Harvesting Behavior of Perennial Cash Crops: A Decision Theoretic Study

by

Segu M.M. Zuhair

Dissertation submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Agricultural Economics

APPROVED:

Randall A. Kramer *Co-chairman*	Daniel B. Taylor *Co-chairman*
Thomas G. Johnson	Stephen D. Reiling

Darrell J. Bosch

October, 1986
Blacksburg, Virginia

Harvesting Behavior of Perennial Cash Crops:

A decision Theoretic Study

by

Segu M.M. Zuhair

Randall A. Kramer, Co-chairman

Daniel B. Taylor, Co-chairman

Department of Agricultural Economics

(ABSTRACT)

This study analyzed the harvesting behavior of perennial cash-crop growers in Sri Lanka. These growers face two alternatives with respect to harvesting; premature and mature harvesting.

The objectives of the study were: to determine the reasons for premature harvesting, to explain this behavior with socio-economic factors as explanatory variables, and to describe the behavior with decision theory.

The first objective was achieved by surveying a sample of 240 farmers. Fear of theft and immediate money needs were the reasons why most farmers harvested their crop at a premature stage.

A logit probability model was used to explain this behavior. Education of the farmer, ratio of lowland to total land operated by the farmer, and the total family income were significantly related to harvesting behavior.

Expected utility theory, expected profit maximization, and a lexicographic safety-first model were used to predict farmer behavior. The expected utility

approach used the exponential utility function, the quadratic utility function, and the cubic utility function. The lexicographic safety-first model minimized the probability of regret as the first objective and maximized the expected income as the second objective, in that order.

The expected utility model with the exponential utility function made the largest number of correct predictions followed by the the expected profit maximizing model. The conclusions of this study, while providing more evidence of the poor predictive ability of the expected profit maximizing model, further supports the usefulness of expected utility theory in describing and predicting farmer behavior. A majority of the studies on farmer behavior have concentrated on resource allocation. This study has demonstrated that even harvesting behavior can be explained by expected utility theory.

There was no consistency in the way the utility functions ranked the two harvesting alternatives; for certain farmers the ranking of one function reversed the ranking of other functions. This study has, thus, demonstrated the influence of utility functional forms on the ranking of prospects. The results were sensitive to changes in the discount rate and the results of the safety-first model were sensitive to changes in the expected income.

In
memory
of
my
beloved
father
and
To
my
mother

with
love
and
eternal
gratitude

Acknowledgements

Writing this dissertation has been an enjoyable and a rewarding experience for me, and I hope the reader will find it useful. Several people were responsible for making this project an enjoyable experience. A great deal of this experience was due to working closely with the co-chairmen of my advisory committee; they indeed maximized my expected utility during the past three years.

I thank my co-chairmen, Dr. Randall Kramer and Dr. Daniel Taylor for their time, guidance, and suggestions at all stages of the research. I thank Dr. Kramer for carrying a computer half way around the world to make my research easier, and for his guidance with my field research in Sri Lanka. This dissertation, and I, have benefited a great deal from their professional and personal contributions. I thank them both for sharing their knowledge and experience, and for all the stimulating discussions which helped me make this a valuable contribution.

The members of my advisory committee, Dr. Thomas Johnson, Dr. Stephen Reiling, and Dr. Darrell Bosch, made valuable suggestions for improving this dissertation. I thank them for their time and suggestions, and for agreeing to serve on my committee. I would also like to thank Dr. George Norton for his assistance at the early stages. I thank Dr. Sriramaratnam for his suggestions on the questionnaire.

Several people helped with the field research in Sri Lanka. I thank Dr. Maxwell de Silva (Head, Division of Economics, Department of Minor Export Crops, Peradeniya, Sri Lanka) for his suggestions and for allowing me to use the services of his assistants to survey the farmers. Messers M.W.M. Silva, A.M. Abeysundara, B. Amerasinghe, and A.D.K. Dissanayake helped me with the first survey. I thank my research assistants Lukman Thalib, Fazal Mohamed, I.H. Dharmasekara, and T.M.G. Tennakoon for helping me compile and tabulate the secondary data. I thank Velivita, Witharama, Kalyani Dias, and I.H. Dharmasekara for helping me with the most difficult part of the study which was eliciting farmers' utility functions.

I thank Shiyamalee Dissanayake for finding all the money I needed, for the numerous phone calls and telexes, and for being a pleasant person to work with. Most of the field survey data and the secondary data were encoded on diskettes in Sri Lanka by Anomie Wickremasuriya. I thank her for patiently entering all those data, which saved me a lot of time. I thank Shanaz Cassim for her help with typing.

I would like to thank all those wonderful people who made my personal life happy during the project. I thank my mother and my brothers and sisters for their love, patience, and understanding. I thank my friends Raffeek and Nissanka for their friendship and all their help during the four months of research in Sri Lanka.

I like to thank those who made my departure from Blacksburg a very sad one. I thank Dr. J.D. Stahl for the continued friendship and teachings, and for giving me a place to live. To my friend Chris Burch: thanks for being a good friend and for teaching me that there is more to a painting than the canvas, shapes, and colors; and that there is more to music than sounds and beats. Chris, thanks for all the night long stimulating conversations on the meaning of life and the meaning of another thing or two. A special word of thanks to Llyn Sharp for being a friend. Thank you all very much for making my life in Blacksburg a happy one and showing me the part of America I liked.

I thank my colleagues Mesfin Bezuneh, Kevin MacNamara, and Edward (Kofi) Adusei for their concern, support, and encouragement. I thank my office-mate Steve Turner for his concerns and the stimulating discussions on the plots to stage a revolution in the methodology of economics.

My stay at Virginia Tech and my dissertation research were funded by the Agricultural Education Development (AED) program of USAID. I thank USAID for their generous support and those at the Office of International Agriculture, Virginia Tech, for co-ordinating the services. I thank Dr. P.H. Massey (Director, International Agriculture, Virginia Tech), and I thank Peggy Hall for being a friend and for taking care of everything that needed to be taken care of to make the participants comfortable during the past seven years. I thank Magarita Driscoll (Project Associate, AED) for her friendship and encouragement.

Finally, I thank my beloved mother for the care, hard work, and patience. I thank my brothers and sisters for their understanding, love, and care.

Table of Contents

List of Tables

List of Figures

Causality is a decent, honorable principle, but it does not have all the answers. If we want to make sense of things, we have to move beyond it. We have to recognize that many important phenomena refuse to be packed into neat causal packages but can be interpreted only by stochastic methods.

R. Silverberg, *The Stochastic Man.* New York: Fawcet, 1975, (p. 9).

Chapter 1

BACKGROUND AND THE PROBLEM

1.1 Introduction

Agriculture is the main occupation and source of income, both domestically and in terms of foreign exchange, in Sri Lanka. The Agriculture, Forestry, and Fisheries sector contributed Rs.24,964 million, Rs.32,180 million, and Rs.40,218 million to the Gross National Product (GNP) in 1982, 1983, and 1984 respectively. This represented 27%, 29%, and 30% of the GNP of Sri Lanka at current factor cost prices (Table 1.1). This sector contributes the largest component of GNP in Sri Lanka.

Agriculture in Sri Lanka plays an even more important role in the economy in terms of export earnings. In 1973 nearly 83% of the total export earnings of the country were from agricultural products, 95% of which were from tea, rubber, and coconut. The contribution of agriculture to the export economy of the country has been decreasing over time. In 1984 it stood at 60.4% of the total export earnings. The contribution of tea, rubber, and coconut has, however, remained around 90% of the total export earnings from agriculture (Table 1.2). The need to diversify Sri Lankan exports to hedge against adverse price and demand conditions in the international markets has resulted in increased emphasis on both alternate agricultural crops and alternate industrial investment. Attention to industrial growth has resulted in an investment promotion zone aimed at attracting investors from abroad into Sri Lanka with the objectives of increasing local employment and increasing foreign exchange earnings. On the

Table 1.1: Gross National Product of Sri Lanka. (Rs. million)[1]

	Current factor cost prices			Constant 1982 factor cost prices	
Sector	1982	1983	1984	1983	1984
Agriculture, forestry and fishery	24964 *(27.4)*	32180 *(29.6)*	40280 *(30.0)*	26212 *(27.6)*	26164 *(26.2)*
Mining and Quarrying	2238 *(2.5)*	2799 *(2.6)*	3153 *(2.3)*	2413 *(2.5)*	2449 *(2.5)*
Manufacturing	13601 *(14.9)*	15958 *(14.7)*	20890 *(15.5)*	13710 *(14.4)*	15390 *(15.4)*
Construction	7959 *(8.7)*	9807 *(9.0)*	11180 *(8.3)*	8039 *(8.5)*	8030 *(8.0)*
Electricity, gas, water and sanitary services	1089 *(1.2)*	1428 *(1.3)*	1633 *(1.2)*	1161 *(1.2)*	1239 *(1.2)*
Transport, storage, and communication	10666 *(11.7)*	12554 *(11.5)*	15499 *(11.5)*	11146 *(11.7)*	12288 *(12.3)*
Wholesale and retail trade	19694 *(21.6)*	21759 *(20.0)*	27192 *(20.2)*	20738 *(21.9)*	22029 *(22.1)*
Banking, insurance, and real estate	2230 *(2.4)*	2281 *(2.1)*	2875 *(2.1)*	2707 *(2.9)*	3005 *(3.0)*
Ownership of dwellings	3250 *(3.6)*	3696 *(3.4)*	3958 *(2.9)*	3315 *(3.5)*	3381 *(3.4)*
Public administration and defence	2899 *(3.2)*	4100 *(3.8)*	5322 *(3.9)*	3786 *(4.0)*	4165 *(4.2)*
Services (non-essential)	4604 *(5.0)*	5414 *(5.0)*	6343 *(4.7)*	4590 *(4.8)*	4636 *(4.6)*
Gross Domestic Product	***93194***	***111976***	***138173***	***97817***	***102776***
Net Income from abroad	*-1959*	*-3214*	*-3401*	*-2936*	*-2996*
Gross National Product	***91235***	***108762***	***134772***	***94881***	***99780***

Source: Central Bank of Ceylon, Review of the Economy- 1984.

