have been a waste and he would never use this kind of software. Finally, there was a person who simply asked a question about how FIRM related to market fundamentals.

Several managers made the observation that the solution from MKTOPT was similar to rules of thumb they had heard in the past. This was a comforting

observation to workshop presenters. There was a slightly bigger group who felt that the recommendations were a little aggressive (more forward pricing than they preferred).

After each workshop, time was spent evaluating the workshop accomplishments among the workshop presenters, as well as among the extension hosts. Most of the tone was guarded optimism, and like the producers, there were several ideas about how the workshop model of FIRM could be improved.

Ideas were also exchanged with producers who lingered, following the workshop. At least three or four producers suggested that a price "trend" could be entered along with the efficient market assumptions about mean and market variance. This contradiction of ideas turned out to be a tremendous teaching moment for forming market expectations.

In Harsh and Alderfer (1990), they wrote that:

Based upon the experience gained in these workshops, the package needs minor refinement and features added. It appears that FIRM is a valuable workshop tool to teach risk principles and management. The marketing alternatives suggested to the producers were found to be very acceptable. The producers were able to use the various software models and thus they felt the workshop was a valuable learning exercise.

5.12 Testing Other Utility Curves on a Case Farm

Earlier in this chapter marketing plans were specific for individual producers and their risk attitudes. The solutions depended on changes of the input data. In this section, changes to the model and the data set will be more systematic for more controlled testing of the model. This section is much like some of the tests in Chapter 4, except rather than constructing five synthetic utility functions, we will focus on 5 empirical functions gathered at the workshops.

Table 5.6 Static Data for Producer CAL3

PARAMETER VALUES FOR THIS RUN

The upper constraints for
 Forward Contracting = 18163.13
 Futures Hedging = 18163.13
 Put Hedging = 18163.13
 Basis Contract = 18163.13
 Speculative Call = 18163.13

 Today's month is 1
 The contract month is 11
 The unbiased Futures price is (\$/bu) 6.1825
 The forward contract price is (\$/bu) 6.08
 The Price of a basis contract is (\$/bu) -.1
 The Call premium is (\$/bu) .44
 The Strike for the Call is (\$/bu) 6
 The Put premium is (\$/bu) .28
 The Strike for the Put is (\$/bu) 6
 Round trip trans. costs for futures (cents/bu) = 1.5
 ONE-WAY trans. costs for options (cents/bu) = 1.5
 Margin costs per bushel on futures (\$/bu) = .30
 Margin costs per bushel on options (\$/bu) = 0
 The ANNUAL interest rate is 10.000
 The cash elevator spread for ASK - BID is (\$/bu) .05

The base farm for testing in this chapter is CAL3. This 250 acre soybean farm expects to produce 36.8 bu./acre for an expected gross margin of \$38122. Static pricing data is listed in Table 5.6 for CAL3.

The tests in this section are the type that could have been performed without conducting workshops, except that they use workshop data. These tests involve slight changes in the model or data, from a particular reference point. The next section involves such a test on producer utility functions and their effect on marketing

recommendations. The primary purpose of the test is to examine whether discrete or fitted utility functions should be used to represent the decision-maker's risk attitude.

The CAL3 farm was re-run with the same costs, prices, probabilities and stochastic production with only two slight changes in the model. The change involved setting all of the control variables except forward contracting to zero. This constriction of a single marketing alternative allows easier comparisons across producers. The second important change was the use of three classes of utility functions.

The first type of utility function was the discrete data from four of the workshop attendees, as well as the case farm. These five producers all had utility curve endpoints extending beyond (or very close to), the second deviation above and below the expected gross margin of CAL3. The range to cover for CAL3 was \$15,500 to 60,600. Figure 5.2 shows the discrete points elicited from the farmer (FRA5) as well as the fitted negative exponential function. Graphs of the other four discrete curves are listed in Appendix C.

Each of the 5 producers in Table 5.7 were similarly fitted to negative exponential functions in the manner done in Figure 5.2. The result is three utility curves for each of five producers. The first curve (Curve 1) for each producer is the original discrete curve used in optimization, in the table-lookup function. These curves have between 9 and 13 observations (pairs of values) for income and utility. In Figure 5.2 these discrete values are represented by small boxes that are connected by lines. The lines between boxes are the linear interpolations used in conversion of \$ to utility (and back).



Table 5.7 Utility Value Coordinates for Five Farms

UTIL	FRA6	MON14	CAL3	FRA5	MON8
----	-----	-----	-----	-----	-----
-500		14000	18000	13000	22000
-400		17000	19000	14000	24000
-300	2000	18000	20000	16000	26000
-200	12000	19000	22000	18000	28000
-100	20000	25000	25000	22000	30000
0	40000	28000	28000	30000	32000
100	44000	31000	31000	40000	36000
200	49000	38000	35000	56500	40000
300	55000	43000	40000	75000	48000
400	65000	55000	45500	100000	56000
500	75000	63000	52000		66000
600	90000	70000	59000		74000
700	105000	79000	68000		
CARA	.000003	.000031	.000042	.000048	.000053
r ² *	.9819	.9891	.9944	.9746	.9946

* Correlation of fitted to actual data values for negative-exponential utility functions.

The second curve (Curve 2) for each producer is also discrete, with the same number of observations as the elicited discrete curves. The difference is that these points are from the best fitted negative exponential function. Like the first curves, these curves were linearly extrapolated between points for conversion of \$ to utility. Figure 5.2 shows this fitted discrete "curve."

The final curve (Curve 3) is smooth and continuous, using the fitted negative exponential function directly, with no linear interpolation. The inverse of the function was used to solve for certainty equivalents (\$), from expected utility. Curve 3 is not graphed in Figure 5.2 since it would be almost exactly on top of the fitted discrete curve.



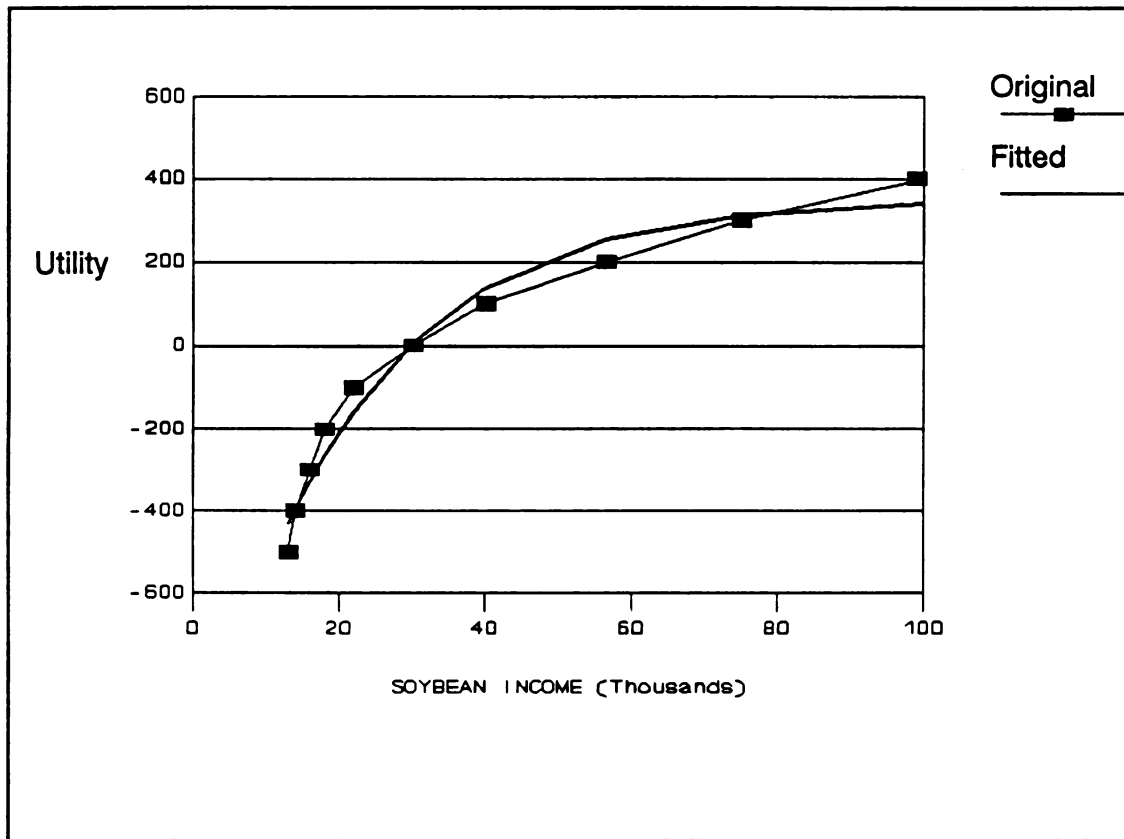


Figure 5.2 Discrete and Fitted Utility Curves for FRA5

It was expected that there would be very little difference between fitted discrete functions and using the smooth continuous function. In fact, the differences between these two represent the difference in error between a smooth function and the discrete one. Also, with risk averse behavior, the expected utility should be higher as the straight lines between utility become arcs. Thus, the local risk aversion was changed from risk neutral along the line segments, to be locally more risk averse. It was expected that discrete utility curves with poor r^2 values for the non-linear function, would have more changes in amounts marketed when moving from one type of utility curve to another.

Table 5.8 Comparisons of Utility Functions

BU TO FORWARD CONTRACT						
USER	R ²	r(x)	Curve1 Direct	Curve2 Discrete	Curve3 Fitted	
-----	-----	-----	-----	-----	-----	
FRA6	.98188	.000003	0	5196	5088	
MON14	.98011	.000031	6054	5828	5577	
CAL3	.99441	.000042	4343	6278	5515	
FRA5	.97463	.000048	4070	5422	5364	
MON8	.99456	.000053	6822	6523	5302	

UTILITY			RISK PREM ABOVE DOING NO MARKETING			
USER	Curve1 Direct	Curve2 Discrete	Curve3 Fitted	Curve1 Direct	Curve2 Discret	Curve3 Fitted
-----	-----	-----	-----	-----	-----	-----
FRA6	45	82.1	82.4	0	21.2	23.1
MON14	174.4	178.1	180.0	272.4	287.5	312.8
CAL3	205.1	213.7	225.3	373.2	398.8	411.6
FRA5	55.4	81.4	85.6	674.4	391.1	469.8
MON8	68.9	59.2	63.9	586.0	441.1	511.4

In Table 5.8, several patterns did emerge. The differences between Curve 2 and Curve 3 in both the utility section and the risk premium sections were uniform in their direction of change. As expected, smoother functions increased expected utility and the RPANM. The changes in Curve 2 and Curve 3 in the marketing section were uniform. The average absolute change in the number of bushels marketed was 480 bushels per farm, when moving from Curve 2 to Curve 3. The change in risk premium for such small changes in marketing can be very small (depending on the $R(X)$ of the function. This can be seen in the nearly risk neutral producer (FRA6). The FRA6 marketing plans increased from zero forward contracting to 5196, while the RPANM changed very little. The change in forward contracting levels between Curve 1 and

Curve 2 were sizable, but the nearly risk neutral producer (FRA6) was responsible for much of the difference, even though the change in risk premiums were small.

Figure 5.2 shows why the FRA5 producer had big risk premium changes between curve 1 and curve 2. The FRA5 bushels marketing (curve 1) and the curve 1 RPANM also seem a little high. The fitted curve across the first six observations of FRA5 at first "under" estimates the utility curve, only to later over estimate it. The net result is that below the $U(\$) = 0$ point, incomes on the fitted line give less utility and above that point they give more utility (than Curve 1). FRA5 had the poorest fit to the negative exponential utility function of any of the five producers in Table 5.8. Fortunately, less than one third of the producers had r^2 values lower than the FRA5 producer, and most of these poorer fitting functions involved much higher risk averse behavior.

One possibility that was not examined is the use of a smoothing function to convert the 10 to 13 discrete producer values into a larger number of smoother coordinate values. Smoothing functions should be a final recourse for the program design since the system designer loses some control or understanding of the system.

5.13 Changing Price Data for the Case Farm

The next three tests are changes in ending period distribution of futures and basis. The case farm (CAL3) is again used as a starting point along with utility functions from a nearly risk neutral producer (FRA6) and a producer (MON8) who is slightly more risk averse than CAL3.

Table 5.9 Testing Futures Price Biases

BEST MARKETING PLANS								
USER	Frwd Cont.	Futures Hedge	Put Hedge	Basis Cont.	Spec. Call	Expectd Utility	Risk Prem Above doing No Mrktng	Descri -ption
=====	=====	=====	=====	=====	=====	=====	=====	=====
FRA6	0	0	0	0	0	38.9	0.	Low Bias
CAL3	6425	0	0	0	0	201.8	658.8	E[futures]
MON8	8257	0	0	0	0	68.0	996.9	minus \$.05
FRA6	0	0	0	0	0	45.0	0.	
CAL3	4541	0	0	0	0	205.1	372.6	Base
MON8	6554	0	0	0	0	68.8	584.5	(no bias)
FRA6	0	0	0	0	0	51.0	0.	Hi bias
CAL3	2478	0	0	2421	0	211.7	180.9	E[futures]
MON8	4541	0	0	0	0	71.6	262.6	plus \$.05

Table 5.9 above shows systematic changes in the ending distribution for futures contracts. Each of the 200 Monte Carlo observations were lowered by \$.05 in the top three rows, held constant in the middle, and in the last three rows raised by \$.05. This bias between today's futures price of \$6.18 and \$.05 higher or lower is a violation of the efficient market hypothesis, but shows how persons with a biased view of the market would behave.

Table 5.9 shows FIRM is well behaved to changing price expectations. Producers who envision higher futures prices in the final period will contract less, get higher utility, and reduce their risk premium. All of these are as expected.

Table 5.10 involves the same type of biased expectations (\$.05), but on the basis level, rather than futures.

Table 5.10 Changing Biases in Basis

BEST MARKETING PLANS								
USER	Frwd Cont.	Futures Hedge	Put Hedge	Basis Cont.	Spec. Call	Expected Utility	Risk Prem Above doing No Mktng	Descri -ption
=====	=====	=====	=====	=====	=====	=====	=====	=====
FRA6	0	0	0	13000	0	44.9	237.7	Base
CAL3	4133	0	0	7346	0	205.5	846.1	E[Basis]
MON8	7874	0	0	3694	0	68.7	1027.3	minus \$.05
FRA6	0	0	0	0	0	45.0	0.	Base
CAL3	4541	0	0	0	0	205.1	372.6	E[Basis]
MON8	6554	0	0	0	0	68.8	584.5	(no bias)
FRA6	0	0	0	0	0	51.0	0.	Base
CAL3	2200	0	0	0	0	211.2	157.2	E[Basis]
MON8	0	6500	0	0	0	73.7	345.8	plus \$.05

Similar results were found in Table 5.10, where basis was expected to widened (first three rows), hold constant (middle three rows) and increase (last three rows. In the first three rows, each producer attempts to capture what he sees as mis-priced basis contracts. In the last triple rows, the basis is expected to improve, so producers reduce forward contracting levels to capture improving basis.

5.14 Summary

In this chapter summaries of results were presented for all the farmers who attended one of four marketing workshops. In addition, all utility curve data appears in Appendix C, and all producer yield distributions appear in Appendix D. It is producer behavioral aspects that are the emphasis of this chapter. Farmer yield distributions and utility curve summaries are the main contributions reviewed in this chapter. Unfortunately, there are few ways to judge the quality of these attitudes or beliefs can be double-checked. One interesting way would be to conduct the

workshops a second time, to see how producer answers and yield expectations changed. Time did not allow for this.

One important finding presented in the chapter was the superiority of the negative exponential function compared to the other three utility functions tested. While marketing plans exhibited a large variety of solutions, risk premiums proved valuable in analysis. There was a noted significant negative correlation between gross margin and the CARA coefficient for the producers. This should be expected, not because producers should or should not be DARA, but because large farms constitute more risk (larger standard deviations) than a highly risk averse person could accept.

Producers, as well as presenters, felt the workshop was educational and worthwhile, with only one dissatisfied workshop participant (out of 29). All workshop attendees stayed for the entire workshop, with none leaving early.

This chapter also examined FIRM and tests of discrete utility functions versus fitted ones. Discrete utility was not as "well-behaved" as fitted data. Changes from actual data to fitted behavior changed marketing recommendations. This gives some evidence that perhaps utility functions should be exponentially smoothed (or some other smoothing function). How this should best be done is not clear at this time and will require additional research.

There was also a test of sensitivity of data biases. Such biases alter recommendations, and risk premiums. If persons expect futures or basis to increase [decrease], then marketing will decrease [increase] as expected.



CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 The Problem	184
6.2 The Research Objectives	184
6.3 Research Findings and their Implications	185
6.4 Limitations of the Research	188
6.5 Future Research	189

6.1 The Problem

Commercial grain farmers can use several cash and futures market instruments prior to harvest, to manage their crop income risk. The producer problem addressed in this research is: "Which pricing alternatives should I use and how many bushels to price for a particular grain commodity, when production and ending period prices are uncertain?" The research problem is to improve marketing information by developing and testing microcomputer tools that help farmers consider their risks and decide how many bushels to price with each pricing alternative.

6.2 The Research Objectives

The objectives of this research were to (1) review relevant literature, (2) build or identify software components to solve the research (and farm) problem, (3) test the model for usefulness, workability and whether the model solutions are close to what should be expected, and (4) identify research contributions and challenges for further research. All of these objectives were reached, in the course of the research. Other research models and microcomputer simulation models were reviewed, along with decision theory and other methods related to the research. ELRISK and MKTOPT were constructed to measure utility and to optimize expected utility for a single period, single crop, marketing problem. Tests of FIRM (the collective components) were promising. None of the solutions from FIRM seemed to contradict what was known about risk reduction and marketing, except with regard to the use of options. Futures price volatility was underestimated, enough that options only entered into solution when no other risk reducing strategies were available.



6.3 Research Findings and their Implications

a. Forward contracting can substantially reduce risk for producers. The reasons for this is that with forward contracting, transaction costs are non-explicit and both futures and basis volatilities are managed. The explicit costs of trading futures (and maintaining margins) reduces the desirability of futures hedging in this stochastic but non-dynamic model. This corresponds to what is known about farmer behavior and their favoring the use of forward contracting.

b. Changing the futures price distribution from normal, to log-normal, to randomly drawn from a normal, had little change on solutions. The normal and log-normal solutions were more alike in their marketing solutions than the 200 Monte Carlo draws from a normal. All three distributions had nearly identical means and variances.

c. Using Utility Theory allows calculation of risk premiums, that are not easily attained through other decision methods. Risk premiums supplement solutions by giving easy to understand measurements that serve as a confidence factor in comparing risk related solutions. They are also useful to measure the direct producer benefits of the risk reduction. The implications of this for the 29 workshop participants was varied. Some had small risk premiums, and others were larger, but as a group nearly \$40,000 of risk reduction was computed.

d. The model testing in Chapter four ,using synthetic CARA utility functions, gave results very similar to tests using utility curves of actual producers elicited in marketing workshops. This consistency helped validate the FIRM model.

e. Workshop data indicate the negative exponential utility ($U(x) = K - a \cdot e^{-bx}$) s the best candidate for functional form, of those forms that were tested. Even when it was not the best fitting form (compared to semi-log and quadratic) its r^2 values were still excellent. This finding is important for decision theory, giving strength to E-V analysis. Quadratic and semi-log were inferior functional forms except in some of the more linear (risk neutral) producers. Even in those cases, the negative exponential function fit very well. These results are based on utility functions with 9 to 13 utility coordinates.

f. ELRISK is a powerful context sensitive expert system, that was developed and tested in this research for risk elicitation. It is seeded by the mean and standard deviation of the expected income distribution, making the elicitation very context sensitive. It differs from the original Halter and Mason (1978) method, to give 9 to 13 discrete "income, utility" coordinates (rather than just 4 or 5). ELRISK is a personal-computer software program, based upon a risk elicitation method that is usually called the Equally Likely Risky Outcome method.

g. The workshops conducted had very positive ratings and comments. Not a single workshop participant (of the 29), left early from the all-day program. Most producers ran extra analysis. Several persons indicated an interest in participating again, and a few persons wondered if and when FIRM would be available for their use.

h. The use of graphics to represent preferences, along with changes in certainty equivalents (risk premiums) were very important to this research, and are strongly recommended for persons working with risk and decision-making.

i. One workshop participant (of 29) was risk neutral, three were nearly risk neutral ($0 < R(x) < .00001$), two were very risk averse ($R(x) > .0002$) when examining the specific problem of soybean marketing risks. The remainder (23) exhibited various degrees of moderate risk aversion ($.00001 < R(x) < .0002$). Risk aversion was shown to be significantly related to the size of the producer problem. Large risky problems require decision-makers who are less risk averse than small problems.

j. Pre-harvest basis contracting did very little to reduce producer risk exposure, compared to methods of pricing the futures portion of price. This was expected to occur, since basis is such a small part of the total soybean price. This might not be the case with some commodities with larger basis risk.

k. Options seldom came into solution, until premiums were lowered. This miscalibration of the ending futures price distribution was unfortunate. An unintentional bias in the futures price volatility was created, possibly due to using a 10 percent interest rates for the producers and a seven percent risk-free short-term interest rate in the OPM. Closer calibration of futures price distributions must be made. Fackler and King (1990) have completed substantial new work in this area, and provide updated non-parametric methods that will be beneficial to future work in the area of price probability distributions.

This research will be useful for other problems where stochastic factors and decision-maker risk attitudes are important. With some effort this approach might be useful for examining investments in irrigation, evaluation of land rental arrangements, factors related to government commodity program participation, and more.

6.4 Limitations of the Research

While the tools developed in this research (GENRINC, ELRISK, and MKTOPT) were successful in meeting the research objectives, there are limitations to FIRM and this research that need to be mentioned. FIRM is a non-dynamic model trying to address a dynamic problem. Ignoring the dynamic aspects of the problem helped keep solutions simple so that farmers could easily provide the data, and understand the solutions. Karp (1987) and Berg (1987) have both examined dynamic marketing, but neither have indicated that their developments provide results that farmers can directly use and understand. While Karp (1987) does capture the dynamic aspects of marketing, other pricing alternatives and strategies available to real decision-makers are not considered.

Users of FIRM must understand the static nature of the model and the market dynamics. Not all of the pricing recommendations from running FIRM need to be taken on the day FIRM is run. Workshop participants were informed that the risk costs computed, were over the entire time until harvest. It may be that a rule of thumb to price $\frac{1}{3}$ at planting, $\frac{1}{3}$ at harvest and $\frac{1}{3}$ post harvest, would be superior over the solutions from FIRM. Working with dynamic strategies, requires conditional probability data that are not available, and the problem may become more difficult than many producers are capable of comprehending

There was no follow-up with producers regarding whether they had followed recommendations from FIRM computed at the workshops. This follow-up idea was presented after the season and the harvest, so workshop participants might not remember workshop answers, and due to the passing of time would probably discount the influence of the workshop.

6.5 Future Research

An end-user design of FIRM must allow use of multivariate distributions, but the research model developed, used independent (uncorrelated) distributions. Research with FIRM incorporating multivariate distributions should be done as quality correlation data becomes available. Further efforts are also needed regarding the best smoothing function for utility, as well as price distributions. This research points out a need for further research in calibrating price distributions based upon options premiums.

In this research, every entry in ELRISK was recorded to disk as entered. If the entry was later revised that second entry was also recorded. Future research with ELRISK could (and should) involve further examination of this data. Behaviorists with interests in decision-making could incorporate the time or time change in seconds for every entry, to gather human behavioral data. From only a brief analysis of this entry by entry data, it appears that most decision-makers started out slowly with the process, making numerous revisions, but learned to evaluate the decisions in ELRISK more promptly and perhaps more reliably. There are numerous research opportunities related to the human or behavioral elements of ELRISK. One example of this kind of research is exploring the difficulty that decision-makers have when elicitation reaches critical lower levels.

In future research with FIRM, follow-up discussions with workshop participants should be done to measure the user acceptance and potential benefits. This same process should also be used if a research project were to involve decision-maker use of FIRM throughout the growing season. Periodic evaluation could assess the use of FIRM up until harvest. With a user database and an end-user version of FIRM, the

database would record the marketing decisions, and if made available to the researcher after harvest, could provide additional feedback.

Much of the elicitation literature reviewed in Chapter 2, indicates that decision-makers have difficulty with changing probabilities. In order to shed more light on this, ELRISK could be modified to include other probabilities. The probability of a good year could be changed from 50 percent to 40 percent (and 60% bad year) or vice versa.

FIRM performed very well in an extension workshop setting to teach elementary applied probability, risk principles, and marketing. If the producers adopt the marketing plans suggested substantial risk reduction would occur. This research was not only an educational program for nearly all who participated, but allows for computation of its own potential benefits. The software development, to date, is very suitable for a workshop setting, but is not ready for individual producer use. Much database development is needed, as well as empirical work on ending period price distributions.

FIRM adds more support for the negative exponential function in empirical and theoretical use. Further tests of the model are needed. Some of these should involve additional workshops and data collection. At this stage FIRM is best used as a supervised educational tool. It could be used by trained Extension personnel, or marketing consultants. Like the B.E.A.R. package discussed in Chapter 2, FIRM could be offered to individuals, but only if they attend a training session.

Based upon the evaluation forms and comments, FIRM has tremendous potential. Very little research has been done to date on context sensitive risk elicitation to solve farm problems. While FIRM is not perfect, it has helped identify needed research, and provided a framework to build upon.

APPENDICES

APPENDIX A - Comments from Workshop Participants

- (1) Could it be simplified? (2) Most problems with this one = ELRISK.
- (3) It was unclear where the game was headed. Additional background is needed.
- (4) Improved ideas on marketing opportunities, interesting. (5) One-on-one was great!
- (6) How does this relate to market fundamentals? (7) Nice meeting, but it probably won't
- change the way I market soybeans. It does open the mind up! (8) First time to use a Computer. Market Risk game- a little hard to understand. I enjoyed the day.
- (9) I wish we had been given better cost - acreage information to reduce guessing. It was a very good meeting with lots of excellent information given. It was a very worthwhile day. It would be nice to be able to work through this again with the understanding gained after a "once through."
- (10) If we had more time, would liked to have heard something about hedging.
- (11) This program was real interesting. Never seen anything like this before, we have in our farmer discussion group talked about something similar.
- (12) The risk preference elicitation requires more time, thought, practice -- to accurately reflect preferences or to give us confidence in the outcome.
- (13) Need a workshop to understand how the software works. There were some parts that were
- hard to understand and I wish (software) were more friendly to use. (14) The risk preferences and
- yield distribution tools put hard to measure subjects into useful facts.
- (15) I strongly doubt that what I learned was worth the time spent. It seems like too much theory and too little practical use.
- (16) One of the best workshops! Please continue and include us!
- (17) This type of program stirs the brain and encourages you to investigate more.
- (18) I had trouble figuring out how to compare Plan A and B. I feel there is good possibilities for a program like this.
- (19) An imperfect science, but keep up the good work.
- (20) Needs simplifying before it will be much use to average farmer. Enjoyed workshop.

APPENDIX B - Workshop Program**HOW TO PRICE PRE-HARVEST SOYBEANS AND HOW MANY BUSHELS
TO PRICE IN ORDER TO MANAGE RISK**

WORKSHOP SPEAKERS: Jim Hilker - Professor, Ag. Econ.
 Steve Harsh - Professor, Ag. Econ.
 Rich Alderfer - Research Assistant, Ag. Econ.

SCHEDULE

8:00 Setup Computers and A.V. Equipment
 9:00 Coffee & Donuts (get acquainted)
 9:15 A Brief Overview of the Program - Steve and Rich
 9:30 Presentation on Yields and Probabilities - Rich
 Run Elicit Software for Soybean Yields - Jim
 Fill out Crop Costs Worksheets - Steve
 Generate Income Distributions - Rich
 10:30 Ten Minute Break
 10:40 Soybean Outlook and Volatility Forecast (including basis forecast) - Jim
 11:00 Risk Preferences (based on income distributions) - Rich
 Run the ELRISK Software
 12:30 LUNCH
 1:30 Solve Individual Marketing Plans Under Base Assumptions
 3:00 Discussion and Evaluation
 3:15 Adjourn

1. A YIELD DISTRIBUTION

Prior to harvest, the final soybean yield per acre is uncertain. In fact, as the crop develops during the growing season, the yield becomes more certain. To examine income risks in soybean production it is necessary to measure this yield uncertainty. To describe the degree of uncertainty in yields at this date we can use a program called ELICIT.

You are welcome to keep the printout of your yield distribution from ELICIT. Please be sure to remember the file name in which you stored your output from ELICIT.

File Name = _____

2. BUDGETING SOYBEAN EXPENSES

In order to determine the risks related to different marketing options it is necessary to know your cost of growing and harvesting the crop. On the following page we have given you some guideline cost figures for your consideration. These are only costs directly associated with soybean production. They do not include any overhead costs. All marketing costs such as brokerage fees are not included in the cost figures since they will be automatically added by the OPT program. You should only use these cost figures to assist you in developing your own cost figures.

	40 bu.	30 bu.	Your Cost
	-----Dollars per acre-----		
Seed	14	14	_____
Fert & Lime	19	12	_____
Chemicals	21	21	_____
Fuel & Repair	18	18	_____
Labor, Irig. Misc	0	0	_____
Interest till Hrvst	5	4	_____
	<u> </u>	<u> </u>	<u> </u>
Var. Cost / ac.	77	69	_____
	----- Dollars per Bushel-----		
Harvest	0.23	0.23	_____
Transport	0.20	0.20	_____
Drying	0.05	0.05	_____
Other	0.00	0.00	_____
	<u> </u>	<u> </u>	<u> </u>
Var. Cost / bu.	0.48	0.48	_____

Now lets examine share rental arrangements if any. Owned and cash rented soybean acres can usually just be added together. In a 50/50 share lease the tenant farms half of the land for himself and supplies labor and equipment for the landowner on the other acres. Of course the tenant and landowner split all production evenly, but it is easy to visualize the costs as previously described. Thus when budgeting for total production expenses, it is helpful to add all owned and cash rented acres to only half of the share rented land.

$$\begin{array}{rcl}
 & \text{acres} & \\
 & \text{share rent} & \text{_____} \\
 & \times & \\
 & \text{share} & \text{_____} \\
 \hline
 \text{owned acres} & + & \text{cash rented} & + & \text{effective} & = & \text{Total Soybean Acres} \\
 & & & & \text{shared} & &
 \end{array}$$

3. GENERATE INCOME DISTRIBUTION

This short simple program (GENRYLDS) generates random observations based on your acreage, costs, yields and distribution of futures and basis. The important output from this program is the average (or mean) income, and the standard deviation. Record them below to the nearest dollar.

Average Income \$ _____ Standard Deviation of Income \$ _____

4. IDENTIFYING YOUR PREFERENCE FOR RISK

This program (ELRISK) divides a large problem into a series of small ones. It examines your preferences for risky situations, based on the income distribution you described. By breaking the larger marketing problem into a series of smaller ones it is possible to solve the larger one. Be sure to view (on the screen) or print your risk attitude curve when you complete the situations presented.

5. DEVELOP MARKETING PLAN

This is a program (OPT) that examines approximately 100 marketing plans for 200 "years" of different combinations of yields and prices to find a set of marketing plan that consider your risk preferences, production costs, and acreage. When finished computing it finds a "best" plan and 14 other similar plans in the area of the best one. The user can also enter custom marketing plans to see how they compare with the first solution.

6. WORKSHOP EVALUATION

Name (optional): _____

Age: _____ Number of years farming: _____

Approximate percentage of total gross farm income from soybean production: _____%

	<u>Good</u>	<u>Fair</u>	<u>Needs Improvement</u>
1. Program overview	____	____	____
2. Elicitation of yield distributions	____	____	____
3. Market outlook and volatility	____	____	____
4. Risk preference elicitation	____	____	____
5. Finding optimal marketing strategies	____	____	____

Other comments: _____

Thank you for your cooperation and assistance.

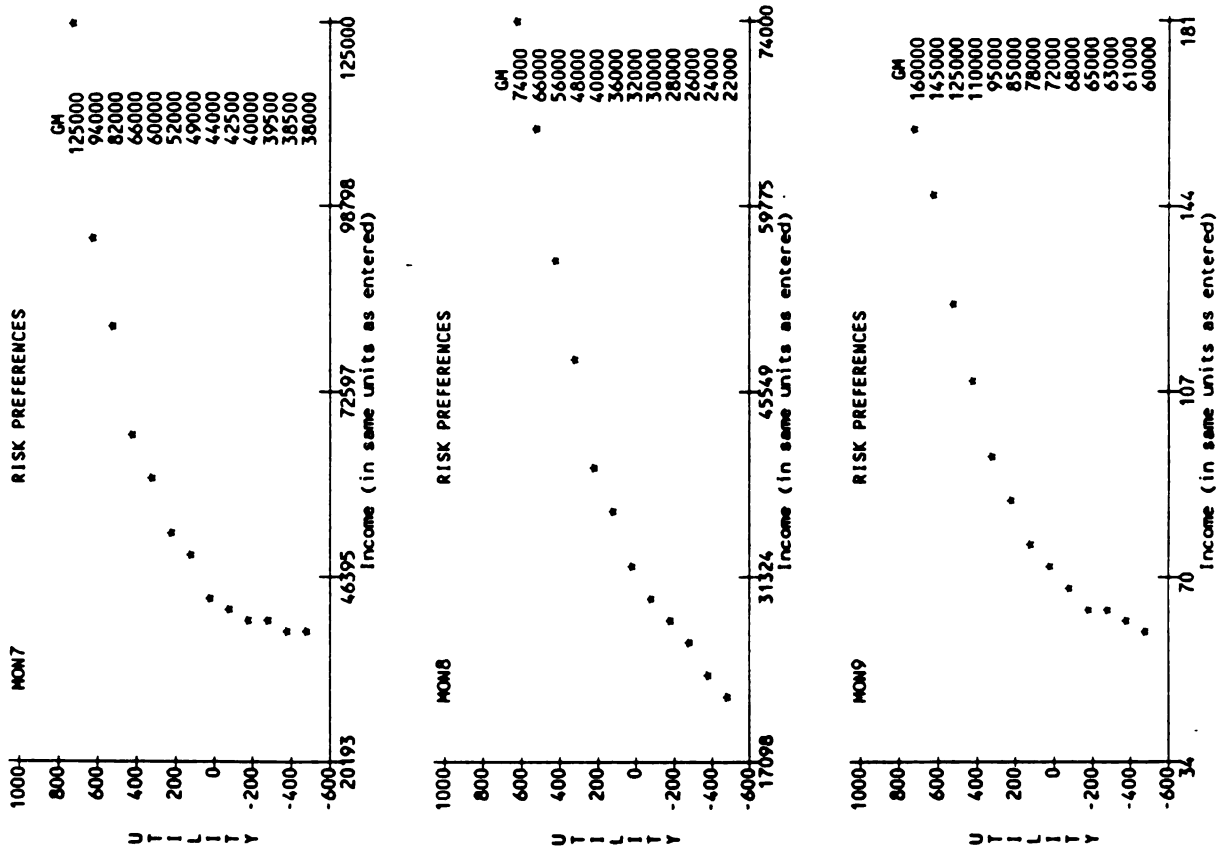
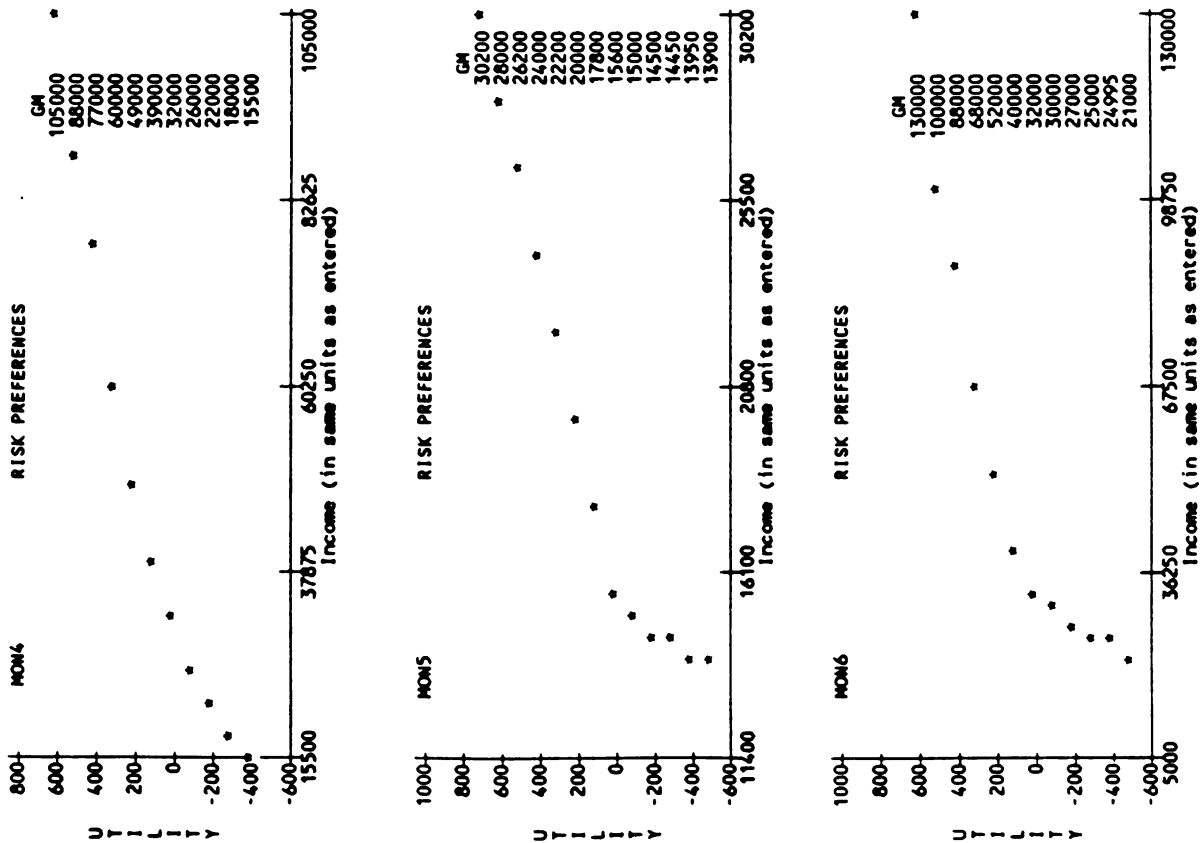
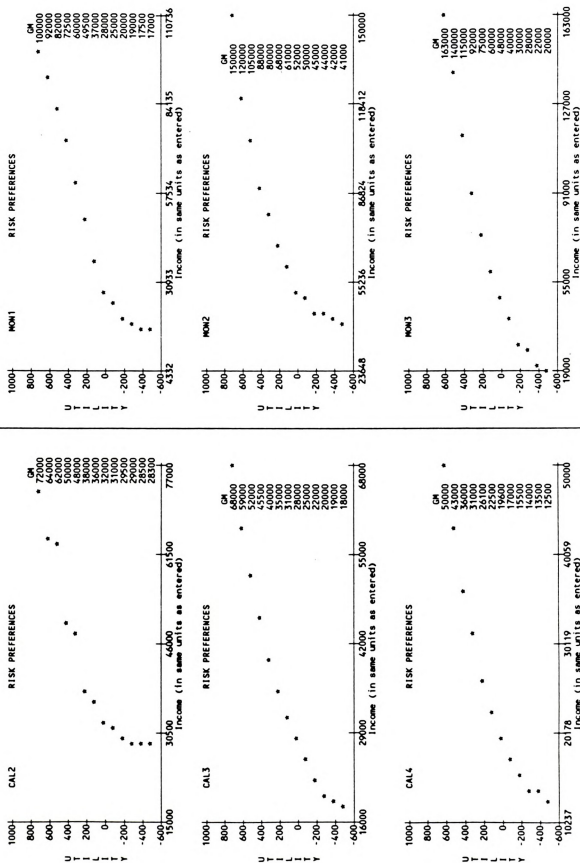
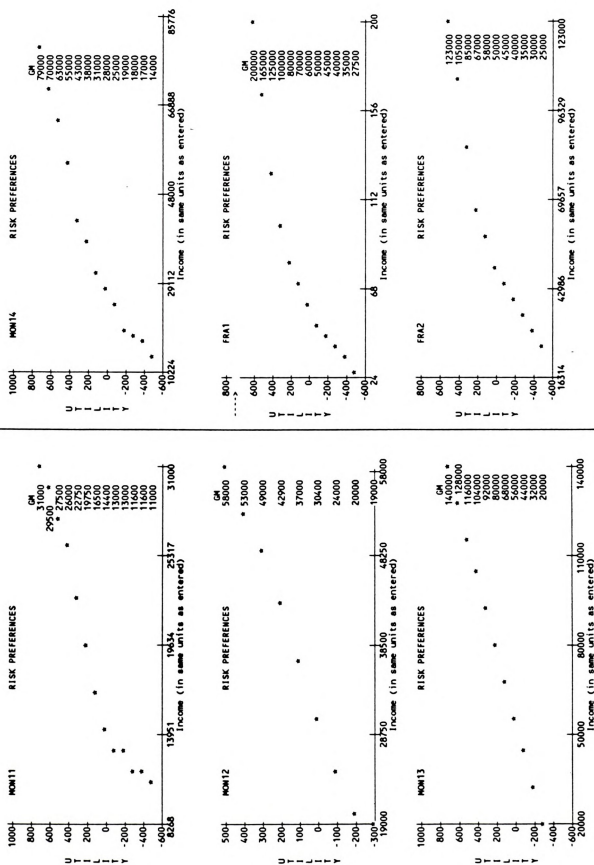
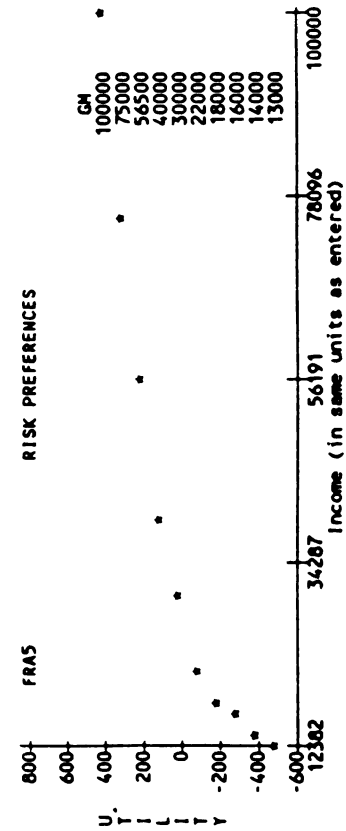
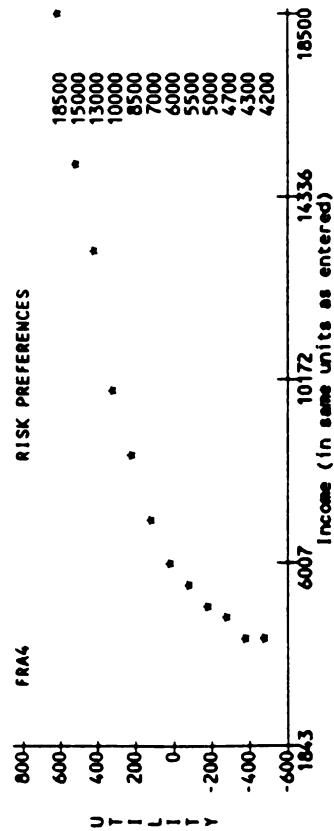
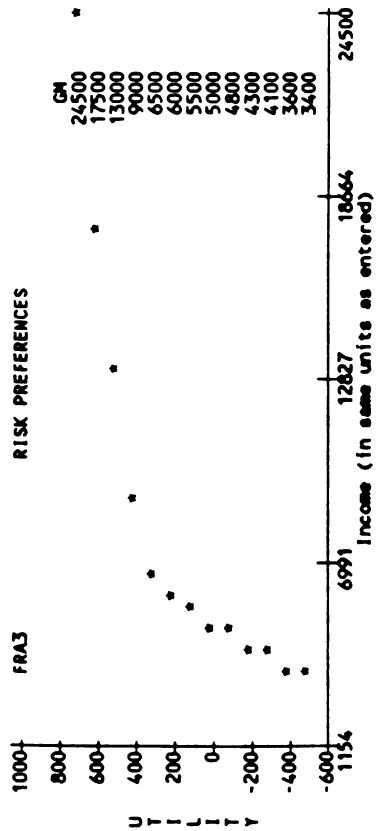
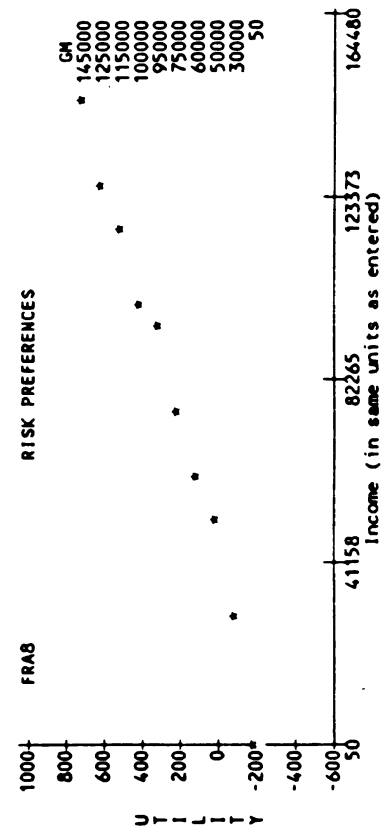
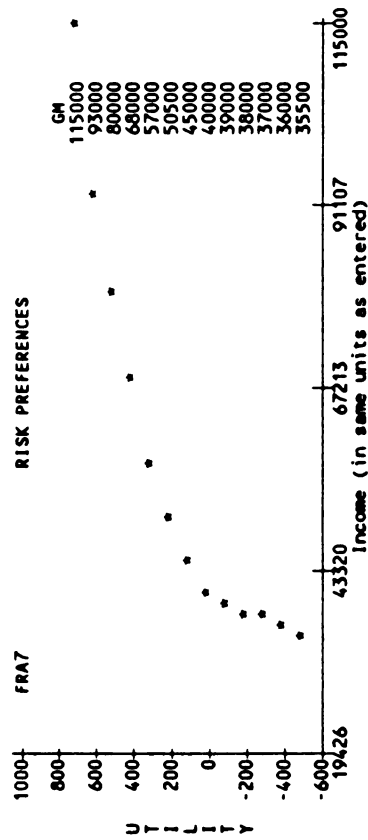
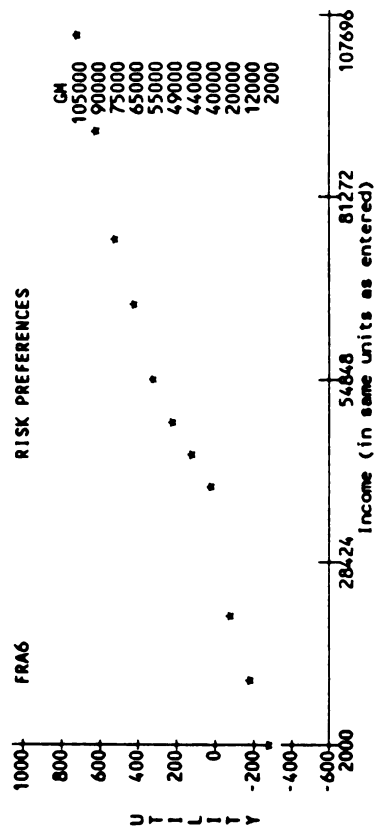