[1] Figures in parenthesis refer to percentage of the GNP.

See table 1.4 for exchange rates.

Table 1.2: Export Earnings from Agriculture in Sri Lanka, 1973-1984.[1] (Rs. million).

Year	Tea	Rubber	C'nut	Total T,R,& C	Other Agric Prod.	Total Agric.	Total Export Earnings
1973	1260.7	591.5	229.2	2081.4	100.2	2181.6	2629.8
	(47.9)	*(22.4)*	*(8.7)*	*(79.1)*	*(3.8)*	*(82.9)*	
1974	1359.7	738.5	540.6	2638.8	152.5	2791.3	3502.9
	(38.8)	*(21.1)*	*(15.4)*	*(75.3)*	*(4.3)*	*(79.7)*	
1975	1931.6	653.7	494.8	3080.1	114.5	3194.6	3968.5
	(48.7)	*(16.5)*	*(12.5)*	*(77.6)*	*(2.9)*	*(80.5)*	
1976	2099.7	889.6	494.4	3483.7	204.2	3687.9	4840.1
	(43.4)	*(18.4)*	*(10.2)*	*(72.0)*	*(4.2)*	*(76.2)*	
1977	3502.5	930.6	495.5	4928.6	332.8	5261.4	6569.1
	(53.3)	*(14.2)*	*(7.5)*	*(75.0)*	*(5.1)*	*(80.1)*	
1978	6400.9	2020.6	1271.0	9692.5	722.8	10415.3	13193.0
	(48.5)	*(15.3)*	*(9.6)*	*(73.5)*	*(5.5)*	*(78.9)*	
1979	5722.2	2491.6	1698.7	9912.5	887.9	10800.4	15282.0
	(37.4)	*(16.3)*	*(11.1)*	*(64.9)*	*(5.8)*	*(70.7)*	
1980	6170.1	2590.4	1234.3	9994.8	878.4	10873.2	17595.0
	(35.1)	*(14.7)*	*(7.0)*	*(56.8)*	*(4.9)*	*(61.8)*	
1981	6444.0	2889.0	1437.6	10770.6	1397.6	12168.2	21043.1
	(30.6)	*(13.7)*	*(6.8)*	*(51.2)*	*(6.6)*	*(57.8)*	
1982	6342.2	2322.6	1468.5	10133.3	1295.2	11428.5	21453.7
	(29.6)	*(10.8)*	*(6.8)*	*(47.2)*	*(6.0)*	*(53.3)*	
1983	8295.2	2851.8	1921.0	13068.0	1485.7	14553.7	25096.2
	(33.1)	*(11.4)*	*(7.6)*	*(52.1)*	*(5.9)*	*(58.0)*	
1984	15764.3	3301.3	2118.3	21183.9	1358.1	22542.0	37346.6
	(42.2)	*(8.8)*	*(5.7)*	*(56.7)*	*(3.6)*	*(60.4)*	

Source: Central Bank of Ceylon, Review of the Economy, 1984.

[1] Figures in parenthesis refer to percentages of total export earnings of Sri Lanka corrected to one decimal place.

See table 1.4 for exchange rates.

agricultural side, diversification has resulted in the export of non-traditional commodities from Sri Lanka.

The agricultural sector in Sri Lanka has been traditionally divided into two sub-sectors. One is the peasant sub-sector and the other is the plantation sub-sector. The peasant sector, which produces mainly food crops, is characterized by fragmented land holdings which vary between 2 to 10 acres and are mostly family managed. The plantation sector, on the other hand, is export oriented and is comprised of large estates growing tea, rubber, and coconut.

In addition to these two sub-sectors, the minor-export crop (MEC) sector of the economy can be identified as a third sub-sector. This sub-sector is comprised of cocoa, coffee, pepper, cardamoms, nutmeg, cloves, cinnamon, vegetables, fruits, arecanuts, sesame seeds, oil seeds, betel leaves, unmanufactured tobacco, pappain, and essential oils. These crops are primarily grown in small holdings. In 1984 the export earnings from these MEC's reached Rs.1,358 million which represents about 3.6% of the Gross National Product of Sri Lanka (Table 1.3).

Of these crops, the ones included in this study are cocoa, coffee, pepper, cardamoms, and nutmeg. The contribution of these crops to the foreign exchange earnings of the country was Rs.441.5 million in 1984 which is 0.011% of the total foreign exchange earnings.

1.2 The Minor-Export Crop Industry of Sri Lanka

Sri Lanka has been long known for its spices. Spices were the reason why some of the imperialists decided to remain on the island [C.R. de Silva]. During ancient times Sri Lanka was primarily known for its cinnamon. Later, under British rule, coffee became a major export crop. With the onset of coffee rust in the 1860's, which wiped out large tracts of coffee plantations, tea replaced coffee and became the major export crop. Tea was followed by large plantings of rubber and coconut and soon tea, rubber, and coconut became the major export crops of Sri Lanka leading to the characterization of coffee and cinnamon as "minor-export crops". Currently, the crops which fall into the category of MEC are: cocoa, coffee, pepper,

Table 1.3: Value of Export of Minor-Export Crops, 1973-1984. (Rs. Million)

Year	Coffee	Pepper	Nut meg	Cardo moms	Cocoa	Total MEC (1)	Other MEC (2)	Total Export (3)	Total (4)
1973	0.6	12.9	2.2	8.4	6.1	30.2 *(29.5)*	72.0	100.2 *(3.8)*	2629.8
1974	2.1	3.4	1.4	6.5	10.8	24.2 *(15.9)*	128.3	152.5 *(4.4)*	3502.9
1975	9.6	1.2	2.5	12.7	11.2	37.2 *(32.5)*	77.3	114.5 *(2.9)*	3968.5
1976	24.5	0.2	3.4	12.2	13.1	53.4 *(26.1)*	150.8	204.2 *(4.2)*	4840.5
1977	33.2	13.3	1.8	11.4	38.8	98.5 *(29.4)*	236.3	334.8 *(5.1)*	6569.8
1978	85.2	35.1	9.4	40.4	50.2	220.3 *(30.5)*	502.5	722.8 *(5.5)*	13193.0
1979	106.3	22.9	8.5	55.2	31.8	224.7 *(25.3)*	663.2	887.9 *(5.8)*	15282.0
1980	40.0	19.0	6.7	44.1	32.6	142.4 *(16.2)*	736.0	878.4 *(5.0)*	17595.2
1981	65.1	51.7	9.8	53.3	30.5	210.4 *(15.1)*	1187.2	1397.6 *(6.6)*	21043.1
1982	110.0	34.2	9.7	49.0	21.8	224.8 *(17.4)*	1070.4	1295.2 *(6.0)*	21453.7
1983	163.3	38.1	10.4	41.9	26.7	280.1 *(18.9)*	1205.6	1485.7 *(5.9)*	25096.2
1984	234.0	93.0	15.3	71.5	27.7	441.5 *(32.5)*	916.6	1358.1 *(3.6)*	37346.6

Source: Central Bank of Ceylon, Review of the Economy, 1984.

(1) This gives the total for the five crops in the study. The figures in parenthesis give the value of these crops as a percentage of all the minor export crops.
(2) Other minor export crops include: vegetables, fruits, arecanuts, cinnomon, cloves, sesame seeds, oil seeds, beetel leaves, unmanufactured tobbacco, pappain, and essential oils.
(3) This column gives the total for all the MEC's.
(4) This column gives the total export for the country.

See table 1.4 for exchange rates.

Table 1.4: End of Period Exchange Rate, 1973-1984.[1]

(Sri Lankan Rupees per unit of foreign currency)

Year	United States of America *(Dollars)*	United Kingdom *(Pound)*	India *(Rupees)*	Pakistan *(Rupees)*
1973	6.74	15.60	0.829	0.675
1974	6.69	15.60	0.829	0.674
1975	7.71	15.60	0.861	0.770
1976	8.86	14.61	0.994	0.585
1977	8.99	15.53	1.021	0.865
1977[1]	15.56	29.85	1.850	1.588
1978	15.50	31.67	1.910	1.653
1979	15.44	34.56	1.940	1.560
1980	18.00	42.69	2.280	1.823
1981	20.55	39.09	2.200	2.043
1982	21.32	34.61	2.160	1.633
1983	25.00	35.89	2.350	1.840
1984	26.28	30.51	2.120	1.722

Source: Central Bank of Ceylon, Review of the Economy, 1984.

[1] Begining midnight of 15 November, 1977, the Sri Lankan Rupee was allowed to float, and daily buying and selling rates of major currencies for telegraphic transfers by Commercial banks were announced by the Central Bank of Ceylon.

cardamoms, nutmeg, cloves, cinnamon, vegetables, fruits, arecanuts, sesame seeds, oil seeds, betel leaves, unmanufactured tobacco, pappain, and essential oils.

Of the total land area of Sri Lanka, the MEC's selected for this study are grown on 76,832 acres, which is 0.47% of total land area. This is about 2% of the total arable land in the country. Of the country's 24 administrative districts, 13 grow some of these MEC's, and the districts of Kandy and Matale have 28,308 and 22,000 acres, respectively, under cultivation with the crops in this study (Table 1.5). Tables 1.6 and 1.7 give the distribution of MEC's in Sri Lanka. The two sets of figures in these tables were compiled from two different sources and as can be seen the figures are different. The major differences are with respect to planted acreage of coffee and pepper. This discrepancy in the recorded data highlights one of the problems in the MEC industry: lack of proper record keeping. Tables 1.6 and 1.7 show that the districts of Kandy and Matale contain nearly a third of the total coffee acreage and more than two thirds of the total acreage of the other crops in this study. This justifies the selection of Kandy and Matale as the area of study.