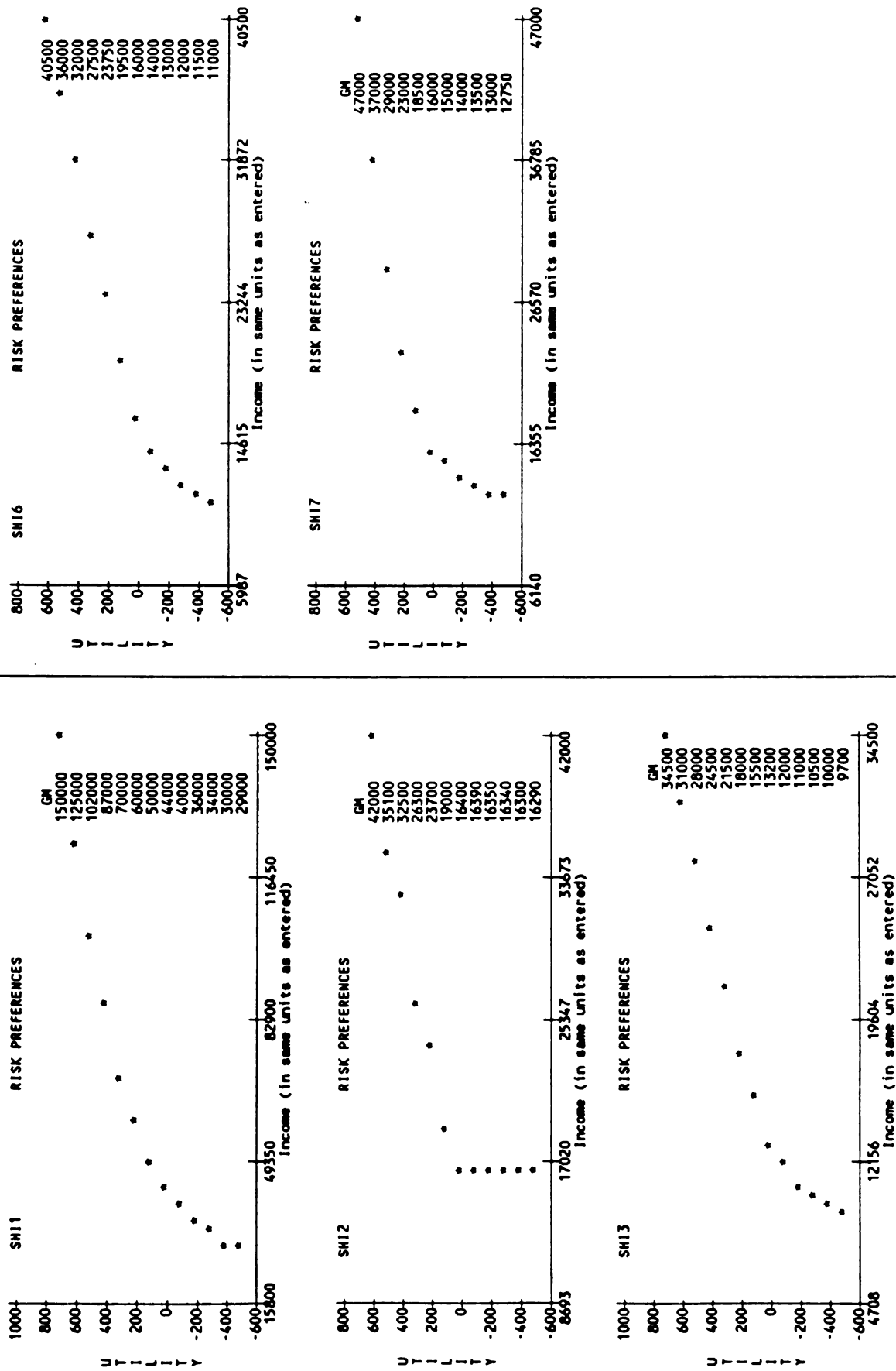
Figure C.1 - Utility Curves for All producers













FR2	43.83	9.82	0.01	0.89
15	19.99	5.00	0.02	2.04
25	29.99	10.00	0.04	4.09
35	39.99	15.00	0.06	6.14
45	49.99	20.00	0.08	8.19
55	59.99	25.00	0.10	10.24
65	69.99	30.00	0.12	12.29
75	79.99	35.00	0.14	14.34
85	89.99	40.00	0.16	16.39
95	99.99	45.00	0.18	18.44
105	109.99	50.00	0.20	20.49
115	119.99	55.00	0.22	22.54
125	129.99	60.00	0.24	24.59
135	139.99	65.00	0.26	26.64
145	149.99	70.00	0.28	28.69
155	159.99	75.00	0.30	30.74
165	169.99	80.00	0.32	32.79
175	179.99	85.00	0.34	34.84
185	189.99	90.00	0.36	36.89
195	199.99	95.00	0.38	38.94
205	209.99	100.00	0.40	40.99
215	219.99	105.00	0.42	43.04
225	229.99	110.00	0.44	45.09
235	239.99	115.00	0.46	47.14
245	249.99	120.00	0.48	49.19
255	259.99	125.00	0.50	51.24
265	269.99	130.00	0.52	53.29
275	279.99	135.00	0.54	55.34
285	289.99	140.00	0.56	57.39
295	299.99	145.00	0.58	59.44
305	309.99	150.00	0.60	61.49
315	319.99	155.00	0.62	63.54
325	329.99	160.00	0.64	65.59
335	339.99	165.00	0.66	67.64
345	349.99	170.00	0.68	69.69
355	359.99	175.00	0.70	71.74
365	369.99	180.00	0.72	73.79
375	379.99	185.00	0.74	75.84
385	389.99	190.00	0.76	77.89
395	399.99	195.00	0.78	79.94
405	409.99	200.00	0.80	81.99
415	419.99	205.00	0.82	84.04
425	429.99	210.00	0.84	86.09
435	439.99	215.00	0.86	88.14
445	449.99	220.00	0.88	90.19
455	459.99	225.00	0.90	92.24
465	469.99	230.00	0.92	94.29
475	479.99	235.00	0.94	96.34
485	489.99	240.00	0.96	98.39
495	499.99	245.00	0.98	100.44
505	509.99	250.00	1.00	102.49
515	519.99	255.00	1.02	104.54
525	529.99	260.00	1.04	106.59
535	539.99	265.00	1.06	108.64
545	549.99	270.00	1.08	110.69
555	559.99	275.00	1.10	112.74
565	569.99	280.00	1.12	114.79
575	579.99	285.00	1.14	116.84
585	589.99	290.00	1.16	118.89
595	599.99	295.00	1.18	120.94
605	609.99	300.00	1.20	122.99
615	619.99	305.00	1.22	125.04
625	629.99	310.00	1.24	127.09
635	639.99	315.00	1.26	129.14
645	649.99	320.00	1.28	131.19
655	659.99	325.00	1.30	133.24
665	669.99	330.00	1.32	135.29
675	679.99	335.00	1.34	137.34
685	689.99	340.00	1.36	139.39
695	699.99	345.00	1.38	141.44
705	709.99	350.00	1.40	143.49
715	719.99	355.00	1.42	145.54
725	729.99	360.00	1.44	147.59
735	739.99	365.00	1.46	149.64
745	749.99	370.00	1.48	151.69
755	759.99	375.00	1.50	153.74
765	769.99	380.00	1.52	155.79
775	779.99	385.00	1.54	157.84
785	789.99	390.00	1.56	159.89
795	799.99	395.00	1.58	161.94
805	809.99	400.00	1.60	163.99
815	819.99	405.00	1.62	166.04
825	829.99	410.00	1.64	168.09
835	839.99	415.00	1.66	170.14
845	849.99	420.00	1.68	172.19
855	859.99	425.00	1.70	174.24
865	869.99	430.00	1.72	176.29
875	879.99	435.00	1.74	178.34
885	889.99	440.00	1.76	180.39
895	899.99	445.00	1.78	182.44
905	909.99	450.00	1.80	184.49
915	919.99	455.00	1.82	186.54
925	929.99	460.00	1.84	188.59
935	939.99	465.00	1.86	190.64
945	949.99	470.00	1.88	192.69
955	959.99	475.00	1.90	194.74
965	969.99	480.00	1.92	196.79
975	979.99	485.00	1.94	198.84
985	989.99	490.00	1.96	200.89
995	999.99	495.00	1.98	202.94
1005	1009.99	500.00	2.00	204.99
1015	1019.99	505.00	2.02	207.04
1025	1029.99	510.00	2.04	209.09
1035	1039.99	515.00	2.06	211.14
1045	1049.99	520.00	2.08	213.19
1055	1059.99	525.00	2.10	215.24
1065	1069.99	530.00	2.12	217.29
1075	1079.99	535.00	2.14	219.34
1085	1089.99	540.00	2.16	221.39
1095	1099.99	545.00	2.18	223.44
1105	1109.99	550.00	2.20	225.49
1115	1119.99	555.00	2.22	227.54
1125	1129.99	560.00	2.24	229.59
1135	1139.99	565.00	2.26	231.64
1145	1149.99	570.00	2.28	233.69
1155	1159.99	575.00	2.30	235.74
1165	1169.99	580.00	2.32	237.79
1175	1179.99	585.00	2.34	239.84
1185	1189.99	590.00	2.36	241.89
1195	1199.99	595.00	2.38	243.94
1205	1209.99	600.00	2.40	245.99
1215	1219.99	605.00	2.42	248.04
1225	1229.99	610.00	2.44	250.09
1235	1239.99	615.00	2.46	252.14
1245	1249.99	620.00	2.48	254.19
1255	1259.99	625.00	2.50	256.24
1265	1269.99	630.00	2.52	258.29
1275	1279.99	635.00	2.54	260.34
1285	1289.99	640.00	2.56	262.39
1295	1299.99	645.00	2.58	264.44
1305	1309.99	650.00	2.60	266.49
1315	1319.99	655.00	2.62	268.54
1325	1329.99	660.00	2.64	270.59
1335	1339.99	665.00	2.66	272.64
1345	1349.99	670.00	2.68	274.69
1355	1359.99	675.00	2.70	276.74
1365	1369.99	680.00	2.72	278.79
1375	1379.99	685.00	2.74	280.84
1385	1389.99	690.00	2.76	282.89
1395	1399.99	695.00	2.78	284.94
1405	1409.99	700.00	2.80	286.99
1415	1419.99	705.00	2.82	289.04
1425	1429.99	710.00	2.84	291.09
1435	1439.99	715.00	2.86	293.14
1445	1449.99	720.00	2.88	295.19
1455	1459.99	725.00	2.90	297.24
1465	1469.99	730.00	2.92	299.29
1475	1479.99	735.00	2.94	301.34
1485	1489.99	740.00	2.96	303.39
1495	1499.99	745.00	2.98	305.44
1505	1509.99	750.00	3.00	307.49
1515	1519.99	755.00	3.02	309.54
1525	1529.99	760.00	3.04	311.59
1535	1539.99	765.00	3.06	313.64
1545	1549.99	770.00	3.08	315.69
1555	1559.99	775.00	3.10	317.74
1565	1569.99	780.00	3.12	319.79
1575	1579.99	785.00	3.14	321.84
1585	1589.99	790.00	3.16	323.89
1595	1599.99	795.00	3.18	325.94
1605	1609.99	800.00	3.20	327.99
1615	1619.99	805.00	3.22	330.04
1625	1629.99	810.00	3.24	332.09
1635	1639.99	815.00	3.26	334.14
1645	1649.99	820.00	3.28	336.19
1655	1659.99	825.00	3.30	338.24
1665	1669.99	830.00	3.32	340.29
1675	1679.99	835.00	3.34	342.34
1685	1689.99	840.00	3.36	344.39
1695	1699.99	845.00	3.38	346.44
1705	1709.99	850.00	3.40	348.49
1715	1719.99	855.00	3.42	350.54
1725	1729.99	860.00	3.44	352.59
1735	1739.99	865.00	3.46	354.64
1745	1749.99	870.00	3.48	356.69
1755	1759.99	875.00	3.50	358.74
1765	1769.99	880.00	3.52	360.79
1775	1779.99	885.00	3.54	362.84
1785	1789.99	890.00	3.56	364.89
1795	1799.99	895.00	3.58	366.94
1805	1809.99	900.00	3.60	368.99
1815	1819.99	905.00	3.62	371.04
1825	1829.99	910.00	3.64	373.09
1835	1839.99	915.00	3.66	375.14
1845	1849.99	920.00	3.68	377.19
1855	1859.99	925.00	3.70	379.24
1865	1869.99	930.00	3.72	381.29
1875	1879.99	935.00	3.74	383.34
1885	1889.99	940.00	3.76	385.39
1895	1899.99	945.00	3.78	387.44
1905	1909.99	950.00	3.80	389.49
1915	1919.99	955.00	3.82	391.54
1925	1929.99	960.00	3.84	393.59
1935	1939.99	965.00	3.86	395.64
1945	1949.99	970.00	3.88	397.69
1955	1959.99	975.00	3.90	399.74
1965	1969.99	980.00	3.92	401.79
1975	1979.99	985.00	3.94	403.84
1985	1989.99	990.00	3.96	405.89
1995	1999.99	995.00	3.98	407.94
2005	2009.99	1000.00	4.00	409.99
2015	2019.99	1005.00	4.02	412.04
2025	2029.99	1010.00	4.04	414.09
2035	2039.99	1015.00	4.06	416.14
2045	2049.99	1020.00	4.08	418.19
2055	2059.99	1025.00	4.10	420.24
2065	2069.99	1030.00	4.12	422.29
2075	2079.99	1035.00	4.14	424.34
2085	2089.99	1040.00	4.16	426.39
2095	2099.99	1045.00	4.18	428.44
2105	2109.99	1050.00	4.20	430.49
2115	2119.99	1055.00	4.22	432.54
2125	2129.99	1060.00	4.24	434.59
2135	2139.99	1065.00	4.26	436.64
2145	2149.99	1070.00	4.28	438.69
2155	2159.99	1075.00	4.30	440.74
2165	2169.99	1080.00	4.32	442.79
2175	2179.99	1085.00	4.34	444.84
2185	2189.99	1090.00	4.36	446.89
2195	2199.99	1095.00	4.38	448.94
2205	2209.99	1100.00	4.40	450.99
2215	2219.99	1105.00	4.42	453.04
2225	2229.99	1110.00	4.44	455.09
2235	2239.99	1115.00	4.46	457.14
2245	2249.99	1120.00	4.48	459.19
2255	2259.99	1125.00	4.50	461.24</



MON14	39.97	8.59	0.00	0.00	0.00	0.24
15.00	19.99	1.00	0.00	0.00	0.00	0.24
20.00	24.99	5.00	0.01	0.01	0.01	1.49
25.00	29.99	20.00	0.05	0.05	0.05	18.64
30.00	34.99	20.00	0.05	0.05	0.05	18.64
35.00	39.99	25.00	0.06	0.06	0.06	22.22
40.00	44.99	25.00	0.06	0.06	0.06	22.22
45.00	49.99	25.00	0.07	0.07	0.07	25.97
50.00	54.99	25.00	0.07	0.07	0.07	25.97
55.00	59.99	25.00	0.08	0.08	0.08	29.68
CAL2	37.16	6.29	0.00	0.00	0.00	0.00
15.00	19.99	1.00	0.01	0.01	0.01	0.47
20.00	24.99	5.00	0.02	0.02	0.02	2.34
25.00	29.99	30.00	0.10	0.10	0.10	12.37
30.00	34.99	65.00	0.22	0.22	0.22	45.39
35.00	39.99	100.00	0.33	0.33	0.33	67.56
40.00	44.99	75.00	0.23	0.23	0.23	92.64
45.00	49.99	50.00	0.05	0.05	0.05	99.56
50.00	54.99	5.00	0.02	0.02	0.02	100.00
55.00	59.99	2.00	0.01	0.01	0.01	100.00
CAL3	36.77	6.85	0.00	0.00	0.00	0.00
15.00	19.99	0.00	0.00	0.00	0.00	0.00
20.00	24.99	5.00	0.02	0.02	0.02	2.00
25.00	29.99	30.00	0.04	0.04	0.04	6.25
30.00	34.99	40.00	0.17	0.17	0.17	31.26
35.00	39.99	100.00	0.42	0.42	0.42	72.92
40.00	44.99	50.00	0.17	0.17	0.17	89.58
45.00	49.99	20.00	0.08	0.08	0.08	97.82
50.00	54.99	5.00	0.02	0.02	0.02	100.00
CAL4	43.34	6.90	0.00	0.00	0.00	0.00
15.00	19.99	1.00	0.01	0.01	0.01	0.37
20.00	24.99	5.00	0.02	0.02	0.02	2.21
25.00	29.99	20.00	0.07	0.07	0.07	9.56
30.00	34.99	50.00	0.19	0.19	0.19	27.74
35.00	39.99	60.00	0.22	0.22	0.22	66.76
40.00	44.99	20.00	0.07	0.07	0.07	94.72
45.00	49.99	10.00	0.03	0.03	0.03	99.56
50.00	54.99	5.00	0.02	0.02	0.02	99.63
55.00	59.99	1.00	0.00	0.00	0.00	100.00
SH11	35.34	7.14	0.00	0.00	0.00	0.00
15.00	19.99	5.00	0.02	0.02	0.02	1.72
20.00	24.99	20.00	0.07	0.07	0.07	8.62
25.00	29.99	60.00	0.21	0.21	0.21	45.10
30.00	34.99	60.00	0.21	0.21	0.21	45.10
35.00	39.99	100.00	0.34	0.34	0.34	77.59
40.00	44.99	40.00	0.14	0.14	0.14	91.38
45.00	49.99	20.00	0.07	0.07	0.07	94.72
50.00	54.99	5.00	0.02	0.02	0.02	99.63
55.00	59.99	1.00	0.00	0.00	0.00	100.00
SH12	35.63	6.24	0.00	0.00	0.00	0.00
15.00	19.99	5.00	0.02	0.02	0.02	1.49
20.00	24.99	10.00	0.03	0.03	0.03	5.06
25.00	29.99	40.00	0.14	0.14	0.14	18.64
30.00	34.99	65.00	0.22	0.22	0.22	40.68
35.00	39.99	100.00	0.34	0.34	0.34	74.58
40.00	44.99	65.00	0.22	0.22	0.22	66.61
45.00	49.99	10.00	0.03	0.03	0.03	100.00
SH13	33.51	5.80	0.00	0.00	0.00	0.00
15.00	19.99	5.00	0.02	0.02	0.02	1.95
20.00	24.99	20.00	0.07	0.07	0.07	22.22
25.00	29.99	35.00	0.13	0.13	0.13	25.22
30.00	34.99	100.00	0.37	0.37	0.37	59.26
35.00	39.99	75.00	0.28	0.28	0.28	87.64
40.00	44.99	35.00	0.13	0.13	0.13	100.00
SH16	33.61	5.41	0.00	0.00	0.00	0.00
15.00	19.99	5.00	0.02	0.02	0.02	1.95
20.00	24.99	10.00	0.06	0.06	0.06	5.56
25.00	29.99	20.00	0.11	0.11	0.11	16.44
30.00	34.99	100.00	0.56	0.56	0.56	72.22
35.00	39.99	30.00	0.17	0.17	0.17	66.89
40.00	44.99	10.00	0.06	0.06	0.06	94.44
45.00	49.99	10.00	0.06	0.06	0.06	100.00
SH17	34.42	6.59	0.00	0.00	0.00	0.00
15.00	19.99	5.00	0.02	0.02	0.02	1.95
20.00	24.99	15.00	0.07	0.07	0.07	7.50
25.00	29.99	50.00	0.25	0.25	0.25	32.50
30.00	34.99	50.00	0.25	0.25	0.25	32.50
35.00	39.99	10.00	0.03	0.03	0.03	99.56
40.00	44.99	20.00	0.10	0.10	0.10	37.50
45.00	49.99	10.00	0.05	0.05	0.05	100.00



APPENDIX E - Discrete Price Distributions

Values of the Standard Normal distribution with
the same mean and standard deviation.

Ang&Tang eqn 3.32 zeta= 0.112582
lambda= 1.815385

mu= 6.1825
sd= 0.69825

Stand. Normal	Prob.	normal mu=6.1825 sd=.69825	ln normal	DIFF
-3.5	0	3.738625	4.140102	-0.40148
-2.57583	0.005	4.383927	4.59435	-0.21042
-2.32635	0.01	4.558126	4.725295	-0.16717
-2.17009	0.015	4.667235	4.809204	-0.14197
-2.05375	0.02	4.748469	4.872643	-0.12417
-1.95996	0.025	4.813958	4.924394	-0.11044
-1.88079	0.03	4.869238	4.968505	-0.09927
-1.81191	0.035	4.917334	5.007204	-0.08987
-1.75069	0.04	4.960081	5.041852	-0.08177
-1.6954	0.045	4.998687	5.07335	-0.07466
-1.64485	0.05	5.033983	5.10232	-0.06834
-1.59819	0.055	5.066564	5.129207	-0.06264
-1.55477	0.06	5.096882	5.154354	-0.05747
-1.5141	0.065	5.12528	5.178021	-0.05274
-1.47579	0.07	5.15203	5.200413	-0.04838
-1.43953	0.075	5.177348	5.221696	-0.04435
-1.40507	0.08	5.20141	5.242004	-0.04059
-1.3722	0.085	5.224361	5.261448	-0.03709
-1.34076	0.09	5.246314	5.280113	-0.0338
-1.31058	0.095	5.267388	5.298093	-0.03071
-1.28155	0.1	5.287658	5.315445	-0.02779
-1.25357	0.105	5.307195	5.332224	-0.02503
-1.22653	0.11	5.326075	5.348489	-0.02241
-1.20036	0.115	5.344349	5.364278	-0.01993
-1.17499	0.12	5.362063	5.379629	-0.01757
-1.15035	0.125	5.379268	5.39458	-0.01531
-1.12639	0.13	5.395998	5.409158	-0.01316
-1.10306	0.135	5.412288	5.423391	-0.0111
-1.08032	0.14	5.428167	5.4373	-0.00913
-1.05812	0.145	5.443668	5.450913	-0.00725
-1.03643	0.15	5.458813	5.464246	-0.00543
-1.01522	0.155	5.473623	5.477316	-0.00369
-0.99446	0.16	5.488118	5.490139	-0.00202
-0.97411	0.165	5.502328	5.502737	-0.00041
-0.95416	0.17	5.516258	5.515116	0.001142
-0.93458	0.175	5.52993	5.527293	0.002637
-0.91537	0.18	5.543343	5.539265	0.004078
-0.89647	0.185	5.55654	5.55107	0.00547
-0.8779	0.19	5.569506	5.562693	0.006814
-0.85962	0.195	5.58227	5.574158	0.008113
-0.84162	0.2	5.594839	5.58547	0.009368
-0.8239	0.205	5.607212	5.596629	0.010582
-0.80642	0.21	5.619417	5.607659	0.011758
-0.78919	0.215	5.631448	5.618553	0.012896
-0.77219	0.22	5.643318	5.629321	0.013997
-0.75542	0.225	5.655028	5.639964	0.015064
-0.73885	0.23	5.666598	5.6505	0.016098
-0.72248	0.235	5.678028	5.660928	0.0171
-0.7063	0.24	5.689326	5.671254	0.018072

-0.69031	0.245	5.700491	5.681477	0.019014
-0.67449	0.25	5.711537	5.69161	0.019927
-0.65884	0.255	5.722465	5.701652	0.020813
-0.64335	0.26	5.733281	5.711608	0.021673
-0.62801	0.265	5.743992	5.721485	0.022507
-0.61281	0.27	5.754605	5.731289	0.023317
-0.59776	0.275	5.765114	5.741012	0.024102
-0.58284	0.28	5.775532	5.750668	0.024864
-0.56805	0.285	5.785859	5.760256	0.025603
-0.55338	0.29	5.796102	5.769781	0.026321
-0.53884	0.295	5.806255	5.779238	0.027017
-0.5244	0.3	5.816338	5.788645	0.027693
-0.51007	0.305	5.826344	5.797996	0.028348
-0.49585	0.31	5.836273	5.807289	0.028983
-0.48173	0.315	5.846132	5.816533	0.0296
-0.4677	0.32	5.855928	5.825731	0.030197
-0.45376	0.325	5.865662	5.834885	0.030777
-0.43991	0.33	5.875333	5.843995	0.031338
-0.42615	0.335	5.884941	5.853059	0.031882
-0.41246	0.34	5.8945	5.862091	0.032409
-0.39886	0.345	5.903996	5.871077	0.032919
-0.38532	0.35	5.91345	5.880038	0.033413
-0.37186	0.355	5.922849	5.888959	0.03389
-0.35846	0.36	5.932205	5.897853	0.034352
-0.34513	0.365	5.941513	5.906715	0.034798
-0.33185	0.37	5.950786	5.915557	0.035229
-0.31864	0.375	5.96001	5.924365	0.035645
-0.30548	0.38	5.969199	5.933152	0.036046
-0.29237	0.385	5.978353	5.94192	0.036433
-0.27932	0.39	5.987465	5.95066	0.036805
-0.26631	0.395	5.996549	5.959386	0.037163
-0.25335	0.4	6.005598	5.968091	0.037507
-0.24043	0.405	6.01462	5.976782	0.037838
-0.22754	0.41	6.02362	5.985466	0.038155
-0.2147	0.415	6.032586	5.994128	0.038458
-0.20189	0.42	6.04153	6.002783	0.038748
-0.18912	0.425	6.050447	6.011423	0.039024
-0.17637	0.43	6.05935	6.020061	0.039288
-0.16366	0.435	6.068224	6.028686	0.039539
-0.15097	0.44	6.077085	6.037308	0.039777
-0.1383	0.445	6.085932	6.04593	0.040002
-0.12566	0.45	6.094758	6.054543	0.040215
-0.11304	0.455	6.10357	6.063155	0.040414
-0.10043	0.46	6.112375	6.071773	0.040602
-0.08784	0.465	6.121166	6.080389	0.040777
-0.07527	0.47	6.129943	6.089003	0.040939
-0.06271	0.475	6.138713	6.097623	0.04109
-0.05015	0.48	6.147483	6.106255	0.041228
-0.03761	0.485	6.156239	6.114886	0.041353
-0.02507	0.49	6.164995	6.123528	0.041467
-0.01253	0.495	6.173751	6.132183	0.041568
0	0.5	6.1825	6.140843	0.041657
0.01253	0.505	6.191249	6.149516	0.041734
0.02507	0.51	6.200005	6.158207	0.041798
0.03761	0.515	6.208761	6.166911	0.04185
0.05015	0.52	6.217517	6.175627	0.04189
0.06271	0.525	6.226287	6.184369	0.041918
0.07527	0.53	6.235057	6.193124	0.041933
0.08784	0.535	6.243834	6.201898	0.041936
0.10043	0.54	6.252625	6.210699	0.041926
0.11304	0.545	6.26143	6.219526	0.041904
0.12566	0.55	6.270242	6.228373	0.04187

0.1383	0.555	6.279068	6.237246	0.041822
0.15097	0.56	6.287915	6.246153	0.041762
0.16366	0.565	6.296776	6.255086	0.041689
0.17637	0.57	6.30565	6.264047	0.041603
0.18912	0.575	6.314553	6.273049	0.041504
0.20189	0.58	6.32347	6.282078	0.041392
0.2147	0.585	6.332414	6.291148	0.041266
0.22754	0.59	6.34138	6.300252	0.041127
0.24043	0.595	6.35038	6.309406	0.040975
0.25335	0.6	6.359402	6.318593	0.040808
0.26631	0.605	6.368451	6.327823	0.040628
0.27932	0.61	6.377535	6.337102	0.040433
0.29237	0.615	6.386647	6.346423	0.040224
0.30548	0.62	6.395801	6.355801	0.04
0.31864	0.625	6.40499	6.365228	0.039762
0.33185	0.63	6.414214	6.374706	0.039508
0.34513	0.635	6.423487	6.384248	0.039239
0.35846	0.64	6.432795	6.39384	0.038955
0.37186	0.645	6.442151	6.403497	0.038655
0.38532	0.65	6.45155	6.413211	0.038338
0.39886	0.655	6.461004	6.422999	0.038005
0.41246	0.66	6.4705	6.432845	0.037655
0.42615	0.665	6.480059	6.442771	0.037288
0.43991	0.67	6.489667	6.452764	0.036904
0.45376	0.675	6.499338	6.462837	0.036501
0.4677	0.68	6.509072	6.472992	0.03608
0.48173	0.685	6.518868	6.483228	0.03564
0.49585	0.69	6.528727	6.493547	0.035181
0.51007	0.695	6.538656	6.503955	0.034702
0.5244	0.7	6.548662	6.51446	0.034202
0.53884	0.705	6.558745	6.525064	0.033681
0.55338	0.71	6.568898	6.535758	0.03314
0.56805	0.715	6.579141	6.546565	0.032576
0.58284	0.72	6.589468	6.557479	0.031989
0.59776	0.725	6.599886	6.568508	0.031378
0.61281	0.73	6.610395	6.579651	0.030744
0.62801	0.735	6.621008	6.590924	0.030084
0.64335	0.74	6.631719	6.602321	0.029398
0.65884	0.745	6.642535	6.61385	0.028685
0.67449	0.75	6.653463	6.625518	0.027945
0.69031	0.755	6.664509	6.637333	0.027176
0.7063	0.76	6.675674	6.649297	0.026377
0.72248	0.765	6.686972	6.661425	0.025547
0.73885	0.77	6.698402	6.673718	0.024684
0.75542	0.775	6.709972	6.686184	0.023788
0.77219	0.78	6.721682	6.698824	0.022857
0.78919	0.785	6.733552	6.711663	0.021889
0.80642	0.79	6.745583	6.724699	0.020883
0.8239	0.795	6.757788	6.737951	0.019837
0.84162	0.8	6.770161	6.751412	0.018749
0.85962	0.805	6.78273	6.765113	0.017617
0.8779	0.81	6.795494	6.779055	0.016439
0.89647	0.815	6.80846	6.793248	0.015212
0.91537	0.82	6.821657	6.807723	0.013934
0.93458	0.825	6.83507	6.822468	0.012602
0.95416	0.83	6.848742	6.83753	0.011213
0.97411	0.835	6.862672	6.85291	0.009763
0.99446	0.84	6.876882	6.868634	0.008248
1.01522	0.845	6.891377	6.884712	0.006665
1.03643	0.85	6.906187	6.901178	0.005009
1.05812	0.855	6.921332	6.918057	0.003275
1.08032	0.86	6.936833	6.935376	0.001458



1.10306	0.865	6.952712	6.95316	-0.00045
1.12639	0.87	6.969002	6.971454	-0.00245
1.15035	0.875	6.985732	6.990292	-0.00456
1.17499	0.88	7.002937	7.009717	-0.00678
1.20036	0.885	7.020651	7.029774	-0.00912
1.22653	0.89	7.038925	7.050524	-0.0116
1.25357	0.895	7.057805	7.072028	-0.01422
1.28155	0.9	7.077342	7.094349	-0.01701
1.31058	0.905	7.097612	7.117581	-0.01997
1.34076	0.91	7.118686	7.141815	-0.02313
1.3722	0.915	7.140639	7.167148	-0.02651
1.40507	0.92	7.16359	7.193729	-0.03014
1.43953	0.925	7.187652	7.221702	-0.03405
1.47579	0.93	7.21297	7.251254	-0.03828
1.5141	0.935	7.23972	7.282607	-0.04289
1.55477	0.94	7.268118	7.31604	-0.04792
1.59819	0.945	7.298436	7.351904	-0.05347
1.64485	0.95	7.331017	7.390639	-0.05962
1.6954	0.955	7.366313	7.432834	-0.06652
1.75069	0.96	7.404919	7.479262	-0.07434
1.81191	0.965	7.447666	7.531007	-0.08334
1.88079	0.97	7.495762	7.589655	-0.09389
1.95996	0.975	7.551042	7.657628	-0.10659
2.05375	0.98	7.616531	7.738941	-0.12241
2.17009	0.985	7.697765	7.841005	-0.14324
2.32635	0.99	7.806874	7.980211	-0.17334
2.57583	0.995	7.981073	8.207603	-0.22653
3.5	1	8.626375	9.107855	-0.48148
		6.1825	6.18256	-6E-05

APPENDIX F - Code for F&BDISTS.EXE

[illegible]