Table 1.8 gives the volume of export of MEC by Sri Lanka from two sources. One is from the records of Central Bank of Ceylon, the other is from the Food and Agriculture Organization (FAO). These figures show that the export of coffee has increased over 28 times during the past 10 years while the export of cocoa has declined about 30% during the same period. The export of pepper has had wide fluctuations while the amount of nutmeg and cardamom exported has remained stable.

The small contribution made by the MEC sector could be the reason why this sector has been neglected. Shultz expresses concern over neglecting sub-sectors of the economy which do not make significant contributions to the economy and attributes this to the *"...state of economic knowledge..."* and *"...widely held doctrines about the agricultural sector..."* (p. 6). Shultz goes on to assert that transforming a traditional type of agriculture has a lot to do with investment. He argues that the contribution of agriculture to economic development can be increased in any country, be it a developed economy or a developing economy. This is achieved best with modernized agriculture. Modernization of rural agriculture involves the

Table 1.5: Distribution of Land to Export Crops by District, 1983. (Acres).

District	Tea	Rubber	Coco-nut	Paddy (Rice)	MEC[1]	TOTAL
Kandy	184087 *(34.5)*	13170 *(2.4)*	15433 *(2.8)*	82562 *(15.5)*	28308.7 *(5.3)*	532952
Nuwara Eliya	98568 *(27.8)*	0	2203	27276 *(7.7)*	2425.0	354988
Matale	17651 *(3.6)*	16235 *(3.3)*	22151 *(4.5)*	49958 *(10.1)*	22000.0 *(4.5)*	492839
Kurunegala	929	12718 *(1.0)*	364458 *(30.9)*	307787 *(26.1)*	7519.9	1179647
Badulla	89006 *(12.8)*	10179 *(1.5)*	1504	73085 *(10.5)*	4880.0	697034
Moneragala	0	0	9124	40528 *(2.9)*	2715.0	1397995
Kegalla	28519 *(6.9)*	118940 *(28.9)*	51425 *(12.5)*	54666 *(13.3)*	3234.5	410712
Ratnapura	55854 *(7.0)*	91583 *(11.4)*	29104 *(3.6)*	75861 *(9.5)*	2135.1	799984
Colombo & Gampaha	788	57314 *(11.1)*	182538 *(35.3)*	103340 *(20.0)*	990.0	517070
Kalutara	8867 *(2.2)*	117276 *(29.4)*	30448 *(7.6)*	90681 *(22.7)*	475.0	399029
Galle	38236 *(9.2)*	49800 *(11.9)*	31828 *(7.6)*	100079 *(24.0)*	559.9	417257
Matara	40058 *(13.0)*	20380 *(6.6)*	40965 *(13.3)*	95527 *(31.0)*	1315.0	307861
Hambantotta	289	210	51398 *(8.0)*	89125 *(13.8)*	274.9	647881
Other Districts[2]	0	0	82124	508235	0	805032
TOTAL	**562851** *(3.47)*	**507804** *(3.13)*	**1035426** *(6.39)*	**2445816** *(15.1)*	**31106.0** *(0.47)*	**16205571** *(100.0)*

Source: Central Bank of Ceylon, Economic and Social Statistics of Sri Lanka. Vol. VII (December, 1984)

[1] This column includes the crops which are included in this study

[2] Other Districts include: Jaffna, Mannar, Vavuniya, Mulaithivu, Batticoloa, Amparai, Trincomalee, Puttalam, Anuradhapura, and Polonnaruwa

Table 1.6: Distribution of Minor-Export Crops in Sri Lanka[1] (Acres).

District	Cocoa	Coffee	Cardo mom	Pepper	Cloves	Nutmeg	Cinna mon
Kandy	9177 *(29.3)*	9317 *(27.0)*	5707 *(39.3)*	15992 *(45.2)*	4846 *(58.7)*	1674 *(74.2)*	18
Nuwara Eliya	118	2203 *(6.4)*	538 *(3.7)*	274	298 *(3.6)*	0	193
Matale	14166 *(45.3)*	4311 *(12.5)*	5085 *(35.0)*	10413 *(29.4)*	707 *(8.6)*	203 *(9.0)*	386
Kurunegala	3958 *(12.6)*	4319 *(12.5)*	264 *(1.8)*	2684 *(7.6)*	227 *(2.7)*	295 *(13.1)*	73
Badulla	100 *(2.9)*	998 *(2.6)*	13	931	0	0	36
Moneragala	2483 *(7.9)*	413 *(1.2)*	0	67	0	0	0
Kegalla	896 *(2.9)*	6335 *(18.4)*	1618 *(11.1)*	2587 *(7.3)*	1929 *(23.4)*	58 *(2.6)*	380
Ratnapura	219	2024 *(5.9)*	1266 *(8.7)*	329	146 *(1.8)*	11	6539 *(9.6)*
Colombo and Gampaha	11	2351 *(6.8)*	8	629 *(1.8)*	11	0	2649 *(4.0)*
Kalutara	123	873 *(2.5)*	0	119	5	2	4998 *(7.6)*
Galle	44	770 *(2.2)*	3	157	10	0	26931 *(40.8)*
Matara	0	544 *(1.6)*	14	241	75	8	21915 *(33.2)*
Hambantotta	1	33	1	944 *(2.7)*	7	6	2034 *(3.1)*
***Total** (Kandy and Matale)*	*23343 (74.6)*	*13628 (39.5)*	*10792 (74.3)*	*26405 (74.6)*	*5553 (67.3)*	*1877 (83.2)*	*404*
TOTAL	**31296**	**34491**	**14520**	**35367**	**8261**	**2257**	**65972**

Source: Department of Census and Statistics, Highland Crops and Livestock Statistics, 1980.

[1] Figures in parenthesis refer to the percentage of the total acreage for the crop. Only the percentages which are greater than 1 are given.

Table 1.7: Distribution of Minor-Export Crops in Sri Lanka (Acres).

District	Cocoa	Coffee	Cardo mom	Pepper	Cloves	Nutmeg	Cinna mon
Kandy	10625 *(33.5)*	4000 *(21.4)*	6210 *(57.2)*	3600 *(30.0)*	3950 *(35.8)*	3875 *(69.8)*	0
Nuwara Eliya	0	1025 *(5.5)*	1065 *(8.8)*	320 *(2.7)*	160 *(2.9)*	15	0
Matale	14900 *(46.9)*	2125 *(11.4)*	2215 *(18.3)*	2600 *(21..7)*	1120 *(10.2)*	160 *(2.9)*	0
Kurunegala	2650 *(8.3)*	3025 *(16.2)*	300 *(2.5)*	1275 *(10.6)*	570 *(5.2)*	270 *(4.9)*	0
Badulla	750 *(2.4)*	3350 *(17.9)*	5	750 *(6.3)*	605 *(5.5)*	25	0
Moneragala	1925 *(6.1)*	725 *(3.9)*	0	65	25	0	0
Kegalla	800 *(2.5)*	1959 *(10.5)*	1250 *(10.3)*	1610 *(13.4)*	2750 *(24.9)*	850 *(15.3)*	10
Ratnapura	25 *(3.2)*	600 *(8.1)*	980 *(3.1)*	375 *(4.5)*	500 *(2.8)*	155 *(9.2)*	3630
Colombo and Gampaha	0	500	0 *(2.7)*	400 *(3.3)*	250 *(2.3)*	90 *(1.6)*	2560 *(6.5)*
Kalutara	80	130	0	250 *(2.1)*	175 *(1.6)*	15	2100 *(5.3)*
Galle	0	225 *(1.2)*	0	300 *(2.5)*	425 *(3.8)*	35	11975 *(30.4)*
Matara	0	850 *(4.5)*	100	300 *(2.5)*	475 *(4.3)*	65 *(1.2)*	16300 *(41.4)*
Hambantotta	0	150	0	125 *(1.0)*	20	0	2775 *(7.1)*
***Total** (Kandy and Matale)*	*25525 (80.4)*	*6125 (32.7)*	*8425 (69.5)*	*6200 (51.8)*	*5070 (46.0)*	*4035 (72.6)*	*0*
TOTAL	**31755**	**18705**	**12125**	**11970**	**11025**	**5555**	**39350**

Source: Administrative Report of the Director, Department of Minor Export Crops, 1981.

[1] Figures in parenthesis refer to the percentage of the total acreage of the crop. Only the percentages which are greater than 1 are given.

Table 1.8: Volume of Export of Minor-Export Crops, 1973-1984.

('000 kg)

Year	Coffee		Pepper		Nutmeg & Cardomoms[1]		Cocoa	
	(C)	(F)	(C)	(F)	(C)	(F)	(C)	(F)
1973	132.1	132.0	2052.7	2052.0	497.9	497.0	1137.9	1137.9
1974	421.7	420.0	335.5	338.0	269.2	271.0	1027.6	1202.0
1975	1254.8	1257.0	96.5	96.5	489.7	479.0	1059.2	1190.0
1976	1708.8	1709.0	70.2	85.0	487.7	489.0	1113.4	1150.0
1977	985.7	986.0	630.0	913.0	238.8	237.0	1322.6	1305.0
1978	2313.2	2319.0	1205.5	1205.5	543.7	544.0	1039.7	1154.0
1979	2603.0	2603.0	875.7	1066.0	540.1	540.0	609.8	737.0
1980	908.8	909.0	646.8	945.0	391.4	441.0	916.3	961.0
1981	2036.6	2037.0	2051.6	2223.0	623.4	623.0	901.9	932.0
1982	2920.4	2920.0	1237.9	1301.0	562.3	562.0	697.5	758.0
1983	3124.4	3124.0	1119.7	1294.0	440.0	563.0	806.5	779.0

Source:

(C): Central Bank of Ceylon, Review of the Economy, 1984.

(F): Food and Agriculture Organization, Rome, Italy. Information obtained from personal communication with the Division of Statistics, April, 1985.