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```

1 transform the vector of multivariate normal random variables
2 into a vector of uniformly distributed random variables
3
4 FOR I = 1 TO MW
5     CALL TABEX(SNI(I), -3.5, .1, 71, RV(I), U(I))
6     RV(I) = INPUT
7     U(I) = OUTPUT
8     SNI(I) = DEPENDENT ARRAY
9     -3.6 = SMALLEST INPUT POSSIBLE
10    .1 = DIFFERENCE IN INPUT VALUES FOR DEP. ARRAY VTE
11    71 = NUMBER OF TABLE INTERVALS
12
13 NEXT I
14
15 "transform the uniformly distributed random variables into
16 "random variables from the specified distributions
17 FOR I = 1 TO MW
18     FOR J = 1 TO K
19         TEMPARG(J) = ARG(I, J)
20     NEXT J
21     CALL TABEX(TEMPARG(I), 0, .025, 41, U(I), Y(I))
22     U(I) = INPUT
23     Y(I) = OUTPUT
24     temparg = DEPENDENT ARRAY (PRICES OR BASIS)
25     0 = SMALLEST INPUT POSSIBLE
26     .025 = DIFFERENCE IN INPUT VALUES FOR DEP. ARRAY VTE
27     41 = NUMBER OF TABLE INTERVALS
28
29 NEXT I
30
31 WRITE #1, Y(1), Y(2) 'output distrib. to file
32
33 NEXT KK
34 LOCATE 1, 1
35 PRINT "THIS IS LOOP NUMBER "; KZZ
36 NEXT KZZ
37 CLOSE #1
38
39 PRINT "TIME TO COMPUTE AND STORE: INMC; "OBSERVATIONS FOR";
40 PRINT " "; MW; "RANDOM VARIABLES, WAS"; (TIMER - START); "SECONDS."
41
42
43 ' end of the generation program - begin the twerk routine
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COV(I, J) = COR(I, J)
COV(J, I) = COV(I, J)
D(I, J) = COV(I, J)
D(J, I) = COV(I, J)
COR(I, J) = COV(I, J) / SD(I) * SD(J)
COR(J, I) = COV(I, J) / SD(I) * SD(J)
NEXT J
NEXT I
ELSE
FOR I = 1 TO MM
FOR J = 1 TO MM
COV(I, J) = COR(I, J) * SD(I) * SD(J)
COV(J, I) = COV(I, J)
D(I, J) = COV(I, J)
D(J, I) = COV(J, I)
NEXT J
NEXT I
END IF
IF
.
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.
IF the determinant is less than .0001 print an error message and halt
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.
program execution. Fortran version of this is on page 159 of Lehman
.
.
.
the method here is called a pivotal condensation algorithm
.
.
.
IWM = 1
I = 2
DO WHILE I < MM
OVERD = D(I, IWM) / D(IWM, IWM)
FOR J = 1 TO MM
D(I, J) = D(I, J) - D(IWM, J) * OVERD
NEXT J
IWM = I + 1
I = I + 1
LOOP
DET = 1
FOR I = 1 TO MM
DET = DET * D(I, I)
NEXT I
IF I < .0001 THEN
PRINT "Singularity in Var/Cov Matrix, check correlations inputs "
END
END IF
.
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CALL COEF
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.
construct lower triangular matrix C.
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.
RANDOMIZE TIMER
FOR KZ = 1 TO LOUTER
FOR KK = 1 TO MD
.
.
.
begin to generate random variates
.
.
.
call sub tabex using SM() which returns a vector of independently
distributed standard normal random variates
FOR I = 1 TO MM
RAN2 = RND
CALL TABEX(SM(), 0, .025, 41, RAN2, E(I))
RAN2 = input
E() = output
vte = dependent array
0 = smallest input possible
.025 = difference in input values for dep. array vte
41 = number of table intervals
NEXT I
construct sample vector from a multivariate normal distribution
FOR I = 1 TO MM
RV(I) = 0
FOR J = 1 TO MM
RV(I) = RV(I) + C(I, J) * E(J)
NEXT J
NEXT I

```

```

NEXT I
CALL SNIEXP(SNIE(X1(), N2LO, N2HI) 'lowest subscript of X1
N1LO = 1 'highest subscript of X1
CALL KSTUO(X1(), N1LO, N1HI, SNIE(X1(), N2LO, N2HI, D, PROB)

PRINT "The D statistic from KS for futures is"; D
PRINT "The PROB stat from KS for futures is"; PROB
*****
INPUT "Hit any key to continue with the test of Normality"; DUMMYS
CLS
CALL MOMENTS(X2(), INMC, AVE, ADEV, SDEV, VAR, SKEW, CURT)
PRINT "The Mean basis price "; AVE
PRINT "Average Deviations in basis "; ADEV
PRINT "The Variance is of basis "; VAR
PRINT "The Stand. Deviation of basis "; SDEV
PRINT "The Skewness of basis "; SKEW
PRINT "The Curtosis of basis "; CURT

CALL QuickSort(1, INMC, X2())

'normalize the distribution to be tested (to a standard normal)
FOR I = 1 TO INMC
  X2(I) = (X2(I) - AVE) / SDEV
NEXT I

CALL SNIEXP(SNIE(X1(), N2LO, N2HI) 'lowest subscript of X2
N1LO = 1 'highest subscript of X2
CALL KSTUO(X2(), N1LO, N1HI, SNIE(X1(), N2LO, N2HI, D, PROB)

PRINT "The D statistic from KS for futures is"; D
PRINT "The PROB stat from KS for futures is"; PROB

END

SUB ADJMEAN (X(), NLO, NHI, THEAN) STATIC
'where x = array to be adjusted
' nlo = subscript of the first (lowest) array element
' nhi = subscript of the last (highest) array element
'tmean = true or desired mean
DSUM = THEAN * (NHI - NLO + 1) 'desired sum of all x()
SSUM# = 0
FOR I = NLO TO NHI
  SSUM# = SSUM# + X(I)
NEXT I
'compute sum of all samples

TOTADJ = DSUM - SSUM#
'adjustment to the total
ADJ = TOTADJ / (NHI - NLO)
'adjustment needed for each observation
FOR I = NLO TO NHI
  X(I) = X(I) + ADJ
NEXT I

END SUB

SUB ADJSD (X(), NLO, NHI, SD, XBAR) STATIC

```

```

PRINT "New mean of futures price is"; XMEAN(X1(), INMC)
PRINT "New mean of basis is "; XMEAN(X2(), INMC)
PRINT
PRINT "The sample St.Dev of futures price was"; XSTDDEV(X1(), INMC)
PRINT "The sample St.Dev of basis was "; XSTDDEV(X2(), INMC)

CALL ADJSD(X1(), 1, INMC, SD(1), EV(1))
'where x1 = the array to be adjusted for standard deviation
' 1 = the subscript of the lowest (first) array
' INMC = the subscript of the highest (last) array
' .84 = the desired standard dev. of the array
' 7.05 = the sample (& desired) data mean.

CALL ADJSD(X2(), 1, INMC, SD(2), EV(2))

PRINT
PRINT "The St.Dev of futures is now"; XSTDDEV(X1(), INMC)
PRINT "The St.Dev of basis is now "; XSTDDEV(X2(), INMC)

PRINT
PRINT "The Cor(futures,basis) is now "; CORREL(X1(), X2(), INMC)
PRINT

OPEN "F&BDIST2.DAT" FOR OUTPUT AS #3
PRINT #3, INMC 'print the inmc value from the top of the file
FOR I = 1 TO INMC
  WRITE #3, X1(I), X2(I)
NEXT I
CLOSE #3

*****
' end of tweaking the data - now test for normality
*****

*****
' The following Kolmogorov-Smirnov Test is for comparing observations
' from a single ordered distribution to a user-supplied CDF function of
' known form. This sub appears on page 474 of Numerical Recipes, in
' This example of the subroutine, the function test is a standard normal
' The KSNOME sub requires a sorted array which is performed by quicksort.
' The integral parts of K-S are KSNOME and PROBK. FUNKSUM is supplied
' by the user/programmer.
'
' A table of Kol-Smir significance levels is on page 44 of a simulation
' text by Lewis (1989).
*****
DIM SNIE(X(0 TO 100)
CLS
INPUT "Hit any key to continue with the test of Normality of futures"; DUMMYS
CALL MOMENTS(X1(), INMC, AVE, ADEV, SDEV, VAR, SKEW, CURT)
PRINT
PRINT "The Mean futures price "; AVE
PRINT "Average Deviations in futures "; ADEV
PRINT "The Variance is of futures "; VAR
PRINT "The Stand. Deviation - futures "; SDEV
PRINT "The Skewness of futures "; SKEW
PRINT "The Curtosis of futures "; CURT

CALL QuickSort(1, INMC, X1())

'normalize the distribution to be tested (to a standard normal)
FOR I = 1 TO INMC
  X1(I) = (X1(I) - AVE) / SDEV

```

```

'where x() = array to adjust to desired stand dev
' nlo = subscript of the first (lowest) array element
' nhi = subscript of the last (highest) array element
' sd = desired standard deviation of the array
' xbar = desired and sample means for the array

TRVAR = SD * 2 'true var is true sdev. squared
DTSS = TRVAR * (NHI - NLO) 'desired total sum of squared deviations
SSD# = 0 'sample sum of squared deviations
FOR I = NLO TO NHI
  SSD# = SSD# + CDBL((X(I) - XBAR) * 2)
NEXT I

RATIO = DTSS / SSD# 'ratio of sample deviations to desired

FOR I = NLO TO NHI
  IF X(I) > XBAR THEN
    X(I) = XBAR + SQR((X(I) - XBAR) * 2 * RATIO)
  ELSEIF X(I) < XBAR THEN
    X(I) = XBAR - SQR((X(I) - XBAR) * 2 * RATIO)
  END IF
NEXT I

END SUB

SUB COEF
  DEFINIT I=1
  'this subroutine constructs the lower triangular matrix C.
  ' it was written by R. Neal Peterson. It is used in generating
  ' multivariate distributions.
  ' Initialize the c() matrix
  FOR J = 1 TO MN
    FOR I = 1 TO MN
      C(I, J) = 0
      C(J, I) = 0
    NEXT J
  NEXT I

  FOR I = 1 TO MN
    PAR(I, 1) = COR(I, 1)
  NEXT I

  IF MN >= 2 THEN
    FOR J = 2 TO MN
      SUM = 0
      FOR K = 1 TO JM1
        SUM = SUM + PAR(J, K) * PAR(J, K)
      NEXT K
      PAR(J, J) = SQR((1 - SUM)
      IF J < MN THEN
        JP1 = J + 1
        FOR I = JP1 TO MN
          PAR(I, J) = 0
        NEXT I
        IF PAR(J, J) < 0 THEN
          SUM = 0
          FOR K = 1 TO JM1
            SUM = SUM + PAR(I, K) * PAR(J, K)
          NEXT K
          PAR(I, J) = (COR(I, J) - SUM) / PAR(J, J)
        END IF
      END IF
    NEXT J
  END IF

```

```

      END IF
    NEXT J
  END IF
  'j is going from one to i
  FOR J = 1 TO I
    C(I, J) = PAR(I, J)
  NEXT J
NEXT I

END SUB

FUNCTION CORREL (ZX(), ZY(), KZ) STATIC
  ZXSUM# = 0
  ZYSUM# = 0
  ZXSQ# = 0
  ZYSQ# = 0
  ZXYZ# = 0
  KZM2 = KZ * 2
  FOR M = 1 TO KZM2
    ZXSUM# = ZXSUM# + ZX(M)
    ZYSUM# = ZYSUM# + ZY(M)
    ZXSQ# = ZXSQ# + ZX(M) * ZX(M)
    ZYSQ# = ZYSQ# + ZY(M) * ZY(M)
    ZXYZ# = ZXYZ# + ZX(M) * ZY(M)
  NEXT M
  ZNUMBER = (KZM2 * ZXYZ#) - (ZXSUM# * ZYSUM#)
  ZDENOM = (((KZM2 * ZXSQ#) - (ZXSUM# * ZXSUM#)) * ((KZM2 * ZYSQ#) - (ZYSUM# * ZYSUM#))) * .5
  IF ABS(ZDENOM) < 1E-10 THEN
    ZDENOM = 1E-10
    LPRINT "Calcs in correlation approached division by zero"
    LPRINT "Hit any key to continue"
    INPUT RS
  END IF
  CORREL = ZNUMBER / ZDENOM
END FUNCTION

SUB IMDATA (X1(), X2(), X3(), IMNC)
  FOR I = 1 TO IMNC
    INPUT #1, D1, D2, D3, X1(I), X2(I), X3(I)
  NEXT I
END SUB

SUB KSTWO (DATUM1(), M1LO, M1HI, DATUM2(), M2LO, M2HI, D, PROB)
  ' This is the Kol-Smir Test for two distributions. M1LO is the lowest
  ' subscript value for the DATUM1() and M1HI the highest subscript. D
  ' is the K-S statistic, and PROB is the significance level of the K-S
  ' statistic. Low PROB values show that the CDF of DATUM1 are different
  ' than the CDF of DATUM2.
  ' Both arrays must be sorted in ascending order before using this sub.
  M1 = M1HI
  M2 = M2HI
  J1 = M1LO
  J2 = M2LO
  F1 = 0
  F2 = 0
  D = 0
  DO WHILE (J1 <= M1HI) AND (J2 <= M2HI)
    D1 = DATUM1(J1)

```



```

CONST EPS1 = .001
CONST EPS2 = .00000001#
A2 = -2 * (ALAM - 2)
FAC = 2
PROBSK = 0
TERMBF = 0
PROBSKX = 0
FOR J = 1 TO 100
  TERM = FAC * EXP(A2 * J - 2)
  PROBSKX = PROBSKX + TERM
  IF (ABS(TERM) <= (EPS1 * TERMBF) OR (ABS(TERM) <= EPS2 * PROBSKX))) THEN
    PROBSK = PROBSKX
    EXIT FUNCTION
  END IF
  FAC = -FAC
  TERMBF = ABS(TERM)
NEXT J
PROBSK = 1
'gets here only by failing to converge
END FUNCTION

SUB Quicksort (LOW, INIGH, Array())
' ===== Quicksort =====
' Quicksort works by picking a random "pivot" element in Array, then
' moving every element that is bigger to one side of the pivot, and every
' element that is smaller to the other side. Quicksort is then called
' recursively with the two subdivisions created by the pivot. Once the
' number of elements in a subdivision reaches two, the recursive calls end
' and the array is sorted.
' There is a non-recursive quicksort on page 153 of the book basic programs
' for scientists and engineers.
' If the array is partially sorted then picking the first element
' of the array slows execution, so random pivot is more desirable.
' Else if the array has absolutely no order, then there is no need
' to randomly choose a pivot, and you might as well choose the
' first element of the array.
' =====
IF LOW < INIGH THEN
  ' Only two elements in this subdivision; swap them if they are out of
  ' order, then end recursive calls:
  IF INIGH - LOW = 1 THEN
    IF Array(LOW) > Array(INIGH) THEN
      SWAP Array(LOW), Array(INIGH)
    ELSE
      ' Pick a pivot element at random, then move it to the end:
      RandIndex = LOW + INT (RND * (INIGH - LOW + 1))
      SWAP Array(INIGH), Array(RandIndex)
      Partition = Array(INIGH)
      DO
        ' Move in from both sides towards the pivot element:
        I = LOW: J = INIGH
        DO WHILE (I < J) AND (Array(I) <= Partition)
          I = I + 1
        LOOP
        DO WHILE (J > I) AND (Array(J) >= Partition)
          J = J - 1
        LOOP
        ' If we haven't reached the pivot element, it means that two
        ' elements on either side are out of order, so swap them:
        IF I < J THEN

```

```

D2 = DATUM2(J2)
IF (D1 <= D2) THEN
  F1 = J1 / EN1
  J1 = J1 + 1
END IF
IF (D2 <= D1) THEN
  F2 = J2 / EN2
  J2 = J2 + 1
END IF
DT = ABS(F2 - F1)
IF (DT > D) THEN D = DT
LOOP
ALAM = SQR(EN1 * EN2 / (EN1 + EN2)) * D
PROB = PROBSK(ALAM)
END SUB

SUB MOMENTS (DATUM(), N, AVE, ADEV, SDEV, VAR, SKEV, CURT)
' ===== This is a simple program to compute the mean (AVE), average dev-
' iations (ADEV), standard deviation (SDEV), variance (VAR), skewness
' (SKEV) and kurtosis (CURT). =====
IF N < 2 THEN
  CLS
  PRINT "Data array length cannot be less than 2."
  INPUT "Hit return (Enter key) to Continue"; RS
END IF
S# = 0
FOR J = 1 TO N
  S# = S# + DATUM(J)
NEXT J
AVE = S# / N
AD# = 0
V# = 0
SK# = 0
CUM# = 0
P# = 0
FOR J = 1 TO N
  S = DATUM(J) - AVE
  AD# = AD# + ABS(S)
  P# = S * S
  V# = V# + P#
  SK# = SK# + P# * P#
  CUM# = CUM# + P# * P#
NEXT J
ADEV = AD# / N
VAR = V# / (N - 1)
SDEV = SQR(VAR)
IF VAR <> 0 THEN
  SKEV = SK# / (N * SDEV - 3)
  CURT = (CUM# / (N * VAR * VAR)) - 3
ELSE
  CLS
  PRINT "There is no kurtosis or skewness when variance is zero."
  INPUT "Hit return (Enter key) to Continue"; RS
  CURT = 0
  SKEV = 0
END IF
END SUB

FUNCTION PROBSK (ALAM)

```



```

SNIEK(37) = .3318; SNIEK(63) = .3318
SNIEK(38) = .3305; SNIEK(62) = .3055
SNIEK(39) = .2797; SNIEK(61) = .2797
SNIEK(40) = .2274; SNIEK(60) = .2274
SNIEK(41) = .2274; SNIEK(59) = .2274
SNIEK(42) = .2018; SNIEK(58) = .2018
SNIEK(43) = .1764; SNIEK(57) = .1764
SNIEK(44) = .1511; SNIEK(56) = .1511
SNIEK(45) = .1256; SNIEK(55) = .1256
SNIEK(46) = .1005; SNIEK(54) = .1005
SNIEK(47) = .0752; SNIEK(53) = .0752
SNIEK(48) = .0502; SNIEK(52) = .0502
SNIEK(49) = .025; SNIEK(51) = .025
END SUB

SUB TAREX (VIE(I), SWE, DIE, XTE, YTE) STATIC
    * ate = input
    * swe = sweepest value
    * die = dependent array
    * xte = smallest input possible
    * yte = largest input possible
    * nte = number of tab intervals
    * nte = number of tab intervals
    *****
    * this sub appears in systems 011 class notes dated Jan 15. This sub
    * calculates the average value of a function over a range of values. The
    * value of the function at each interval is calculated and averaged.
    * those which are unequal observations,
    *****
    IF IEI < 1 THEN
        ITEX = ITEX + 5 * (DOME / DIE))
    ELSE
        ITEX = ITEX + XTE THEN
            ELITE = ITEX * XTE THEN
                END IF
            END IF
        END IF
    END SUB

FUNCTION TABEX(V, ARG(J), DUM, K) STATIC
    * A table lookup function for argument values that are unequally spaced.
    * The function can extrapolate to find values that lie beyond the highest
    * and lowest values of the table. The function uses linear interpolation
    * and the same code was used by King(1979, p. 226) and Maratich.
    * VALU(I) is table values of the desired function output.
    * ARG(J) is the argument values in the same units of measure
    * DUM is the number of elements in the ARG & VALU arrays
    * K is the number of elements in the ARG & VALU arrays
    *****
    * this func was corrected for an error on 4/4/89
    *****
    IF DUM > ARG(J) THEN
        *****
        -----) * VALU(K - 1)
        *****
    ELSE
        FOR J = 2 TO K
            TABEX = (DUM - ARG(J - 1)) * (VALU(J) - VALU(J - 1)) / (ARG(J) - ARG(J - 1))
            TABEX = (DUM - ARG(J - 1)) * (VALU(J) - VALU(J - 1)) / (ARG(J) - ARG(J - 1))
        NEXT J
    END IF
    RETURN TABEX

```

```

END FUNCTION

FUNCTION XMEAN (XNUM(), IOBS) STATIC
TOT# = 0#
FOR I = 1 TO IOBS
    TOT# = TOT# + XNUM(I)
NEXT I
XMEAN = CSNG(TOT# / CDBL(IOBS))      ; CDBL function to change to db prec.
                                      ; CSNG is func to change to single prec.
END FUNCTION

FUNCTION XSTDDEV (XNUM(), IOBS) STATIC
SUM# = 0
SUMSQ# = 0
FOR I = 1 TO IOBS
    SUM# = SUM# + XNUM(I)
    SUMSQ# = XNUM(I) * XNUM(I) + SUMSQ#
NEXT I
XSTDDEV = SQR((SUMSQ# - SUM# * SUM# / IOBS) / (IOBS - 1))
END FUNCTION

```



APPENDIX G - Code for GENRINC

```

DECLARE SUB MOMENTS (DATUM(1), M%, AVE%, ADEV%, SDEV%, VAR%, SEEM%, CURT%)
DECLARE FUNCTION TABEXP (VAL(1), INT(1), D%, LOGS, INTS)
DEFINT I-N

DIM YID(1 TO 20), CDF(1 TO 20)
' read in the yid array (called YID) and the cdf array (called CDF)
IF ERR = 53 THEN
  OPEN "F&B01572.DAT" FOR INPUT AS #1
  IF ERR = 53 THEN
    PRINT "I need the price data file called 'F&B01572.DAT'"
    PRINT "and I couldn't find it."
  ELSE
    PRINT "The following data files are available."
    PRINT "F&B01572.DAT"
    PRINT "END IF"
  END IF
END IF

10 INPUT "what file name contains the elicited data"
FILESPEC = FILESPEC + ".prg"
IF ERR = 53 THEN
  PRINT "I can't find a file by the name "; FILEMMS
  PRINT "PRINT "But I could find":
  CDF(20) = 1
  ERR 53 means file not found
END IF

INPUT #1, INMCID
' the number of futbas monte carlos (in the header)
IF INMC > INMCID THEN
  PRINT "How many Monte Carlo observations should be run": INMC
  PRINT "I will run INMC observations"
  PRINT "I am reducing Monte Carlo observations to": INMCID
  PRINT "because that is all of the price data that is available."
END IF
INMC = INMCID

INPUT #1, ISOTACRE
' zero acres causes problems
IF ISOTACRE < .01 THEN ISOTACRE = 1
INPUT "Costs PER ACRE that you wish to consider": ACRCOST
INPUT "Costs PER BUSHEL you wish to consider": BUSHCOST

***** end of user input - initialize monte carlo arrays
DIM BUSHEL$(INMC), INCOME$(INMC), FUTURE$(INMC), BASIS$(INMC)
FOR I = 1 TO INMC
  INPUT #1, FUTURE(I), BASIS(I)
  NEXT I
CLOSE #1

***** read in all 20 cdf and yield values
FOR J = 1 TO 72
  INPUT #1, YID(J), CDF(J)
  NEXT J
FOR I = 1 TO 20

```

```

  INPUT #2, YID(I), DUM1, DUM2, DUM3, CDF(I)
  CLOSE #2

***** end of input

PREVCDT = 0
FOR J = 1 TO 20
  CDF(J) = PREVCDT + .01
  PREVCDT = CDF(J)
NEXT J
CDF(20) = 1

'now we have two arrays: YID(1-20) and cdf(1-20) for use in table lookups
'note that both yields and cdf values are not in equal increments.