[1] FAO Statistics report the data for these two crops together.

traditional farmers, and one way of improving traditional agriculture is to show the farmers the opportunities and then to provide them with incentives to modernize. In Shultz's own words (p. 5): *"Incentives to guide and reward farmers are a critical component. Once there are investment opportunities and efficient incentives, farmers will turn sand into gold."* Many studies analyze the effect of agriculture at the macro level and ignore the growth potential. Any industry with a potential for growth should be regarded as important as an industry with large potential contributions to the national income of the country.

The potential for growth and larger contribution to the national economy by the MEC sector of Sri Lanka is evident in a recent study [Agroskills]. This potential has not gone unrecognized by the government as indicated by the increasing importance given to MEC in government programs and policies. The following section gives the highlights of government programs and development plans which included the group of crops referred to as MEC's.

1.2.1 A Brief Review of Government Programs Affecting MEC's

The first reference to the MEC's in a national development plan in Sri Lanka was made in the *Agricultural Plan* prepared by the Ministry of Agriculture and Food in 1958. The goal of this plan was to replant uneconomical small holdings of tea with coffee. The target was set at planting 7500 acres in 10 years. An incentive was provided in the form of subsidies for replanting uneconomic small tea holdings with coffee. The selection of coffee as the replacement crop was understandable because most of the tea land was under cultivation with coffee until coffee rust wiped out most plantations in the 1860's.

The National Planning Council issued the *10 Year Plan* in 1959 which was the first national development plan prepared by independent Ceylon[1]. This plan also included only coffee and the objective was to attain self-sufficiency in coffee by 1968. A target was set at planting 4,000 acres with an expected yield of 4 cwt. per acre.

---

[1] *Sri Lanka* was called *Ceylon* until July 1972.

The first major reference to minor-export crops in a national planning program was made in the *Short-Term Implementation Programme* prepared by the Department of National Planning in 1962. This plan stressed the importance of the MEC's in absolute terms rather than as a replacement for major export crops on marginal land. The approach suggested in the plan was more comprehensive because it emphasized expanding acreage, increasing yields, improving quality, and expanding markets for these crops. The plan also stressed the need for studying the technical aspects of growing these crops, processing, quality control, and expanding the export market. With this increased attention, an urgent need was expressed for the establishment of an institute to carry out these functions.

The most comprehensive treatment of MEC in a national development plan is seen in the *Draft Agricultural Development Plan* of the Ministry of Agriculture and Food for the period 1971-77. This plan could be mentioned as a turning point for the MEC because of the special recognition gained by these crops in government development plans. This draft plan recommended incentives, subsidies, and institutional support to strengthen the MEC industry and to increase production. A range of subsidies with strong emphasis on fertilizer and intensification of production with long term credit were strong recommendations of the plan along with research and extension efforts.

Introduction of the *Five Year Plan* prepared by the Ministry of Planning and Employment for the period 1972-1976 gave a boost to the MEC sector. It is pertinent to note that the Draft Agricultural Plan for 1971-1977 and the Five Year Plan for the period 1972-76 were commissioned during the same government but under two different ministries; the two plans placed emphasis on developing the MEC sector for different reasons.

The Five Year Plan prepared by the Ministry of Planning and Employment emphasized the development of the MEC sector with a view to strengthening the foreign exchange earnings of the country. It was argued that development of MEC would increase the foreign exchange earnings as well as diversify the sources of foreign exchange earnings. This need to diversify the foreign exchange earnings arose as a result of large fluctuations in the price of tea, rubber, and coconut. The Plan also recognized the potential of MEC to generate employment and increase rural income. To achieve these objectives, the Five-Year Plan set a target of 165,000 acres to be brought under MEC production. This would be composed of new planting, replanting, rehabilitation of existing plants, and improved cultural practices such as fertilizer application, pruning, shading, and pest control. At this point, a need was felt to establish an institution to execute and operationalize these plans and programs. This proposal, however, took a different route.

An important landmark in the establishment of an institution for MEC was the Tea Commission that was appointed in 1968. This commission was appointed to study the tea industry with an objective of improving the output and quality of tea. The commission in its report published as *Sessional Paper no. XVIII of 1968* recommended diversifying uneconomical, marginal tea lands with fruits, spices, coffee, cocoa, yams, timber, and pasture. Of these crops, the commission paid considerable attention to cocoa, coffee, cinnamon, pepper, cloves, and nutmeg-mace as potential crops for diversifying. The details of the recommendations are given in the report and are not relevant to this dissertation. Once these crops were accepted as viable alternatives for marginal tea lands, the policy was extended to uneconomic rubber and coconut lands. Coconut, by virtue of large areas of exposed land between palms, offers the potential for inter-cropping, especially with coffee and pepper.

The Tea Commission report in 1968 resulted in the involvement of the first international agency to develop the MEC industry of Sri Lanka. In April, 1970, the *Crop Diversification Project* was launched by the Ministry of Agriculture and Food with assistance of the *United Nations Development Program (UNDP).* This project has grown into a research station for carrying out varietal screening, spacing, fertilizer, and shading trials on the MEC's.

The inauguration of the diversification project was soon to be followed by one of the major landmarks in the history of MEC in Sri Lanka: the establishment of a government department. It was called Department of Minor-Export Crops (DMEC) and was established under the Ministry of Plantation Industries. The DMEC was established for the following reasons [Agroskills]:

1. The export objective of the program; potential to develop the export market for these crops.

2. The importance of MEC for crop diversification and inter-planting in the traditional tea, rubber, and coconut lands.

3. The affinity of these crops to tea, rubber, and coconut by virtue of their perennial nature.

The objectives of the DMEC were [Agroskills]:

1. The promotion, development, and organization of the cultivation of perennial crops with export potential excluding tea, rubber, and coconut. The crops at present dealt with are: Cocoa, Coffee, Cashew, Cinnamon, Cardomom, Pepper, Cloves, Nutmeg, Citronella, Papaw (for Pappain), Mulberry, and Oil palm.

2. Research on the above crops.

3. Implementation of policy relating to these crops developed from the studies on agricultural diversification on uneconomic tea and rubber lands made by the UNDP/FAO (Food and Agriculture Organization of the United Nations) assisted agricultural diversification programme.

In September, 1975 the DMEC came under the Ministry of Agriculture and Lands. Food came under the Ministry of Food and Co-operatives. The DMEC eventually came under the Ministry of Agricultural Development and Research in 1977 with the change of government.

Over the years, thus, the DMEC has changed hands among four ministries. During this period MEC has gained national recognition as an important sector in the development process of the country as a part of the ministries of Plantation Industries, Agriculture and Food, Agriculture and Land[2], and finally the Ministry of Agricultural Development and Research. This periodical relocation of the DMEC bears evidence that the government of Sri

[2] *Food* sector broke away from agriculture and was replaced by *Land*. The DMEC, therefore, remained under the same ministry.

Lanka was uncertain where to locate the administration of this sector of the economy. The MEC's are perennials and are cash crops. According to this description, MEC should be under Ministry of Plantation Industries which has tea, rubber, and coconut. The MEC on the other hand is a small holdings venture with a mixed type of farming. According to this description, the MEC should be under the Ministry of Agriculture whose main function is the development of the small holding food sector of the economy. The MEC's share a great deal of similarities with the plantation sector and the small holdings sector. It thus seems more appropriate to place the DMEC in a separate ministry and at present the DMEC seems to be under an appropriate ministry.

In spite of the national recognition gained by the sector as a whole, the producer seems to have been left unrecognized. The few studies that have been done so far [de Silva and Premaratne; Hathurusinghe; Tennekoon] have been on the production and marketing of these crops. The producer, as a manager and an entrepreneur, has not been studied. The MEC grower in Sri Lanka faces constraints which are somewhat special to these crops, resulting in farmers frequently harvesting these crops prematurely.

The major constraints to production, as reported by farmers, are: crop theft, pests and diseases, and drought [Agroskills; M. P. de Silva]. The problems of pest and disease attack, as well as theft, compel the farmer to harvest the crop before they are damaged or stolen [M.P. de Silva; Tennekoon]. Another reason why farmers harvest these crops before maturity is that the farmers harvest the crop whenever they need the money, regardless of the state of maturity at harvest. Harvesting the crop before it is fully matured results in lower income because there is a reduction in quantity and a deterioration of the quality. Rectifying these constraints, thus, would enable the country to harness the full potential of this expanding sub-sector of the economy.

The problems of crop theft, pests, and diseases, and drought suggest that the MEC grower operates in a risky environment. Risk is considered to be an important factor in improving subsistent agriculture [Wharton; Barker]. These two authors argue that though risk is one of the many serious impediments to agricultural development, eliminating or reducing the risk faced by subsistence farmers will contribute a great deal to technological innovation. Technological innovations are an important aspect of economic development [Mosher].

The multiple role of agriculture in economic development has been widely recognized. Kuznets identifies four roles or contributions of agriculture towards economic development. They are:

1. **Product contribution:** The non-agricultural sector of an economy heavily depends on the agricultural sector for food and raw materials.
2. **Market contribution:** The large agricultural population, which is characteristic of early phases of economic development, forms a very significant share of the market for producer and consumer goods.
3. **Factor contribution:** The relative role of agriculture in the economy invariably decreases with economic growth. This decline results in surplus investment capital in agriculture which can be transferred to the industrial sector. Associated with a surplus investment capital is surplus labor which can be transferred to the industrial sector. At times, this transfer can be achieved without any significant loss of output in the agricultural sector due to near zero marginal productivity of labor in agriculture.
4. **Foreign Exchange contribution:** Agriculture can contribute to a country's foreign exchange earnings by increasing production to strengthen the export earnings, by diversifying export earnings, and by increased production of import substitutes.

The MEC industry in Sri Lanka contributes in two of the four roles identified by Kuznets: factor contribution and foreign exchange contribution. Any improvement to the industry will increase the income of the growers and result in increased savings for the household which in turn can be used in investment, either recycled into agriculture or diverted into the industrial sector. This is the factor contribution. The factor contribution, which involves investment, can have an indirect market contribution. The role of MEC in foreign exchange earnings of Sri Lanka is seen clearly in tables 1.2 and 1.3.