OPEN "B&B01572.DAT" FOR OUTPUT AS #3
RANDOMIZE TIMER
'write a header to the busbale and income file
WRITE #3, INMC, ISOTACRE, ACRCOST, BUSHCOST, "Footer has the moments"
WRITE #3, "Total bu. Gross Inc. Total costs Net Inc." 'label line
FICOST = ISOTACRE * ACRCOST

FOR I = 1 TO INMC
  'remember INID is a random num. genr. function
  I = INT (RND * 1000)
  X = TABEXP(YID(I), CDF(I), Z, 1, 20)
  BUSHEL$(I) = ISOTACRE * X
  FUTURE$(I) = BASIS(I)
  INCOME$(I) = FICOST + (BUSHEL$(I) * BUSHCOST)
  TGCOSTS = GROSSING - TGCOSTS
  WRITE #3, BUSHEL$(I), GROSSING, TGCOSTS, INCOME$(I)
NEXT I

WRITE #3, "Var. Average St.Dev. Skewness Kurtosis"
PRINT #3, "Var. Average St.Dev. Skewness Kurtosis"
CALL MOMENTS(BUSHEL$, INMC, AVE, ADEV, SDEV, VAR, SEEM, CURT)
PRINT "Bu. Prod. ", AVE, SDEV, SEEM, CURT
PRINT USING "#####.##": AVE; SDEV; SEEM; CURT

CALL MOMENTS(INCOME$, INMC, AVE, ADEV, SDEV, VAR, SEEM, CURT)
WRITE #3, "Net Income", AVE, SDEV, SEEM, CURT
PRINT "Net Income", AVE, SDEV, SEEM, CURT
PRINT USING "#####.##": AVE; SDEV; SEEM; CURT
CLOSE #3

END

SUB MOMENTS (DATUM(1), M%, AVE%, ADEV%, SDEV%, VAR%, SEEM%, CURT%)
*****
' This is a simple program to compute the mean (AVE), average deviation (SDEV), variance (VAR), standard deviation (SEEM), and kurtosis (CURT).
' *****
IF M < 2 THEN
  CLS
  PRINT "data array length cannot be less than 2."
  INPUT "Hit return (Enter key) to Continue": RS
  END
FOR J = 1 TO M
  SF = 0
  SF = SF + DATUM(J)

```

```

NEXT J
AVE = S# / N
AD# = 0
V# = 0
SK# = 0
CU# = 0
P# = 0
FOR J = 1 TO N
  S = DATUM(J) - AVE
  AD# = AD# + ABS(S)
  P# = S * S
  V# = V# + P#
  SK# = SK# + P#
  P# = P# * S
  CU# = CU# + P#
NEXT J
ADEV = AD# / N
VAR = V# / (N - 1)
SDEV = SQR(VAR)
IF VAR <> 0 THEN
  SKEW = SK# / (N * SDEV ^ 3)
  CURT = (CU# / (N * VAR * VAR)) - 3
ELSE
  CLS
  PRINT "There is no kurtosis or skewness when variance is zero."
  INPUT "Hit return (Enter key) to Continue"; RS
  CURT = 0
  SKEW = 0
END IF
END SUB

FUNCTION TABEX4 (VA(), AR(), D, ILO, IHI) STATIC
*****
** This is a table lookup function for use when the ARGU() array is not
** available in equal increments. This function requires that VALU() and
** ARGU() are both of length ILO TO IHI. D is an observation similar to
** those in the AR array and measured in the same units. TABEX4 is the
** function value returned and measured in the same units as VA.
** adopted for DB by RDA on 7-16-89.
** An example use is when D gets a 0-1 random input to generate a value
** called tabex4 that is similar to the cdf in the VA array.
*****
IF D <= AR(ILO) THEN
  TABEX4 = VA(ILO)
ELSEIF D >= AR(IHI) THEN
  TABEX4 = VA(IHI)
ELSE
  I = ILO + 1
  DO WHILE D > AR(I)
    I = I + 1
  LOOP
  TABEX4 = (D - AR(I - 1)) * (VA(I) - VA(I - 1)) / (AR(I) - AR(I - 1)) + VA(I -
  ----> 1)
END IF
END FUNCTION

```

Appendix H - Code for ELRISK

```

C *****
C C This version rounds the mean and sd to nearest 2,000 NOT 4,000 see *
C C Check program lines 85-155 and 155-230
C C SUBROUTINE BOXES(*)
C C ----- the * is for escapes to the main menu (line 100 of calling program)
C C INCLUDE:'ERBLOXDT.INC'
C C -----Start of common/erbk1 for variables unique to elrisk-----
COMMON/ERBK1/MEAN,ISTDEV,MODE,ILOWST,IMIST,IUTIL(20),ISAFETY,
A ITARGET,OUTNAM,MUORLO,RSPCH2
INTEGER*4 MEAN,ISTDEV,MODE,ILOWST,IMIST,IUTIL,ISAFETY
A ITARGET
CHARACTER*8 OUTNAM
CHARACTER*2 MUORLO
CHARACTER*1 RSPCH2
C -----End of COMMON/ERBK1-----
C C -----Start of variable definition-----
INTEGER*2 I,J,K,IRTM,ISUB,ILSTDE,ISCHO,MOSCRM,IFHOPRT,IFMRIM,IUMERE
INTEGER*4 I4,NGAME,IMUZER
CHARACTER*1 MONMO,STATUS
CHARACTER*8 OFLNM
C -----End of variable definition-----
C C -----Start of COMMON/ERBK2-----
COMMON/ERBK2/XMIN,XMAX,YMIN,YMAX,USERR(5),NGAME
CHARACTER*78 USERR
C -----End of COMMON/ERBK2-----
C C ----- the following variables are used in graphs
C C 5 IF(MUORLO.EQ.'LO')THEN
C C - - - the user must have inserted mode,lo and hi
C C MEAN = MODE
C C ISTDEV = NINT((IMIST-ILOWST)*.25)
C C itopend is the stop value for the top, ibotend for the bottom
C C ITOPEND = IMIST
C C IBOTEND = ILOWST
C C ELSEIF(MUORLO.EQ.'MU')THEN
C C - - - the user inserted a mean and stand. dev.
C C ITOPEND = MEAN + ISTDEV + ISTDEV
C C IBOTEND = MEAN - ISTDEV - ISTDEV
C C ELSE
C C RETURN 1
C C ENDIF
C C ----- set the max and min values expected on the xaxis
C C XMIN = FLOAT(ITOPEND)
C C XMAX = FLOAT(IBOTEND)
C C ----- set the min and max values expected on the yaxis
C C YMIN = -200.
C C YMAX = 600.
C C ----- set the number of games played to zero
C C NGAME = 0
C C -----Initialize the output array iutil(i) to some unlikely number
C C -----this number is later checked to see if any entry has been made
C C -----if -99999999 could occur, it may be necessary to change the value used
C C DO 10 I=1,20,1
C C IUTIL(I) = -99999999
C C 10 CONTINUE

```

```

C *** Start processing the form
C C --- large is the factor for a large mean (needed for printout)
C C LARGEM = 1
C C --- if the mean is very large largem becomes 1000.
C C ----- if the mean is small, the units on the screen will be in dollars
C C IF (MEAN.LT. 100000) THEN
C C USERR(1) = ' '
C C USERR(2) = ' '
C C USERR(3) = ' '
C C USERR(4) = ' '
C C USERR(5) = ' '
C C ENDIF
C C ----- round the values for mean and st.dev that will be used
C C IF (ABS(MEAN) .LT. 100) THEN
C C MEAN = (MEAN / 2) * 2
C C IF (ISTDEV.GT. 1000) THEN
C C ISTDEV = NINT(ISTDEV / 200.) * 200
C C ELSEIF (ISTDEV .GT. 100) THEN
C C ISTDEV = NINT(ISTDEV / 20.) * 20
C C ELSEIF (ISTDEV .GT. 5) THEN
C C ISTDEV = NINT(ISTDEV / 2.) * 2
C C ENDIF
C C ELSEIF (MEAN .LT. 1000) THEN
C C MEAN = (MEAN / 20) * 20
C C IF (ISTDEV .GT. 1000) THEN
C C ISTDEV = NINT(ISTDEV / 200.) * 200
C C ELSEIF (ISTDEV .GT. 100) THEN
C C ISTDEV = NINT(ISTDEV / 20.) * 20
C C ELSEIF (ISTDEV .GT. 5) THEN
C C ISTDEV = NINT(ISTDEV / 2.) * 2
C C ENDIF
C C ELSEIF (MEAN .LT. 10000) THEN
C C MEAN = NINT(MEAN / 200.) * 200
C C IF (ISTDEV .GT. 10000) THEN
C C ISTDEV = NINT(ISTDEV / 2000.) * 2000
C C ELSEIF (ISTDEV .GT. 1000) THEN
C C ISTDEV = NINT(ISTDEV / 200.) * 200
C C ELSEIF (ISTDEV .GT. 100) THEN
C C ISTDEV = NINT(ISTDEV / 20.) * 20
C C ENDIF
C C ELSEIF (MEAN .LT. 100000) THEN
C C MEAN = NINT(MEAN / 2000.) * 2000
C C IF (ISTDEV .GT. 10000) THEN
C C ISTDEV = NINT(ISTDEV / 2000.) * 2000
C C ELSEIF (ISTDEV .GT. 1000) THEN
C C ISTDEV = NINT(ISTDEV / 200.) * 200
C C ELSEIF (ISTDEV .GT. 100) THEN
C C ISTDEV = NINT(ISTDEV / 20.) * 20
C C ENDIF
C C ELSE
C C ----- the mean must be very large - so convert units to thousands
C C ----- set the user messages to warn that units are in k dollars.
C C LARGEM = 1000
C C USERR(1) = ' '
C C 10DOLLARS OF INCOME.'
C C USERR(2) = ' '

```



```

CALL BADDR(LA1, LA2, LB1, LB2, IRTM, ISUB, *100)
IF (IRTM .EQ. 1) RETURN 1
C ----- begin the third game. need a value for LB2 (good year)
300 LA1 = IUTIL(11)
    LA2 = IUTIL(12)
    LB1 = IUTIL(10)
    ISUB = 13
    NGAME = 3
DO 301 I=2,5,1
    USERR(1) = 1
301 CONTINUE
CALL GDDYR(LA1, LA2, LB1, LB2, IRTM, ISUB, *200)
IF (IRTM .EQ. 1) RETURN 1
C ----- the next game is a check on the value of IUTIL(12) which
C ----- was elicited in game 2. We are seeking LB1 (bad year).
C ----- the fourth game begins on line 350
400 LA1 = IUTIL(13)
    LA2 = MEAN + (.5 * ISTDEV)
    LB2 = MEAN + ISTDEV
C ----- check to see if LA1 > LA2 if so switch them
IF (LA1.GT.LA2) THEN
    LA2 = LA1
    LA1 = IUTIL(13)
ENDIF
NGAME = 4
ISUB = 20
C ----- IUTIL(20) is the value of the check since 20 doesn't get used
DO 401 I = 2,5,1
    USERR(1) = 1
401 CONTINUE
CALL BADDR(LA1, LA2, LB1, LB2, IRTM, ISUB, *300)
IF (IRTM .EQ. 1) RETURN 1
410 CONTINUE
DIF1=FLOAT(IUTIL(12))-IUTIL(11)
DIF2=FLOAT(IUTIL(20))-IUTIL(11)
C -----dif1 is the dollars difference between util(200)-util(100)
C -----dif2 is the dollars diff. between the check value and util(100)
PDIF=ABS(DIF1-DIF2)/DIF1
C -----pdif is the percentage difference between dif1 and dif2
CRITICAL = 0.05
IF (PDIF .LT. CRITICAL) THEN
    NGAME = 5
    GOTO 500
ENDIF
450 CONTINUE
C ----- since LB1 was not equal to IUTIL(12) print message and get
C ----- user response for what s/he wants to do.
C ----- options are: 1 = go back to games 2, 3 and 4
C ----- 2 = use the game 2 value and proceed
C ----- 3 = average games 4 and 2 - redo 3 then on to 5
CALL MTMCHN(IUTIL(12), MTSPSG(1,3), 10,1)
CALL MTMCHN(IUTIL(20), MTSPSG(1,4), 10,1)
14=15
C ----- where mtspsg are the char*1 being sent to the menu.
460 CALL MTMEMU(14, RSPCHR, *450)
    WRITE(2, *) RSPCHR

```

```

USERR(3) = 1
USERR(4) = 1
USERR(5) = 1
C ----- now round the mean and st.dev. and change units to K dollars
MEAN = NINT(MEAN / 2000.) * 2
IF (ISTDEV .GT. 10000) THEN
    ISTDEV = NINT(ISTDEV / 2000.) * 2
ELSEIF (ISTDEV .GT. 1000) THEN
    ISTDEV = NINT(ISTDEV / 2000.)
ELSE
    (the mean > 100000, but st.dev. < 500, not very interesting)
    so make the st.dev a minimum of 1000 (expressed in K dollars)
    ISTDEV = 1
ENDIF
C ----- also need to reduce graphic max& min as well as stop rule values
XMIN = XMIN * 0.001
IBOTEND = IBOTEND * .001
XMAX = XMAX * .001
ITOPEND = ITOPEND * .001
ENDIF
C ----- so now the mean and stand dev. are in nice round units
C ----- and the initial user messages are set. The stopping rule values
C ----- and the graphics endpoints are also reduced.
14=14
90 CALL MTMEMU(14, RSPCHR, *99)
C ----- a menu message to explain the games that follow
USERR(2) = 1
USERR(3) = 1
C ----- the figures above are based on your input describing y
C ----- our particular sit-
USERR(4) = 1
C ----- uation or more specifically your income distribution.
USERR(5) = 1
C ----- begin the first game. need value for LB1
100 LA1 = MEAN - ISTDEV
    LA2 = MEAN + ISTDEV
    LB2 = MEAN + (.5 * ISTDEV)
    ISUB = 11
    NGAME = 1
CALL BADDR(LA1, LA2, LB1, LB2, IRTM, ISUB, *105)
C ----- a pageup gives irtn=10 & escapes to main menu from this 1st game
105 IF (IRTM .EQ. 10) THEN
    RETURN 1
ELSEIF (IRTM .EQ. 1) THEN
    RETURN 1
ENDIF
C ----- la1 is arbitrarily set to IUTIL(10)
IUTIL(10) = LA1
C ----- the value for IUTIL(isub)=lb1 is set in the subroutine bodyr
200 LA1 = IUTIL(11)
    LA2 = MEAN + ISTDEV
    LB2 = MEAN + (.5 * ISTDEV)
    ISUB = 12
    NGAME = 2
DO 201 I=2,5,1
    USERR(1) = 1
201 CONTINUE

```




```

IF(RSPCHR(1) .EQ. 'A') THEN
  NGAME = 2
  GOTO 200
ELSEIF (RSPCHR(1) .EQ. 'B') THEN
  NGAME = 5
  GOTO 500
ELSEIF (RSPCHR(1) .EQ. 'C') THEN
  TUTIL(12) = NMIT(.5*(UTIL(12)+LB1))
  C ----- begin the third game again. need a value for LB2 (good year)
  LA1 = UTIL(11)
  LA2 = UTIL(12)
  LB1 = UTIL(10)
  NGAME = 3
  ISUB = 13
  USERR(2) = 'In this situation the bed year outcome for plan
  AB is fixed.'
  AB USERR(3) = 'You can only modify the outcome for the good year.'
  A Remember that you'
  USERR(4) = 'need to input a value which makes you indifferent be
  Atween the two'
  USERR(5) = 'marketing plans.'
  CALL GOODYR(LA1,LA2,LB1,LB2,IRTN,ISUB,*400)
  IF (IRTN .EQ. 1) RETURN
  GOTO 500
ELSE
  C ----- the answer to the question was not A, B, or C
  I4=0
  GOTO 460
ENDIF

500 CONTINUE
IF(UTIL(14).EQ.-9999999)THEN
  I4 = 16
  CALL MTHENCU14,RSPCH,*500
  C ----- menu to say that future games arent preceded by "choose a/b"
  ENDF

IF (UTIL(13) .GE. ITOPEMD) THEN
  YMAX = 300.
  YMIN = -500.
  XMAX = FLOAT(UTIL(13))
  GOTO 890
ENDIF
NGAME = 5
ISUB=14
LA1 = UTIL(12)
LA2 = UTIL(13)
LB1 = UTIL(11)

USERR(2) = ' '
USERR(3) = 'Think about whether B is more or less preferred and a
/djust accordingly.'
USERR(4) = ' '
USERR(5) = ' '
501 CONTINUE
CALL GOODYR(LA1,LA2,LB1,LB2,IRTN,ISUB,*400)
IF (IRTN .EQ. 1) RETURN
510 IF (UTIL(13) .GE. ITOPEMD) THEN
  YMAX = 400.
  YMIN = -400.
  XMAX = FLOAT(UTIL(13))
  GOTO 890
ENDIF

600 LA1 = UTIL(13)

```

```

LA2 = UTIL(14)
LB1 = UTIL(12)
NGAME = 6
ISUB = 15
DO 601 I=2,5,1
  USERR(1) = ' '
601 CONTINUE
CALL GOODYR(LA1,LA2,LB1,LB2,IRTN,ISUB,*500)
IF (IRTN .EQ. 1) RETURN
610 IF (UTIL(13) .GE. ITOPEMD) THEN
  YMAX = 500.
  YMIN = -500.
  XMAX = FLOAT(UTIL(13))
  GOTO 890
ENDIF
700 LA1 = UTIL(14)
LA2 = UTIL(13)
LB1 = UTIL(13)
NGAME = 7
ISUB = 16
DO 701 I=2,5,1
  USERR(1) = ' '
701 CONTINUE
CALL GOODYR(LA1,LA2,LB1,LB2,IRTN,ISUB,*600)
IF (IRTN .EQ. 1) RETURN
710 IF (UTIL(13) .GE. ITOPEMD) THEN
  YMAX = 600.
  YMIN = -200.
  XMAX = FLOAT(UTIL(13))
  GOTO 890
ENDIF
800 LA1 = UTIL(15)
LA2 = UTIL(16)
LB1 = UTIL(14)
NGAME = 8
ISUB = 17
DO 801 I=2,5,1
  USERR(1) = ' '
801 CONTINUE
CALL GOODYR(LA1,LA2,LB1,LB2,IRTN,ISUB,*700)
IF (IRTN .EQ. 1) RETURN
IF (UTIL(13) .GT. ITOPEMD) THEN
  YMAX = 700.
  YMIN = -100.
  XMAX = FLOAT(UTIL(13))
  ENDF
890 LSUB = ISUB
LCAME = NGAME
C ----- game is the last game played before working below the mean
C ----- isub is the last sub stored before working below the mean
900 CONTINUE
NGAME = LCAME + 1
C ----- begin the section for utility below the zero
LA1 = UTIL(10)
LA2 = UTIL(11)
LB2 = UTIL(12)

```



```

1 SUB = 9
USERR(2) = ' '
USERR(3) = 'This situation focuses on worse than expected outcomes
A. You can only modify'
USERR(4) = 'the outcome for the BAD year. Remember that you need
A to revise the value'
USERR(5) = 'Until you become indifferent between the two plans.'

CALL BADYR(LA1, LA2, LB1, LB2, IRTM, ISUB, *950)
IF (IRTM .EQ. 1) RETURN 1

IF (YMIN .GT. -100.) THEN
  YMIN = -100.
ENDIF

910 IF (IUTIL(ISUB) .LE. IBOTEND) THEN
  XMIN = FLOAT(IUTIL(ISUB))
  GOTO 2000
ENDIF

GOTO 1000

C ----- section 950 only gets executed if there is a pageup during game 9
950 IF (LGAME.EQ.5) THEN
  GOTO 500
ELSEIF (LGAME.EQ.6) THEN
  GOTO 600
ELSEIF (LGAME.EQ.7) THEN
  GOTO 700
ELSEIF (LGAME.EQ.8) THEN
  GOTO 800
ELSE
  GOTO 500
ENDIF

C ----- there was an error is setting the lgame value so go to 500 by default
GOTO 500
ENDIF

1000 LA1 = IUTIL(9)
LA2 = IUTIL(10)
LB2 = IUTIL(11)
NGAME = LGAME + 2
ISUB = 8
DO 1001 I=2,5,1
  USERR(1) = ' '
1001 CONTINUE

CALL BADYR(LA1, LA2, LB1, LB2, IRTM, ISUB, *900)
IF (IRTM .EQ. 1) RETURN 1

IF (YMIN .GT. -200.) THEN
  YMIN = -200.
ENDIF

1010 IF (IUTIL(ISUB) .LE. IBOTEND) THEN
  XMIN = FLOAT(IUTIL(ISUB))
  GOTO 2000
ENDIF

1100 LA1 = IUTIL(8)
LA2 = IUTIL(9)
LB2 = IUTIL(10)
NGAME = LGAME + 3
ISUB = 7
USERR(2) = ' '
USERR(3) = ' '
USERR(4) = ' '
USERR(5) = ' '
      Almost Finished....'

CALL BADYR(LA1, LA2, LB1, LB2, IRTM, ISUB, *1000)

```

```

IF (IRTM .EQ. 1) RETURN 1
IF (YMIN .GT. -300.) THEN
  YMIN = -300.
ENDIF
1110 IF (IUTIL(ISUB) .LE. IBOTEND) THEN
  XMIN = FLOAT(IUTIL(ISUB))
  GOTO 2000
ENDIF

1200 LA1 = IUTIL(7)
LA2 = IUTIL(8)
LB2 = IUTIL(9)
NGAME = LGAME + 4
ISUB = 6
DO 1201 I=2,5,1
  USERR(1) = ' '
1201 CONTINUE

CALL BADYR(LA1, LA2, LB1, LB2, IRTM, ISUB, *1100)
IF (IRTM .EQ. 1) RETURN 1

IF (YMIN .GT. -400.) THEN
  YMIN = -400.
ENDIF
1210 IF (IUTIL(ISUB) .LE. IBOTEND) THEN
  XMIN = FLOAT(IUTIL(ISUB))
  GOTO 2000
ENDIF

1300 LA1 = IUTIL(6)
LA2 = IUTIL(7)
LB2 = IUTIL(8)
NGAME = LGAME + 5
ISUB = 5
USERR(2) = ' '
USERR(3) = ' '
USERR(4) = ' '
USERR(5) = ' '
      This is the last situation.'
CALL BADYR(LA1, LA2, LB1, LB2, IRTM, ISUB, *1200)
IF (IRTM .EQ. 1) RETURN 1
IF (YMIN .GT. -500.) THEN
  YMIN = -500.
ENDIF
IF (IUTIL(ISUB) .LE. IBOTEND) THEN
  XMIN = FLOAT(IUTIL(ISUB))
ENDIF

C ----- begin output of the Iutil(). this list form will later be
C converted to print out in a graphical form as well.
2000 CONTINUE

C ----- the next section defines graphic defaults for print and screen
2100 CONTINUE
      14=21
2420 CALL RTMENU(14, RSPCHR, *2100)
WRITE(2, *) RSPCHR
IF (RSPCHR.EQ.'A') .OR. (RSPCHR.EQ.'B')) THEN
  C ----- "a" is to view the graph, b is to print
  IF ((YMAX-YMIN).LT. 850.) THEN
    CALL tgsup(1, 4, 8, 20, 76, XMIN, XMAX, YMIN, YMAX)
    title = 'RISK PREFERENCES'
    CALL tgsup(title, 2, 16)
    xlabel = 'Income (in some units as inputted'

```



[illegible]



```

C ----- treat this like the "old" version of escape handling
      IRTN=1
      RETURN
    ELSE
      C ----- the answer to the question was not A,B,C or X
      I4=0
      GOTO 420
    ENDIF
  ELSEIF (IFMRTN.EQ.19) THEN
    C ----- the user pressed f10 to move on
    CALL FMGETI(12,STATUS,LB1)
    IUTIL(1SUB)=LB1
    IRTN=IFMRTN
  ENDIF
  RETURN
END

C -----
SUBROUTINE MTFMAP(IFORM,IDE,STATUS,RSPCH,ISPSKP,IEROR)
C A routine to do after processing for forms

C ----- Start of COMMON/MTCTL2/-----
COMMON/MTCTL2/MTSPSG(50,4),MTSPNO(12,4),MTDLSG(50),MTIPSG(40),
A MTGSTG(50),MMFCTL,DVFCIL,MNFUSR,DVFUSR,MHFCNF,DVFDAT,
B PROBNM(40),PROGMM,MTDATE,MTTIME
C CHARACTER*1 MTSPSG,MTSPNO,MTDLSG,MTIPSG,MTGSTG,DVFCIL,DVFUSR,
A DVFDAT,PROGMM
C CHARACTER*8 MTDATE,MTTIME
C CHARACTER*14 MMFCTL,MNFUSR,MHFCNF
C CHARACTER*36 PROGMM
C CHARACTER*79 TITLE,XLABEL,YLABEL
C ----- End of COMMON/MTCTL2/-----

C CHARACTER*40 ERSTR1
C CHARACTER*10 ERSTR2

C ----- Start of COMMON/ERBK2/-----
COMMON/ERBK2/XMIN,XMAX,YMIN,YMAX,USERR(5),NGAME
C CHARACTER*78 USERR
C ----- End of COMMON/ERBK2/-----

C ----- Start of Variable definition for variables passed to the routine-----
INTEGER*2 IFORM,IDE,ISPSKP,IEROR
C CHARACTER*1 STATUS,ASPCN
C EQUIVALENCE (MTSPSG(1,1),ERSTR1)
C EQUIVALENCE (MTSPSG(1,2),ERSTR2)

C ----- End of Variable definition for variables passed to the routine-----

C CHARACTER*1 XSTAT
IF (IFORM.EQ.2) THEN
  CALL FMGETI(12,XSTAT,112)
  CALL FMGETI(22,XSTAT,122)
  CALL FMGETI(11,XSTAT,111)
  CALL FMGETI(21,XSTAT,121)
  X=(112+122)/2.
  IAVR=NINT(X)
  CALL FMPUTI(32,'P',IAVR)
  WRITE(2,5) IFORM,IDE,STATUS,IEROR,111,121,112,122,NGAME
5 FORMAT(15,A3,15,A3,18,A8,18,A4)
  IF ((112.EQ.111).AND.(122.EQ.121)) THEN
    C ----- a rare occurrence where all cells are equal

```

```

      ELSE
      CALL G1BDYR(IFMRTN,LA1,LA2,LB1,LB2,1SUB)
      ENDIF
    IUTIL(1SUB)=LB1

410 IF (IFMRTN.EQ.10) THEN
C ----- pageup was pressed
      IRTN = 10
      IUTIL(1SUB) = -9999999
      RETURN 1
    ELSEIF (IFMRTN.EQ.1) THEN
C ----- escape key was pressed set the return variable to 1 for escape
      CALL FMGETI(12,STATUS,LB1)
      IUTIL(1SUB)=LB1
      I4 = 20
420 CALL MTHENC(14,RSPCHR,*410)
      IF (RSPCH.EQ.'A') THEN
C ----- "a" is to view the graph
        IF ((YMAX-YMIN).LT.850.) THEN
          CALL tgsup(1,4,8,20,76,XMIN,XMAX,YMIN,YMAX)
          title = 'RISK PREFERENCES'
          CALL tgsent(title,2,16)
          xlabel = 'Income (in same units as Inputted)'
          CALL tglab(xlabel,22)
          ylabel = 'UTILITY'
          CALL tglab(ylabel,1)
          CALL tgsca(3,0,0)
          CALL tgsca(7,100.,0)
        ELSE
          YMAX=1000.
          YMIN=-600.
          CALL tgsup(1,4,8,20,76,XMIN,XMAX,YMIN,YMAX)
          title = 'RISK PREFERENCES'
          CALL tgsent(title,2,16)
          xlabel = 'Income (in same units as Inputted)'
          CALL tglab(xlabel,22)
          ylabel = 'UTILITY'
          CALL tglab(ylabel,1)
          CALL tgsca(3,0,0)
          CALL tgsca(7,200.,0)
        ENDIF
      DO 440 I = 1,19,1
        IF (IUTIL(1).NE.-9999999) THEN
          UT = FLOAT((I - 10) * 100)
          CALL TGPLOT(FLOAT(IUTIL(1)),UT,'*',***)
        C ----- where iutil() is dollars on x axis & ut is utility on y axis
      ENDIF
440 CONTINUE
      I = 0
      CALL MTOUTS(1,1,*499)
      IUNIT = 0
      CALL tgsow(IUNIT,*499)
      I4 = 20
      GOTO 420

499
      ELSEIF (RSPCH.EQ.'B') THEN
C ----- set irtn=pageup but dont use return1 - this will refill with old
C ----- value and paging up will return to the present game.
      IRTN=10
      RETURN
    C //////////////////////////////////////////////////////////////////// the above line was previously "return 1"
      ELSEIF (RSPCH.EQ.'X') THEN

```



```

DOO L3 I=2,5,1
3S CONTINUE
ELSEIF (.I112.GE.I117).AND.(I122.LE.I213) THEN
    USERR(2) = 'your response has created an unfair situation where
    Answering plan B' always better than A.' In this situation you could
    Ad not be indifferent'
    USERA(4) = 'between'
    Answering plan B' always better than A.'
    USERB(5) = 'is not always better than A.'
    TERROR = 1
ELSEIF (.I112.LE.I111).AND.(I122.LE.I213) THEN
    USERR(2) = ''
    USERR(3) = 'your response has created an unfair situation where
    Answering plan B' always best. In this situation you could not be
    A different between'
    USERA(5) = 'the two plans. Revise your response to improve the
    Answering plan B.'
    TERROR = 1
ELSE
    C ----- user input did not create an unfair gamble
    C ----- create messages to encourage continued revision
    USERR(2) = ''
    USERR(3) = ''
    C -----
    Ared.. Then <f10> to go'.
    USERR(6) = 'to the next situation.'
    TERROR = 0
ENDIF
C ----- print error message
CALL PRNUT(102,'P',USERR(1))
CALL PRNUT(102,'P',USERR(2))
CALL PRNUT(103,'P',USERR(3))
CALL PRNUT(104,'P',USERR(4))
CALL PRNUT(104,'P',USERR(5))
CALL PRNUT(104,'P',USERR(6))
C ----- end of the outer if regarding whether this is form 1.
ENDIF
RETURN
END
C -----
SUBROUTINE GOODTREL(LA2,LB1,LB2,ITIN,ISUB,P)
*****
C a routine to fill the screen's request data for a "gooden" year
C the B2 value is returned from the sub, the others are sent to it.
C no error checking on B2 occurs within the sub.
C Ifn is Unomval, Z8 is Unopage, I11page, I12f10, 2 etc.
C Iutl is the output array and iSub the sub for that array
C The asterisk is location for a pageup or down key
C *****
COMMON/ERRK1/MEAN,ISTDEV,MODE,ILOST,IHIST,IUTL,I5AFFY
A ITAGG OUTMAN,MORLO,RSPECR
COMMON/ERRK4/MEAN,ISTDEV,MODE,ILOST,IHIST,IUTL,I5AFFY
CHARACTER*4 MEAN
CHARACTER*2 MORLO
CHARACTER*2 RSPECR
*****
INCLUDE:'ERRLODT.INC'
```



```

CALL tgetxt(title, 2, 16)
xlabel = 'Income (in same units as inputted'
CALL txlabel(xlabel, 22)
ylabel = 'UTILITY'
CALL tylabel(ylabel, 1)
CALL tpxsca(3, 0, 0)
CALL tpxsca(7, 200, 0)
ENDIF

DO 440 I = 1, 19, 1
  IF (IUTIL(I).NE.-99999999) THEN
    UT = FLOAT((I - 10) * 100)
    CALL TGPLOT(FLOAT(IUTIL(I)), UT, 'x', 'x')
    C ----- where iutil() is dollars on x axis & ut is utility on y axis
    ENDOF
  440 CONTINUE
  I = 0
  CALL MTOUTS(1, 1, *499)
  IUNIT = 0
  CALL tshow(IUNIT, *499)
  499 I4 = 20
  GOTO 420

  ELSEIF(RSPCH.EQ.'B')THEN
    C ----- set intrpageup but dont use return - this will refill with old
    C ----- value and paging up will return to the present game.
    IRTN=10
    RETURN
  C ////////////////////////////////////////////////////////////////// the above line was previously "return 1"
  ELSEIF(RSPCH.EQ.'X')THEN
    C ----- treat this like the "old" version of escape handling
    IRTN=1
    RETURN
  ELSE
    C ----- the answer to the question was not A,B,C or X
    I4=0
    GOTO 420
  ENDOF
  ELSEIF(IFMRTN.EQ.19)THEN
    C ----- the user pressed f10 to move on
    CALL FMGETI(22, STATUS, I82)
    IUTIL(IJOB)=I82
    IRTN=IFMRTN
  ENDOF
  RETURN
END

```

[illegible]

```

*****
DIM CASH(MMC), FUTUR(MMC), CARRY(MMC) 'stoch. rev. from cash, futures & carry
DIM OUTMTR1(23, 10, 2) 'where dimensions are row, column, page

FOR I = 1 TO MMC
  CASH(I) = 0 'stoch revenue from prev. cash commitments(not yet delivered)
  FUTUR(I) = 0 'stoch revenue from prev. futures transactions(not yet offset)
  CARRY(I) = 0 'stoch carrying costs due to prev. commitments.
NEXT I
*****
END OF INITIALIZATION - BEGIN USER INPUT ***
*****
REVPRICES = "q"
PRINT
DO UNTIL REVPRICES = "y" OR REVPRICES = "n"
  INPUT "DO YOU WANT TO CHANGE STATIC PRICING INFORMATION (Y or N)"; REVPRICES
  IF REVPRICES = "n" THEN REVPRICES = "n"
  IF REVPRICES = "y" THEN REVPRICES = "y"
  IF REVPRICES = "y" THEN
    PRINT "Today's month is "; MONTH;
    INPUT "Make the month "; AS
    IF AS <> "" THEN MONTH = VAL(AS)
  END IF
  PRINT "The contract month is "; MONTH;
  INPUT "Make it "; AS
  IF AS <> "" THEN MONTH = VAL(AS)
  PRINT "The unbals futures price is ($/bu)"; PFUT;
  INPUT "Make the price "; AS
  IF AS <> "" THEN PFUT = VAL(AS)
  PRINT "The forward contract price is ($/bu)"; PFORC;
  INPUT "Make it "; AS
  IF AS <> "" THEN PFORC = VAL(AS)
  PRINT "The Price of a basis hedge is ($/bu)"; PBASH
  PRINT "Remember: Basis = Cash - Futures"
  INPUT "Make the price "; AS
  IF AS <> "" THEN PBASH = VAL(AS)
  PRINT "The Call premium is ($/bu)"; PCALL1;
  INPUT "Make the premium "; AS
  IF AS <> "" THEN PCALL1 = VAL(AS)
  PRINT "The Strike for the Call is ($/bu)"; SCALL1;
  INPUT "Make the strike "; AS
  IF AS <> "" THEN SCALL1 = VAL(AS)
  PRINT "The Put premium is ($/bu)"; PPUT1;
  INPUT "Make the premium "; AS
  IF AS <> "" THEN PPUT1 = VAL(AS)
  PRINT "The Strike for the Put is ($/bu)"; SPUT1;
  INPUT "Make the Strike "; AS
  IF AS <> "" THEN SPUT1 = VAL(AS)
  PRINT "Round trip trans. costs for futures (cents/bu) = "; TRHDG;
  INPUT "Make it "; AS
  IF AS <> "" THEN TRHDG = VAL(AS)
  PRINT "ONE-WAY trans. costs for options (cents/bu) = "; TROPT;
  INPUT "Make it "; AS
  IF AS <> "" THEN TROPT = VAL(AS)
  PRINT "Margin costs per bushel on futures ($/bu)"; TMARGF;
  INPUT "Make it "; AS
  IF AS <> "" THEN TMARGF = VAL(AS)
  PRINT "Margin costs per bushel on options ($/bu)"; TMARGO;
  INPUT "Make it "; AS
  IF AS <> "" THEN TMARGO = VAL(AS)
  PRINT "The ANNUAL interest rate is ";
  PRINT USING "###.###"; RATE1
  PRINT "Enter eleven percent as 11 and not .11"
  INPUT "Make it "; AS
  IF AS <> "" THEN RATE1 = VAL(AS)
  PRINT "The cash elevator spread for ASK - BID is ($/bu)"; PSPRED;
  INPUT "Make it "; AS
  IF AS <> "" THEN PSPRED = VAL(AS)
  PRINT
  INPUT "DO you wish to revise the above"; REVZS
  IF REVZS = "y" OR REVZS = "n" THEN
    REVPRICES = "q"
  END IF
END IF
LOOP
'for revising static pricing information
'EXBUSH will be expected number of uncommitted bushels
EXBUSH = XMEAN(SYLD(), MMC) 'XMEAN is a function to solve for sample mean
'convert cents per bushel of transactions costs into dollars per bu
TRHDG = TRHDG * .01 'trans costs of futures (round trip)
TROPT = TROPT * .01 'trans costs of options (one way)
RATE1 = (RATE1 / 12) * .01 'convert interest rate to monthly fractional
*****
RANDOMIZE TIMER 'seeds the random number generator with timer value
***** input exogenous variables
'all values computed or inputted need to be shared in this section
NS = 5 'Num of search Variables in opt
MC = 6 'Num of total constraints in opt
NV = 15 'number of stochastic vertices to examine in opt
DIM RR(NV, NS) 'random component to locate the vertices
DIM IORD(NV) 'index array to hold int values for order of util ranking 1=best
ITMAX = 100 'default max # of iterations complex will try
DIM SHARED XX(MV, NC) 'xx() are the control variables
DIM XXOLD(MV, NC) 'the first ns of cu() are upper explicit constraints
DIM SHARED CU(NC) 'later cu are implicit constraints
DIM SHARED CL(NC) 'the first ns of cl() are lower explicit constraints
DIM SHARED XC(NS) 'later cl are implicit constraints
DIM FF(30) 'coordinates for the centroid or for this problem
' the bushels marketed by each method
' value returned from the marketing sub that will be
' MAXIMIZED by complex
' an example of an implicit constraint is when quantity marketed by search
' variables 1 and 2 cannot exceed expected production. In that case you
' can compute search var. 2 = expected prod - search var. 1 and put a lower
' implicit constraint of zero on sv2 and a cu(sv2) = expected production
IPEN = 0 'the number of penalties used in this complex
DIM SHARED UPEN(IPEN)
' UPEN(1) = 0 'the size of penalty ipen
' UPEN(IPEN) = 0 'the size of penalty ipen
ALPHAP = 1.35 'set alpha = 1.35 for all runs, unless alpha = "y"
ALPHS = "y" 'always use variable alpha

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[illegible]