1.3 Objectives and Approach of the Study

Scientific research is an attempt to establish a relation between two or more variables so that the behavior of certain variables can be predicted conditional on certain other variables. The need for scientific research arises because of problems. Kerlinger defines a scientific problem as *"...an interrogative sentence or statement that asks: what relationship exists between two or more variables."*(p. 42). According to Kerlinger's criteria, a good scientific problem statement should:

1. express a relation between two or more variables,
2. be stated clearly in question form, and
3. avail itself to empirical testing.

In this study the research goal is to determine the factors affecting the harvesting behavior of minor export crop growers in Sri Lanka and to identify a decision model which best predicts their behavior. Premature harvesting, in this study, is defined as harvesting before the crop is mature in an agronomic sense. The problems addressed in this study can be stated in question form as:

1. Why do MEC farmers harvest before the crops mature?
2. What is the nature of the relation between the harvest behavior and the socio-economic characteristics of the farmer?
3. Is it possible to predict the behavior of farmers using a decision model?

With the stated goal and the problems, the corresponding objectives of the study are:

1. *To determine the reasons for the practice of premature harvesting by farmers.*
2. *To determine the relationship between the practice of premature harvesting and socio-economic characteristics of MEC growers.*
3. *To compare* ***Expected Profit Maximization, Expected Utility Maximization,*** *and* ***Bounded Rationality*** *decision models to determine which model best describes farmer behavior.*

The approach to this research will be discussed in relation to each objective.

Objective 1:

This objective will be achieved by conducting a personal interview survey of farmers. For this purpose, 120 farmers will be picked at random from each of the two districts studied. The hypothesized reasons for premature harvesting are: fear of theft, pests and diseases, and immediate money needs. The farmers will be presented with these reasons and will be asked to rank them in the order of importance. This will indicate which of the reasons should be addressed first in the formulation of policies to improve harvesting practices of the MEC growers in Sri Lanka.

Objective 2:

This objective will be achieved by a qualitative choice model expressing the behavior of the farmer as a function of the socio-economic characteristics of the farmer. Age, level of education, family size, family income, and the type of land owned will be modelled as the determining factors. The results of this analysis can be used to predict behavior of farmers outside the sample, but who are within the sampling frame, and to determine which socio-economic and family characteristics are significantly related to the behavior.

Objective 3:

This objective will determine the decision model which best predicts the behavior of minor export growers with respect to decisions regarding harvesting of the crop. Analyzing the decision-making process of farmers will indicate the farmers' objective in harvesting behavior which can be used in formulating policies to solve the problem. Three different decision rules will be used, which are: expected profit maximization (EPM); expected utility maximization (EUM); and bounded rationality. Bounded rationality decision rules encompass a wide range of decision rules and the one used in this study is called lexicographic safety-first (LSF). The terms bounded rationality and lexicographic safety first will be used interchangeably in this study. Following is a brief introduction to the decision theoretic models used in this study. The theory underlying these models will be explained in chapter two and their application to the study problem will be explained in chapter three.

1. Expected Profit Maximization: This is based on the rule that the decision maker maximizes the expected profit of a set of alternative choices. For each farmer the expected profit of each category will be computed numerically.

2. Expected Utility Maximization: For this analysis the axioms of *Expected Utility Theory (EUT)* will be applied to model decision-making by the farmers. The EUT requires an assessment of the decision maker's preferences and beliefs. Preferences of the decision maker will be assessed via the elicitation of utility functions from each farmer in a sub-sample of 30 farmers picked at random from the larger sample of 240 farmers. Beliefs of the decision maker regarding the outcome of farming activities will be captured in subjective probability distribution functions elicited from farmers for price and yield distributions.

The utility measures of the farmers will be obtained using the Equally Likely risky prospects and eliciting its Certainty Equivalents (ELCE) (Anderson, *et al.*). Suitable functional forms will be fitted to the data for each farmer. The set of net returns and their probabilities will be computed by Monte-Carlo simulation techniques using the probability functions elicited from the farmers. These net returns will be used in the estimated utility functions to compare the expected utility values of various harvesting strategies. These harvesting strategies will then be compared with the actual behavior of the farmer. In view of the large number of crops involved in the study, the price and yield distributions will be elicited as a three parameter triangular distribution.

3. Bounded Rationality: Decision theories and decision rules which include the limitations of a decision maker in terms of his computational and comprehensional abilities to make a decision when faced with a complex situation, are called *Theories of Bounded Rationality.*

These theories use decision rules which result in satisfying choices in accordance with the decision maker's aspirations rather than producing optimal solutions. Computationally, however, once the aspiration levels are included in the model as constraints, a numerical computation technique can be used to obtain the solutions. The aspiration levels and the probability levels will be elicited from the decision makers.

This objective can, thus, be summarized as a comparison of an optimization decision rule which maximizes expected profits, an optimization decision rule which maximizes expected utility, and a bounded rationality decision rule which satisfices rather than optimizes.

1.4 Organization of the Dissertation

This chapter discusses the position of the minor-export crops sector in Sri Lanka's economy and provides evidence for the sector's potential contribution to the economic development of the country. Risk is identified as one of the problems facing the MEC grower. Considering the evidence on the importance of in agricultural development, and the role of agriculture in economic development, a study of farmer decision making under uncertainty seems very relevant. The goal and the specific objectives of the study were outlined with the identified problem and the reader was briefly introduced to the approaches of the study.

Chapter two of this dissertation reviews several accepted theories of decision making with emphasis on the theories applicable to situations with risky outcomes. The choice of relevant theories is justified and further explained. Chapter three reviews the various methods which are available to link the theories with the objectives of the study, followed by the choice of methods to be used in this study. Discussed next are the methods used in collecting the data, eliciting the utility functions and subjective probability distribution functions, and estimating the utility functions. The first part of chapter four presents descriptive summary statistics of the study sample; the second part discusses the results of the various analyses. A summary of the dissertation, its implications, and suggestions for further studies in the problem area and the methods are discussed in chapter five.

When the temptation strikes to reconcile your view of the world with facts through an appeal to risk aversion, resist it, at least for a while. Try revising your view of the world first.

J.A. Roumasset, *Rice and Risk: Decision Making among Low-income Farmers*. Amsterdam: North-Holland. 1976. (p. 234)

Chapter 2

THEORETICAL CONCEPTS

2.1 Introduction

This chapter reviews several accepted theories of decision making with emphasis on models which include risk. Initially, the terms *risk* and *uncertainty* are defined and these definitions are carried through the rest of the dissertation. This is followed by a discussion of the various measures of risk and how these measures are incorporated into decision models. The theories used in this study, *Expected Profit Maximization*, *Expected Utility Theory*, and *The Theories of Bounded Rationality* are discussed in detail together with the related concepts of preferences and beliefs of the decision maker.

2.2 Risk and Uncertainty

Despite the extensive literature on risk and uncertainty in decision analysis, authors have yet to agree on one definition for these two terms. This is partly because the terms risk and uncertainty take different meanings depending on the theoretical model used for the analysis. Of the several definitions of risk and uncertainty only two are relevant for this study. They are [Young *et al.*]:

1. *A measure of dispersion*, such as the variance or the standard deviation of an outcome about the expected value. This definition is suitable for decision models based on the expected utility theory [Young *et al.*; Roumasset, (1976); Dillon and Anderson]. Under this definition, comparing two prospects with equal expected values, the one with the wider dispersion will be termed more risky than the one with the narrower dispersion. Prospects with unequal means cannot be compared without further analysis.

2. *A probability of loss*; which is the probability of the expected value of an outcome falling below some critical level. For example, in production the probability of loss can be illustrated as:

$$P(y < \bar{d}) = \alpha. \qquad [2.1]$$

Where:

P is a probability operator;

y is the net income;

d is some critical disaster level; and

α is the probability.

This definition of risk is more appropriate for models based on the theories of bounded rationality, known as safety first models. These models will be discussed later in this chapter.

The terms *risk* and *uncertainty* have been used to mean different things. For instance, Knight defines *risk* as describing a situation where the probability of outcomes is known and *uncertainty* as describing a situation where the probability of outcomes is not known. Several authors argue and provide evidence that subjective probabilities can always be assigned to outcomes based on past experience or based on other related outcomes [Anderson *et al.*; Horrowitz; Magnusson]. This study, in accordance with the current notion, will use the terms *risk* and *uncertainty* interchangeably to mean an event with several possible outcomes.

2.3 Expected Profit Maximization

Perhaps the most widely used objective function in decision analysis is profit maximization, either as minimization of cost or as maximization of net returns. The simplest way to introduce risk into this objective function is by maximizing expected net profits. Expected net profit is defined as the weighted average of all profit levels by their respective probability of occurrence [Henderson and Quandt]. Consider a situation where a producer faces prices $p_1, p_2, \ldots, p_n$ with their respective probabilities of occurrences $\theta_1, \theta_2, \ldots, \theta_n$, where, $\sum_{i=1}^{n} \theta_i = 1$. The cost function is given by $C(q)$ and is non-stochastic. The producer's expected profit $E(\pi)$ is then given by:

$$E(\pi) = \sum_i \theta_i \left[p_i q - C(q) \right]. \qquad [2.2]$$

The first order condition for maximization of $E(\pi)$ is:

$$\frac{\partial E(\pi)}{\partial q} = \sum_i \theta_i \left[p_i - \frac{\partial C(q)}{\partial q} \right] = 0, \qquad [2.3]$$

$$= \sum_i \theta_i \, p_i - c'(q) = 0.$$

where, $\Sigma \theta_i \, p_i$ is the mathematical expected price and $c'(q)$, ($= \partial c(q)/\partial q$), is the marginal cost. The first order condition, therefore, implies that at maximum $E(\pi)$, the expected price, $\bar{p}$, equals marginal cost, MC.

For a firm with several inputs, consider a production function:

$$q = f(x_1, x_2, \ldots, x_n), \qquad [2.4]$$

where, q is the output level and the x_j's are the levels of respective inputs. The cost function is then:

$$C = \sum_{j=1}^{m} r_j x_j, \qquad [2.5]$$

where, r_j is the unit cost of j^{th} input. Combining the price, output, and the cost function the expected profit function can be expressed as:

$$E(\pi) = \sum_{i=1}^{n} \theta_i \left[p_i q - \sum_{j=1}^{m} r_j x_j \right]. \qquad [2.6]$$

The first order conditions for maximum $E(\pi)$ are:

$$\frac{\partial E(\pi)}{\partial x_j} = \sum_i \theta_i \left[p_i \frac{\partial q}{\partial x_j} - r_j \right] = 0, \qquad [2.7]$$

$$= \sum_i \theta_i \, p_i \frac{\partial q}{\partial x_j} - r_j = 0. \qquad j = 1,2, \dots, m.$$

In this expression $\sum_i \theta_i \, p_i$ is $\bar{p}$, and $\partial q/\partial x_j$ is the marginal product of the j^{th} input. The product $[(MP)(\bar{p})]$ can then be interpreted as *expected marginal revenue, E(MR)*. The first order conditions therefore imply that at equilibrium:

$$E(MR_j) = r_j. \qquad j = 1,2, \dots, m. \qquad [2.8]$$

That is, the expected marginal revenue of each input must be equal to their respective costs.

Following a similar argument, it can be shown that under yield uncertainty a firm producing one product with one input will reach equilibrium when the price of the input is equal to the expected marginal cost of the output, that is $p = E(MC)$. Extending this result to a multi-product, multi-input firm it can be demonstrated that at equilibrium:

$$E(MR_j) = E(MC_j), \qquad j = 1, \dots n. \qquad [2.9]$$

That is, the expected marginal revenue of each input in the production of each output is equal to the expected marginal cost of the input.

The expected profit maximization model only includes the expected values of the variables, price and yield, hence it ignores risk. Based on the definitions of risk, several theories have been developed to model choice behavior under uncertainty. The rest of the chapter will discuss in detail two of these theories. One is the expected utility theory which considers the risk of prospects by including the entire distributions. The other is a safety-first model based on the theory of bounded rationality.

2.4 The Expected Utility Theory

Decision models based on *Expected Utility Theory (EUT)* are the most widely used to study individual behavior under uncertainty [Roumasset (1976)]. This theory states that based on a set of axioms an individual makes decisions concerning alternate outcomes in such a way that the individual's expected utility is maximized. The EUT was first conjectured by Bernoulli in 1738 who was inspired by what is now called the St. Petersburg Paradox. This paradox can be stated as (Bernoulli, p. 31):[3]

> *Peter tosses a coin and continues to do so until it should land 'heads' when it comes to the ground. He agrees to give Paul one ducat if he gets 'heads' on the very first throw, two ducats if he gets it on the second, four if on the third, eight if on the fourth, and so on, so that with each additional throw the number of ducats he must pay is doubled.*

Paul's expectation in this game is given by:

$$\sum_{i=1}^{\infty} [(1/2)^i (2)^i],$$

which reduces to:

$$\sum_{i=1}^{\infty} (1/2)^i = \textit{infinity}.$$

[3] The reference to Bernoulli is really to Sommer's English translation of the original article by Bernoulli in Latin.

Therefore, if Paul wishes to maximize his profits he will let Peter toss the coin forever. Bernoulli continues *"...it has, he said, to be admitted that any fairly reasonable man would sell his chance, with great pleasure, for twenty ducats."*[4]

Because of this kind of paradox, Gabriel Cramer (1728) and then Daniel Bernoulli (1738) argued and proposed a theory stating that the value of an item depends on the utility it yields rather than the market value. Continuing his argument, Bernoulli further asserts that all individuals face the same market value for an item, but the utility of the same item is more of a function of the individual; the utility of an item can vary between two individuals. Bernoulli suggested the utility function:

$$U(X) = b\left[\log\frac{(\alpha + x)}{\alpha}\right], \qquad [2.10]$$

where b is a constant, α is the initial wealth, and x is the increase in wealth. The first derivative of this function with respect to x is:

$$\frac{\partial U(x)}{\partial x} = \frac{b}{(\alpha + x)},$$

which is a decreasing function of wealth. Schoemaker (1980) applies this function to the St. Petersburg game to show that for any $\alpha \geq 0$, the function has a finite maximum, which is true for any concave function. Ramsey proved the expected utility theorem in 1926. Later von Neumann and Morgenstern (N-M) proved the theorem independently of Ramsey and outlined the application of the theorem to individual decision making. The N-M model however is not identical to the original postulation of Bernoulli. Bernoulli postulated that individuals maximize expected utility, while the N-M axioms of choice show that an individual always

---

[4] The article by Bernoulli shows that the original thoughts on the expected utility theory were formulated by Gabriel Cramer; the "he" in this quote refers to Cramer. Bernoulli developed Cramer's thoughts into a theory together with a concave logarithmic utility function. For more information on this the reader is referred to: Raiffa (p. 276); Roberts (p. 185; p. 311; p. 327); and Sinn (p. 69-70; p. 124-25).

chooses the outcome or set of outcomes with the highest expected utility. In the N-M sense, therefore, an individual may or may not maximize his total utility.

The N-M theory is called an axiomatic theory because to implement this normative theory certain axioms have to be satisfied. These axioms are known as the Axioms of Choice under Uncertainty.

2.4.1 The Axioms of Choice under Uncertainty.

Axiom 1: Ordering of Choices and Transitivity: Consider three prospects, *A, B,* and *C*. This axioms says that the decision maker has a consistent preordering. If two of the prospects are taken, then the decision maker either prefers *A* to *B*, prefers *B* to *A*, or is indifferent to a choice between them. The transitivity part asserts that if *C* is included in the set and *A* is preferred to *B* and *B* is preferred to *C*, then *A* must be preferred to *C*. Consistency includes monotonicity which states that if a decision maker is faced with two prospects with the same outcome, the one with a higher probability of the more favorable outcome will be preferred.

Axiom 2: Continuity of Preferences: If *A* is preferred to *B* and *B* preferred to *C*, then at some probability p the decision maker is indifferent to a choice of *B* for certain or *A* with a probability p and *C* with a probability $(1 - p)$. This axiom is also called the axiom of certainty equivalent among choices and it can be applied to situations where A, B, and *C* are monetary values of outcome and not prospects. For instance consider x, y, and z which are monetary values of outcomes. Then at some probability p, y is the certainty equivalent of $(p)x + (1 - p)z$.

Axiom 3: Independence of Tastes and Beliefs: This axiom facilitates the separability of the utility of a prospect into a weighted average of the utilities of the outcomes. Consider two prospects *A* and *B*, with outcomes x and z, and y and z. The outcomes x and y occur in

A and B with the same probability p, and z occurs with a probability of $(1 - p)$ in each prospect. This axiom has two implications:

1. If the individual is indifferent to a choice between x and y, then he is indifferent to a choice between A and B.
2. If the individual prefers x to y (y to x) then he would prefer A to B (B to A).

Axiom 4: The axiom of complexity: Consider prospects A and B. Prospect A has x and y as outcomes, while prospect B has two other prospects, C and D, as outcomes. Prospects C and D have only x and y as outcomes. The preference of the decision maker then depends on the expected values of A and B as computed by the calculus of probability. This implies that: If $E(A) = E(B)$ the decision maker is indifferent and if $E(A) > E(B)$ $(E(A) < E(B))$ the decision maker prefers A to B (B to A) . Arrow and Hurwicz (1972) refer to this axiom as valuation of action by consequences. This also implies the axiom of reduction of compound lotteries [Roumasset (1976)].

Axiom 5: This axiom can be stated as a special case of Axiom 3. Consider prospects A and B with each having only x and y as outcomes. If x is preferred to y (y preferred to x), then A is preferred to B only if the probability of x is greater in A than in B (B than in A).

It should be noted that several sets of axioms are seen in the literature [Marschak; Herstein and Milnor; Arrow and Hurwicz; Luce and Raiffa; Radner (1964)]. All of these different sets of axioms, however, imply the five axioms given above. The first three axioms discussed above follow closely the system of Radner (1972) and are considered adequate to apply the EUT [Dillon (1979), Roumasset (1976)]. The axioms 4 and 5 are seen in the systems of Luce and Raiffa (1957), and von Neumann and Morgenstern (1944). Roumasset (1976) draws attention to the similarity between the axioms of 1 and 3 to 4 and 5.

Following the axioms of ordering, continuity, and independence, the EUT can be stated as [Dillon (1979)]: For a decision maker whose preferences do not violate the axioms of ordering, continuity, and independence, there exists a function U called a utility function:

1. by which cardinal values can be assigned to possible outcomes, and
2. whose expected value in terms of the decision maker's probability distribution for outcomes under each choice alternative gives a comparative measure of attractiveness consistent with the decision maker's preferences for each of the available choice alternatives under uncertainty.

The EUT implies that if a decision maker behaves in a manner consistent with the axioms of choice, the individual will choose the alternative which maximizes his expected utility for a set of alternatives under uncertainty. The EUT distinguishes and incorporates the preferences and the beliefs of the decision maker. The preferences enter the model as the utility function and the beliefs enter as subjective probability. A decision model built on the principles of the EUT is called an *Expected Utility Model (EUM)*.

The certainty equivalent axiom plays a vital role in estimating the utility function. Methods to estimate the utility function can be classified into direct and indirect methods. These methods however, still revolve around the CE axiom. Specifically, of the four pieces of information in the axiom, A, B, C, and p, three are presented to the decision maker and the fourth is elicited by repeated application of the CE axiom.