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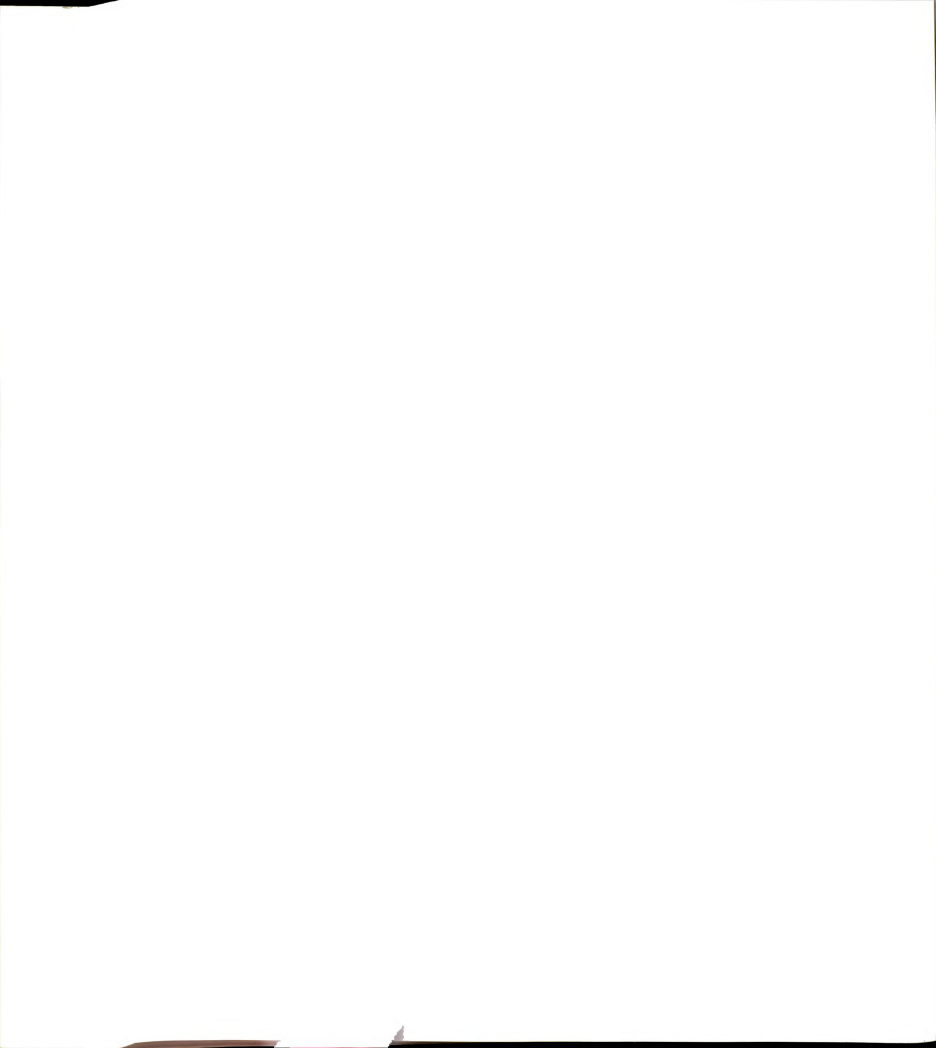
XX(IEV1, J) = XXOLD(IEV1, J)
NEXT J
KSTK = 0
PRINT : PRINT "REPLACING CENTROID BY BEST POINT"
GOTO 102
END IF
FOR J = 1 TO MS
  XX(IEV1, J) = (XX(IEV1, J) + XC(J)) / 21
NEXT J
IIS = IEV1
CALL CONSTRAINTS(IIS)
NFE = NFE + 1
CALL FUNKSHUM(FF(IIS), XX()) 'the function subroutine to be optimized
GOTO 104
END IF
KSTK = 0
IT = IT + 1
'increment the number of iterations
'relates to while IT <= ITMAX
LOOP
  IF IT >= ITMAX THEN
    PRINT "THE NUMBER OF ITERATIONS HAS EXCEEDED"; ITMAX
    PRINT "PROGRAM TERMINATED PREMATURELY"; PRINT
    STUCKS = "Y"
    'stuck referring to max iterations exceeded
  END IF
  IF STUCKS = "N" THEN
    'print final output
    FOR JZ = 1 TO MS
      XX(IEV1, JZ) = XC(JZ)
    NEXT JZ
    IIS = IEV1
    CALL FUNKSHUM(FF(IIS), XX()) 'the function subroutine to be optimized
    ELSEIF STUCKS = "Y" THEN
      PRINT
      IEV3 = 1
      FOR ICH = 2 TO NV
        IF FF(IEV3) <= FF(ICH) THEN IEV3 = ICH
      NEXT ICH
      FOR J = 1 TO MS
        XX(1, J) = XX(IEV3, J)
      NEXT J
      'set initial best guess = best point
      'this restarts program near the max
      'or stuck point if search was stuck.
    END IF
  999 REM
  Z$ = "N"
  DO UNTIL Z$ = "Y" OR Z$ = "N"
    INPUT "RERUN Optimization (Y/N)"; Z$
    IF Z$ = "Y" THEN Z$ = "N"
    IF Z$ = "Y" THEN Z$ = "Y"
    IF Z$ = "Y" THEN
      PRINT "I will re-run the program and allow you to change input values."
      INPUT "HIT RETURN AND I WILL PROCEED ", AS
      RATEI = RATEI * 1200 'convert back to annual (the input units)
      TROPT = TROPT * 100 'convert $ back to cents (the input units)
      TRHDG = TRHDG * 100 'convert $ back to cents (the input units)
      GOTO 100
    END IF
  LOOP
  're-run sim and output summary data here
  'especially the inputs and performance values
  REM $DYNAMIC
  DIM Rerun(1, MS)
  'dimension a dynamic array for followup runs of complex

```




[illegible]

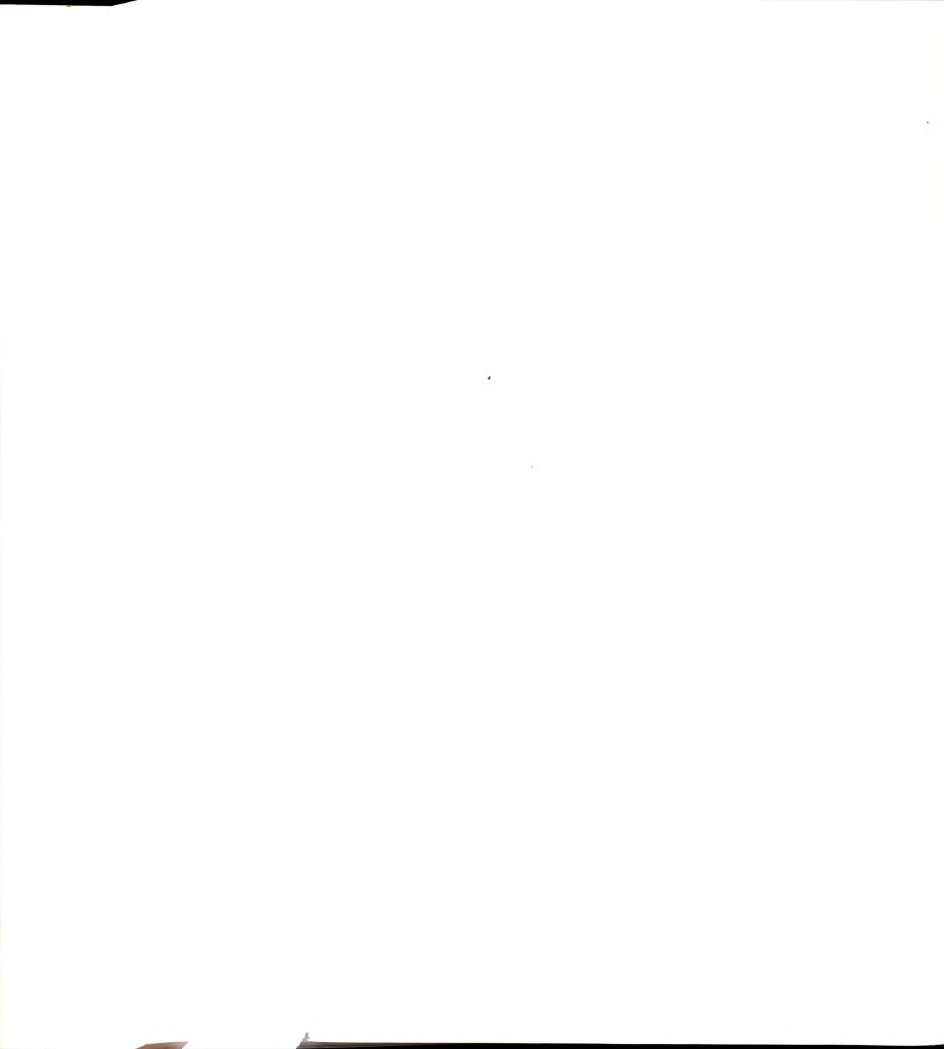




```

LPRT USING " #####"; OUTMATRIX(1,5,1); OUTMATRIX(1,6,1); OUTMATRIX(1,7,1);
LPRT USING " #####"; OUTMATRIX(1,8,1);
LPRT USING " #####.#"; OUTMATRIX(1,9,1); OUTMATRIX(1,10,1)
NEXT I
LPRT "
LPRT " Expected SDev. ----- PERCENTILES -----"
LPRT "plan Util. SDev. 5th 10th 20th 80th"
FOR I = 1 TO (NV + IRRUN)
  LPRT USING " ##"; OUTMATRIX(1,1,2);
  LPRT USING " ###.#"; OUTMATRIX(1,2,2);
  LPRT USING " #####"; OUTMATRIX(1,3,2); OUTMATRIX(1,4,2);
  LPRT USING " #####"; OUTMATRIX(1,5,2); OUTMATRIX(1,6,2);
  LPRT USING " #####"; OUTMATRIX(1,7,2); OUTMATRIX(1,8,2)
NEXT I
LPRT "
LPRT "Today's month is "; MONTH
LPRT "The contract month is "; MONTH
LPRT "The unbiased futures price is ($/bu) "; PFUT
LPRT "The forward contract price is ($/bu) "; PFORC
LPRT "The Price of a basis hedge is ($/bu) "; PBASH
LPRT "The Call premium is ($/bu) "; PCAL1
LPRT "The Strike for the Call is ($/bu) "; SCAL1
LPRT "The Put premium is ($/bu) "; PPUT1
LPRT "The Strike for the Put is ($/bu) "; SPUT1
LPRT "Round trip trans. costs for futures (cents/bu) = "; (TRHOG * 100)
LPRT "ONE-WAY trans. costs for options (cents/bu) = "; (TROPT * 100)
LPRT "Margin costs per bushel on futures ($/bu) "; TMARGF
LPRT "Margin costs per bushel on options ($/bu) "; TMARGO
LPRT "The ANNUAL interest rate is ";
LPRT USING "###.###"; (RATE1 * 1200)
LPRT "The cash elevator spread for ASK - BID is ($/bu) "; PSPRED
FOR I = 1 TO 10
  LPRT "
  LPRT "get to a new page
  NEXT I
  LPRT "The upper constraints for"
  LPRT "Forward Contracting = "; CU(1)
  LPRT "Futures Hedging = "; CU(2)
  LPRT "Put Hedging = "; CU(3)
  LPRT "Basis Contract = "; CU(4)
  LPRT "Speculative Call = "; CU(5)
  LPRT "
  LPRT "PARAMETER VALUES FOR THIS RUN"
  LPRT "MS="; MS; "MC="; MC; "NV="; NV; "ITMAX="; ITMAX
  LPRT "ALPHA="; "ALPHA"; "BETA="; BETA; "GAMMA=";
  LPRT GAMMA, "DELTA="; DELTA; PRINT
  LPRT
  LPRT "this "i#" is related to printing
  LPRT
  LPRT "end of output section
  LPRT "Input a NEW valid filename for saving the output."
  INPUT "The name must be 8 or fewer letters. ", Fname2$
  Fname2$ = Fname2$ + ".OUT"
  OPEN Fname2$ FOR OUTPUT AS #5
  PRINT #5;
  LPRT "PARAMETER VALUES FOR THIS RUN"
  PRINT #5; "MS="; MS; "MC="; MC; "NV="; NV; "ITMAX="; ITMAX
  PRINT #5; "ALPHA="; "ALPHA"; "BETA="; BETA; "GAMMA=";
  PRINT #5; GAMMA, "DELTA="; DELTA; PRINT
  PRINT #5;
  LPRT "The upper constraints for"
  PRINT #5; "Forward Contracting ="; CU(1)
  PRINT #5; "Futures Hedging = "; CU(2)
  PRINT #5;

```



[illegible]



```

: QBASIC (Microsoft).
: =====
IF LOW < INIGH THEN
    ' Only two elements in this subdivision; swap them if they are out of
    ' order, then end recursive calls:
    IF INIGH - LOW = 1 THEN
        IF Array(LOW) > Array(INIGH) THEN
            SWAP Array(LOW), Array(INIGH)
        END IF
    ELSE
        ' Pick a pivot element at random, then move it to the end:
        RandIndex = LOW + INT(RND * (INIGH - LOW + 1))
        SWAP Array(INIGH), Array(RandIndex)
        Partition = Array(INIGH)
        DO
            ' Move in from both sides towards the pivot element:
            I = LOW: J = INIGH
            DO WHILE (I < J) AND (Array(I) <= Partition)
                I = I + 1
            LOOP
            DO WHILE (J > I) AND (Array(J) >= Partition)
                J = J - 1
            LOOP
            ' If we haven't reached the pivot element, it means that two
            ' elements on either side are out of order, so swap them:
            IF I < J THEN
                SWAP Array(I), Array(J)
            END IF
        LOOP WHILE I < J
        ' Move the pivot element back to its proper place in the array:
        SWAP Array(I), Array(INIGH)
        ' Recursively call the QuickSort procedure (pass the smaller
        ' subdivision first to use less stack space):
        IF (I - LOW) < (INIGH - I) THEN
            QuickSort LOW, I - 1, Array()
        ELSE
            QuickSort I + 1, INIGH, Array()
        END IF
    END IF
END SUB

FUNCTION TABEXU (VALU(), ARG(), DUM, K) STATIC
    ' A table lookup function for argument values that are unequally spaced.
    ' The function can extrapolate to find values that lie beyond the highest
    ' (or lowest) ARG. This code was modified from Llewellyn(1965, p.4-22),
    ' and the same code was used by King(1979, p. 224) and Manetsch.
    ' VALU() is table values of the desired function output
    ' ARG() & DUM are in the same units of measure
    ' DUM is the particular value to be looked up
    ' K is the number of elements in the ARG & VALU arrays
    ' this func. was corrected for an error on 4/4/89
    IF DUM > ARG(K) THEN
        TABEXU = (DUM - ARG(K - 1)) * (VALU(K) - VALU(K - 1)) / (ARG(K) - ARG(K - 1))
    ELSE
        FOR J = 2 TO K
            IF DUM <= ARG(J) THEN
                TABEXU = (DUM - ARG(J - 1)) * (VALU(J) - VALU(J - 1)) / (ARG(J) - ARG(J - 1))
            ELSE
                TABEXU = (DUM - ARG(J - 1)) * (VALU(J) - VALU(J - 1)) / (ARG(J) - ARG(J - 1))
            END IF
        NEXT J
    END FUNCTION

```

```

XADDED = XX(IIS, 1) + XX(IIS, 2) + XX(IIS, 3) + XX(IIS, 4) + XX(IIS, 5)
PRINT USING " #####.##"; XX(IIS, 1); XX(IIS, 2); XX(IIS, 3); XX(IIS, 4); XX(IIS, 5);
---->S); XADDED;
PRINT USING " ##.## "; IIS; ALPHA;
PRINT USING " #####.##"; ANSWER 'these 3 lines scroll on screen at run time
END SUB

SUB ORDERX (X(), ISUB(), I, N) STATIC
    ' This program evaluates the unsorted array X. The array ISUB() and X() are
    ' both of dimension I TO N. X() is sorted, but its subscripts and associated
    ' values are not re-assigned as they would be in a true sort. Instead,
    ' ISUB(I TO N) = a value of from I to N. ISUB(I) = the subscript value for
    ' the X() that is highest, and ISUB(N) the X() that is lowest. For example:
    ' Suppose that X(3) is the second highest of all X(). Then ISUB(1+1) = 3.
    ' Because this is based on a bubble sort it is good when the X array is not
    ' too long.
    ' Initialize the ISUB array
    FOR J = I TO N
        ISUB(J) = J
    NEXT J
    FOR J = I TO (N - 1)
        FOR K = (J + 1) TO N
            IF X(ISUB(J)) < X(ISUB(K)) THEN
                SWAP ISUB(J), ISUB(K)
            END IF
        NEXT K
    NEXT J
END SUB

FUNCTION PERCENTILE (X(), LOW, INIGH, PTILE) STATIC
    ' This function finds percentiles of sorted arrays if the array is sorted from
    ' lowest value to highest. The LOW parameter is the lowest subscript value
    ' for the array (usually 0 or 1), and INIGH is the highest subscript value
    ' for the array. Since the array is sorted X(LOW) is the smallest value of
    ' the variable and X(INIGH) is the highest. PTILE is the desired percentile.
    ' For the 10Xtile the value of PTILE must be .1 and NOT 10.
    ' =====
    IF PTILE > 1 THEN PTILE = PTILE * .01
    J = INT((INIGH - LOW + 1) * PTILE)
    PERCENTILE = X(J)
END FUNCTION

SUB QuickSort (LOW, INIGH, Array())
    ' ===== QuickSort =====
    ' QuickSort works by picking a random "pivot" element in Array, then
    ' moving every element that is bigger to one side of the pivot, and every
    ' element that is smaller to the other side. QuickSort is then called
    ' recursively with the two subdivisions created by the pivot. Once the
    ' number of elements in a subdivision reaches two, the recursive calls end
    ' and the array is sorted.
    ' There is a non-recursive quicksort on page 153 of the book basic programs
    ' for scientists and engineers. (Miller, Alan; 1981)
    ' If the array is partially sorted then picking the first element
    ' of the array slows execution, so random pivot is more desirable.
    ' Else if the array has absolutely no order, then there is no need
    ' to randomly choose a pivot, and you might as well choose the
    ' first element of the array. This is a recursive quicksort supplied with

```



```

      GOTO FOUNDIT
    END IF
  NEXT J
END
FOUNDIT: REM
END FUNCTION

      'foundit is a line label

FUNCTION XMEAN (XNUM(I), IOBS) STATIC
  DIM TOT#
  FOR I = 1 TO IOBS
    TOT# = TOT# + XNUM(I)
  NEXT I
  XMEAN = TOT# / IOBS
END FUNCTION

FUNCTION XSTDDEV (XNUM(I), IOBS) STATIC
  DIM SUMSQ#
  ' This function computes the standard deviation of the input array.
  ' IOBS is the length of the input array.
  ' the pound subscript indicates double precision (DP) which results in
  ' a more accurate answer than single precision (SP) which would be
  ' larger. Without DP, SUM would get large and subsequent xnum() values
  ' would add very little and possibly nothing to the value of SUM.
  SUM# = 0
  SUMSQ# = 0
  FOR J = 1 TO IOBS
    SUM# = SUM# + XNUM(J)
    SUMSQ# = SUMSQ# + XNUM(J) * XNUM(J) + SUMSQ#
  NEXT J
  XSTDDEV = SQR((SUMSQ# - SUM# * SUM# / IOBS) / (IOBS - 1))
END FUNCTION

```



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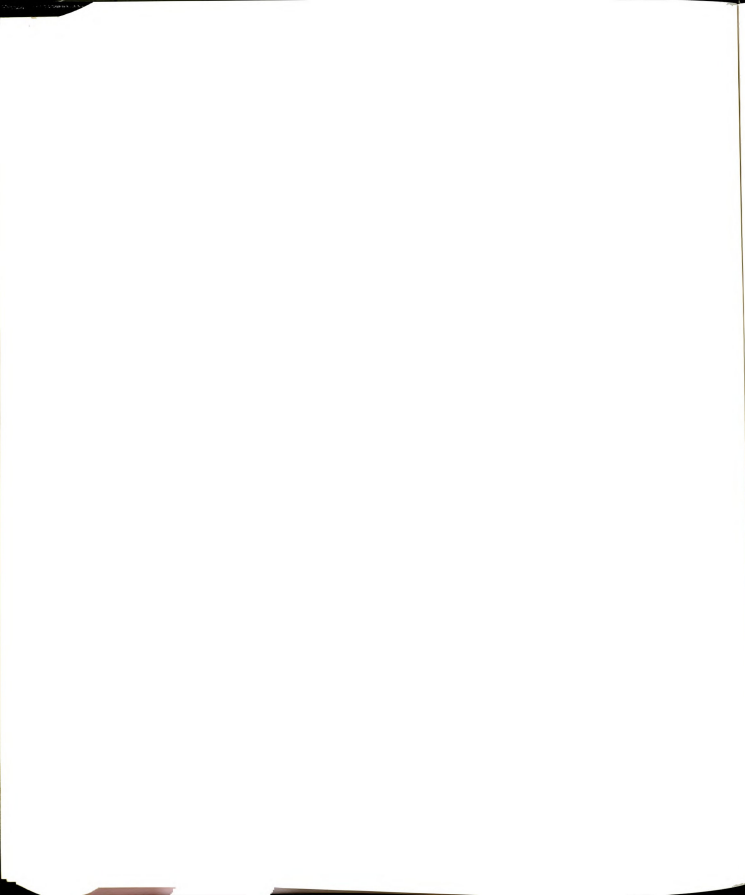
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