2.4.2 Representation of the Expected Utility Model.

The appealing feature of the EUM is its ability to postulate the preferences or attitudes and the beliefs of a decision maker regarding outcomes into a single valued index which then can be used to rank prospects. This can be represented by considering a set of prospects, $\{A_j \mid j = 1,2, \ldots, n\}$. Each A_j has a set of outcomes x_i; the number of i's in an A_j can vary. The i^{th} outcome of the j^{th} prospect is represented by x_{ij}. The decision maker's beliefs about the i^{th} outcome are expressed as discrete probability density functions $p(i)$. The decision maker's utility function is U. For a prospect A_j the expected utility is then the sum of the utility of each x_i weighted by its probability of occurrence. Mathematically, this can be represented as:

$$EU(A_j) = \sum_i U(x_{ij})\ p(x_i).$$

The prospects in the decision maker's choice set are ranked based on the value of $EU(A_j)$, the one with the highest value will be the most preferred. Thus, the goal function of a decision maker can be expressed as [Robison *et al.*]:

$$\max_j \ EU(A_j) = \sum_i U(x_{ij})\ p(x_i) \qquad j = 1,2, ..., n. \qquad [2.11]$$

On the assumption that the decision maker obeys the axiom of choice under uncertainty, a decision maker's preferences can be embodied in a utility function [Hey]. One of the qualitative measures in analyzing decision under uncertainty is an individual's attitude towards uncertainty. This is referred to as risk preference. Very much as with preference towards goods or prospects, an individual can be classified as risk averse (if he prefers certain outcomes to uncertain outcomes), risk preferring (if he prefers risky outcomes to certain outcomes), and risk neutral (if he is indifferent between risky outcomes and certain outcomes). These attitudes can be determined from the properties of utility functions.

Risk Attitudes: The shape of the utility function of a decision maker determines the attitude towards risk [Robison *et al.*]. In estimating utility functions from empirical data, therefore, the choice of a functional form is critical to the implications derived from the analyses using such forms. Specifically, the second order derivative of the utility function describes the risk attitude. Let the second order derivative of the utility function be represented by $U''(x)$. Then if $U''(x) = 0$, implying a linear utility function, the decision maker is risk neutral, $U''(x) < 0$ (concave function) implies risk aversion, and $U''(x) > 0$ (convex function) implies risk preference. Depending on the functional form, therefore, it is possible to have two or more of the attitudes expressed in the same utility function. For instance, if a quadratic utility function is used it could have concave and convex parts along its domain, connoting changes of risk attitude over a range of income. Risk attitude in this case is a function of the monetary value of the outcome. Three concepts associated with risk attitudes are: Expected Monetary Value (*EMV*), Certainty Equivalent (*CE*), and Risk Premium (*RP*).

Expected Monetary Value. The Expected Monetary Value (EMV) of a prospect is the weighted average of the outcomes of the prospect. Using notation defined earlier, EMV could be defined as:

$$EMV(A_j) = \sum_i x_{ij}\, p(x_i).$$

Certainty Equivalent: Certainty Equivalent (CE) is defined in terms of a prospect. The amount of money which makes a decision maker indifferent between the amount and a prospect A is called the certainty equivalent of the prospect. This indifference implies that $U(CE) = EU(A)$.

Risk Premium: The risk premium, RP, for a decision maker for a prospect is the difference between the EMV and the *CE*, ($RP = EMV - CE$). Risk premium is also defined as the amount the decision maker is willing to pay to avert a risky outcome, or how much a decision maker should be paid so that he or she will take part in a lottery. For a risk preferring decision maker the RP can be negative, meaning this decision maker would have to be paid this amount to get him to give up a risky prospect.

Risk Aversion Coefficient: The question arises whether it is possible to compare risk attitudes among individuals as exhibited by the utility function. An individual's risk attitude is indicated by the sign of the second order derivative of the utility function. Robison *et al.* (p. 16) argue that *"... the magnitude of the second derivative cannot be used for interpersonal comparisons of risk aversion, because an individual's utility function is only unique up to a positive linear transformation."* For interpersonal comparisons of risk attitudes, two measures of risk aversion, derived by Arrow and Pratt independently, can be used. They are:

1. Absolute Risk Aversion Coefficient:

$$R_a(x) = -\frac{\partial^2 U/\partial x^2}{\partial U/\partial x}, \text{ and} \qquad [2.12]$$

2. Relative Risk Aversion Coefficient:

$$R_r(x) = -x\,\frac{\partial^2 U/\partial x^2}{\partial U/\partial x}. \qquad [2.13]$$

The sign of these coefficients indicates the risk attitude and the magnitude is a measure of the degree of risk aversion. These coefficients are very useful in testing hypotheses regarding the effect of the object of the utility function (the independent variable or variables of the utility function such as wealth or income) on risk aversion. For a risk neutral decision maker $R_a(x) = 0$ and for a risk averse (risk preferring) decision maker $R_a(x) > 0$ ($R_a(x) < 0$). The degree of risk aversion is then proportional to R_a. The absolute risk aversion coefficient can vary with the units of x and U. The relative risk aversion coefficient is unitless.

A favorable property of the Arrow-Pratt (A-P) R_a over the second order derivative of a utility function as a measure of risk attitude is that R_a is not affected by arbitrary linear transformations of the utility function. The second order derivative of a utility function can change with linear transformations. The utility function is then used in combination with the distribution function of the outcomes to rank prospects. While no assumptions are made about the distribution of the outcomes, the chosen utility function should exhibit certain properties for a valid implementation of EUT.

2.4.3 Properties of the Utility Function

The utility function has several properties [Anderson, *et al.*]. Each one of these properties will be discussed in detail in this section. These properties are:

1. *If a risky prospect* A *is preferred to* B *then the utility index of* A *is higher than the utility index of* B. Mathematically, If *A* preferred to *B*, then $U(A) > U(B)$.

2. *The utility of a risky prospect is given by its mathematical expectation.* The decision maker's subjective probability distribution functions are used to compute this expectation. Mathematically, $U(A) = E[U(A)]$. For a discrete distribution, the expectation is a summation while for the continuous case it is an integral. For the discrete case:

$$\begin{aligned} U(A) &= \sum_j [U(A) \mid X_j]\, P(X_j), \\ &= \sum_j [U(X_j)]\, P(X_j). \end{aligned} \qquad [2.14]$$

For the continuous case:

$$\begin{aligned} U(A) &= \int_x (x \mid X)\, f(x)\, \partial x, \\ &= \int_x U(A)\, f(x)\, \partial x. \end{aligned} \qquad [2.15]$$

The integral is over the entire range of *x*. Higher moments of utility such as variance, skewness, and kurtosis are not needed for decision making [Anderson *et al.*]. An important implication of the axioms of choice is that only the expected value of utility is required for choice under uncertainty. The statistical properties of the utility function (moments of the preference function) and the beliefs are all embodied in the utility index.

3. *The scale on which utility is measured is arbitrary rather than absolute.*The utility indices can therefore be used to compare prospects by the same individual but not to compare interpersonal utilities. These indices cannot be used to compare the utilities of two prospects by an individual. For instance, if $U(A) = 2$ and $U(B) = 4$, this does not imply that the decision maker derives twice as much utility from *B* as from *A*. The only implication of this is that the decision maker prefers *B* to *A* under the axioms of choice under uncertainty.

2.4.4 Operationalizing the Expected Utility Theory

Decision rules related to the EUT involve three components: the intentions, preferences, and beliefs of the decision maker. The intention is the objective, (maximize expected utility), the preference is captured in a utility function, and the beliefs are captured in subjective probability distribution functions. The next section discusses the elicitation of utility functions in one variable followed by a discussion of the elicitation of subjective probabilities.

2.4.4.1 Elicitation of Preferences

Preferences can be expressed as a function of one variable, univariate or several variables, multivariate. Following the conclusion of Officer and Halter that a decision maker's preferences can be expressed as a univariate utility function of net income, and the conclusion of Herath *et al.* demonstrating better performance of a univariate utility function compared to a multivariate utility function, this study will use a single variable utility function of net income.

Several methods have been used in empirical studies to measure risk attitudes. The choice of an appropriate method, however, should depend on the research objective [Robison *et al.*]. Normative studies have the freedom of choosing a specific utility function for the decision makers. Descriptive studies, due to their methodological nature, require a study of the risk attitude of the decision maker and a classification of them as risk averse, risk neutral, or risk preferring. Predictive studies may choose to measure the risk attitudes empirically. Robison *et al.* classify the approaches of measuring risk attitudes as:

1. Direct Elicitation of Utility functions (DEU),
2. Interval measures of risk aversion,
3. Experimental methods, and
4. Observed Economic Behavior (OEB).

Of these methods, only the first results in a workable utility function which can be used in a decision model. The other three methods result in measures of risk aversion but do not yield a utility function. The decision model specified in this study requires an explicit utility function. At least four methods have been used to elicit utility functions of decision makers. They are [Robison *et al.*, Roumasset 1976]:

1. Direct measurement,
2. Von Neumann - Morgenstern Method,
3. The modified von Neumann-Morgenstern Method, and
4. Ramsey method.

The direct method of measurement elicits the utility function on an arbitrary scale by asking direct questions such as *"How much money would you need to feel twice as happy as $100 would make you feel."* [Roumasset, 1976 (p: 29)]. The other three methods use the certainty equivalent axiom of the axioms of choice under uncertainty. Recall that the CE axiom entails the certainty equivalent of a risky prospect. Mathematically:

$$U(CE) = U[p(x) + (1 - p)y], \qquad [2.16]$$

which involves four pieces of information: *CE, p, x, and y.* The three methods based on the CE axiom construct the utility function of an individual by eliciting various pieces of information in a hypothetical situation. The von Neumann-Morgenstern method elicits the probability, *p*, which will satisfy equation [2.16] [Roumasset, 1976, 1979]. The Ramsey method attempts to overcome any biases that might exist on the part of the decision maker with regard to gambling or for a particular probability level. This is achieved by presenting the decision maker with a series of risky prospects and eliciting the CE for each prospect. Each prospect has two equally likely outcomes. Three of these values are specified and the fourth one, which will result in indifference between the two prospects, is elicited from the decision maker. This method is called the Equally Likely but Risky Outcomes (ELRO) method by Anderson *et al.* and is also known as the standard reference contract method. The modified von Neumann-Morgenstern method elicits the CE of equation [2.16] when $p = 0.5$. Anderson *et al.* call this the *Equally Likely risky prospect and finding its Certainty Equivalent (ELCE).* They assert this to be the *"... simplest recommended method."* (p. 28).

Even though a number of criticisms have been directed at DEU methods to derive risk attitudes, these are the only developed and tested methods to elicit utility functions. Dillon (1971) argues that the Ramsey method and the modified von Neumann-Morgenstern method are superior to the other methods. Of these two methods, the Ramsey method involves reaching indifference by varying the probability while keeping the outcomes constant. The modified von Neumann-Morgenstern method varies the certain prospect while maintaining the probabilities and the outcomes of the risky prospect constant. The argument against the Ramsey method, in favor of the modified von Neumann-Morgenstern method, is that individuals have difficulty thinking in terms of probability, which, if used, may result in errors in the elicited utility functions. Despite cost and time involved in implementing the ELCE method due to prolonged interaction between the decision maker and the researcher, ELCE is favored for studies involving basic research about farmer's decision making at the individual level [Robison *et al.*, Anderson *et al.*, Dillon (1971)]. Of these two methods, the ELCE method is deemed appropriate for this study in view of its simplicity [Anderson *et al.*] and the proven effectiveness of this method in Sri Lanka [Herath *et al.*]. Elicitation methods which involve interaction between the decision maker and the researcher perform better than the methods which do not have a personal interaction [Gottinger]. Another advantage of the ELCE method is that a 50-50 probability does not leave much room for distortions, thus reducing the chances for a misrepresentation of the preferences in a utility function [Schoemaker (1980)]. Schoemaker further argues that eliciting levels of outcome to which a decision maker is indifferent is a better approach to eliciting utility functions than eliciting the probabilities to which a decision maker is indifferent. Karmakar has shown that utility functions could depend on the probability values used in the elicitation process. The details of eliciting a utility function using the ELCE method will be discussed in detail in Chapter 3.

2.4.4.2 Objective Versus Subjective Probability

Laws of the Form in science demonstrate that an event will take place in experiments when a set of conditions are satisfied [Roberts]. For instance a light bulb burns (= *A*) when it is in order, is correctly placed, and current is passed (conditions = *C*). In economics, theory asserts that when the demand for a product increases, with other things remaining constant, the price of the good increases. In certain instances *A* is not possible with *C*; that is the conditions make sure the result does not occur. The law, thus implies two extreme outcomes:

C always results in *A* [*A* is certain relative to *C*];

C always does not result in *A* [*A* is impossible relative to *C*]

In a majority of situations *C* may or may not result in *A*. For instance, let *C* be tossing an unbiased coin and *A* be the event of getting a head at the fall. A coin has two sides and it may come down with heads up or heads down. The outcome is therefore neither impossible nor certain; it can only be described as possible. In this case one can speak of the degree of possibility. This degree of possibility is called probability of occurrence. The objective probability is defined as *"... the relative frequency or properties of occurrences of A if conditions C are realized a large number of times... "* [Roberts, p. 370]. Roumasset (1976 p. 13) gives a clearer definition of objective probability as *"...the percentage of equally likely and mutually exclusive events [A] which are consistent with (favorable to) that outcome [C]..."*

The notion of objective probability can be traced back to Pascal and Fermat in the seventeenth century [Roberts]. Another definition of objective probability is *"... the limit of relative frequency ..."* [Roumasset (1976, p. 13-14)]. This implies that although the probability of getting heads up at the toss of a coin is 0.5, this actual probability can only be realized on a large number of tosses. Objective probabilities have the property of universality and replicability. That is, given the conditions *C*, it is always possible to get the result *A* with the same probability repeatedly and universally.

Despite the valuable contribution made by the concept of objective probability, Roumasset (1976) argues that it has little value in real-world decision making. Roumasset

(1976) attributes this character of objective probability to a lack of clear definition for it and its *"... artificiality..."* (p. 14). This view is supported by Roberts who observes that individuals prefer to use subjective estimates of probabilities even when it is possible to calculate objective probabilities.

2.4.4.3 Subjective Probabilities

Even though the notion of subjective probability was postulated in the 18th century [Roberts], its potentials and functionality in decision analysis remained unrecognized until the work of Ramsey in the 1920's and 1931. This was followed by de Finnetti (1937) and Savage (1954, 1971). Savage formally defined this concept and developed a theory within the framework of consistent preference under uncertainty.

Subjective or personal probability can be defined as an individual's expressed belief about the possibility of an outcome or his belief in the truth of a premise [Savage (1954)]. The first attempt to measure subjective probability experimentally was made by Preston and Baratta in 1948. The subjects in their study consistently underestimated objective probabilities greater than 0.2 and overestimated probabilities less than 0.2. Even though this result has been repeatedly observed in many studies, results with different types of relationship have been reported [Hogarth; Luce and Suppes]. Anderson *et al.* make some strong statements against the use of objective probabilities in agricultural decision analysis. They argue that real world decisions involve finite states and invariably the states cannot be repeated (eg. annual rainfall pattern). This, however, does not preclude a decision maker from consulting experts, historical data, forecasts, and whatever resources available to him in forming beliefs about the occurrence of an event [Anderson *et al.*]. Nonetheless, Anderson *et al.* assert that *"... objectivity in science is a myth, in life an impossibility and in decision making an irrelevance. Its loss need not be regretted"* (p. 18).

De Finetti developed three axioms for the existence of subjective measures of probability for a finite case. These axioms were demonstrated to be insufficient by Savage (1954) and later by Kraft, Pratt, and Seidenberg. Kraft *et al.* developed a set of axioms for the existence of subjective probability which were demonstrated to be sufficient. A very readable form of these axioms can be seen in Scott (1964). Related formulations of these axioms can be seen in Domotor, Fishburn (1969), and Krantz *et al.* A set of axioms for an infinite case has been developed by Suppes and Zanotti.

The existence of subjective probability and its usefulness in empirical decision analysis is therefore well established [Bessler]. Following Savage's definition, a subjective probability distribution can be defined as *"...a series or a set of expressed beliefs about the possibility ofan outcome or his belief in the truth of a premise."* [Roumasset (1976), p. 16]. These outcomes and premises, however, should be mutually exclusive [Bessler]. Of the axioms for the existence, and therefore the elicitation of subjective probability distributions, the most important one is that of *coherence* [de Finetti; Bessler].

The coherence principle can be stated as: *"... a necessary condition for rational beliefs and actions on the part of an individual is that they should be all consistent with each other, involving no mutual contradictions."* [Bunn, p. 11]. This principle implies that a set of probabilities for a particular system of bets should not guarantee *a priori* a winner or loser [Bessler]. If any belief an individual has is incoherent with all other beliefs that are held, this individual can be made into a *"... perpetual money making machine..."* [Lindley, p. 58]. Rescher makes a philosophical argument to conclude that coherence is only a necessary condition for rationality; it does not, however, guarantee rationality. Other restrictions on beliefs which are addition, multiplication, and equivalence, can be derived from the principle of coherence [Bessler].

The basic assumption of decision analysis is that the rational individual's world view, set of facts, beliefs, and assumptions form the basis for the individual's coherent collection of other opinions, values, and justifications [Bunn]. The world view, however, may not always be correct, due to flaws in the facts, beliefs, and assumptions. These flaws may be the result of the individual's incapacity to decompose a complex problem into its components. Total coherence requires strong introspection concerning all the beliefs and facts held by an individual, thus is an *"... unattainable deal..."* [Bunn, p. 12]. This study will assume that decision makers are totally coherent with all of their objectives and alternatives. Winkler and Murphy add an additional condition to this, arguing that it is not only the individual's ability to assess the probability of an outcome which is important but also the ability to incorporate this information in the decision process. This appears to be an implied assumption of the EUT, which is not expressed explicitly.

2.4.4.4 Eliciting Subjective Probability

Methods for eliciting subjective probability are classified into two groups based on whether or not a motivational procedure is built into the method. A method is called, in this respect, a motivational procedure if it has a reward or a pay-off to the subject depending on the outcome of the unforeseen event.

Non-motivational methods do not explicitly have a pay-off or a reward system. This lack of a reward is said to result in less accurate measures [Bessler]. Non-motivational methods are, however, easier to implement and are suggested for situations where an approximate assessment of the probability would suffice [Bessler; Murphy and Winkler]. This study used a non-motivational method.

Subjective probability distributions are elicited in this study for the yield and the price of five crops. Because these two variables are continuous, only methods which are suitable for eliciting continuous variables are discussed here. Winkler (1967, 1971) classifies the methods of eliciting subjective probability distributions as direct and indirect. Direct measurements include the elicitation of cumulative distribution functions (CDF) and probability density functions (PDF) directly. Indirect elicitation is carried out via an equivalent past or future hypothetical sample. Indirect methods are considered more suitable for statistical analysis than for decision analysis [Anderson *et al.*]. Eliciting the PDF of a continuous variable using the direct method is a tedious task and often does not give reliable results [Anderson *et al.*]. This leaves direct elicitation of CDF as an appropriate method for continuous variables.

Subjective probability distributions can be elicited directly by using the visual impact method [Anderson *et al.*] or the judgmental fractile method [Raiffa]. The visual impact method involves specifying a range for the variable under consideration and dividing the range into a finite number of mutually exclusive and exhaustive intervals. The assessor is then supplied with some sort of counters (eg. matches, seeds, tokens), and requested to place the number of counters that he feels reflect the likelihood that the value of the variable will fall within this range. The exhibited probability ratios are then used to determine the points on the CDF.

The second method is the judgmental fractile method [Raiffa] which is also called the indirect estimation method. This method involves determining equally likely probability intervals from the assessor [Anderson *et al.*; Raiffa].

The visual impact method and the judgmental fractile method involve specifying a probability and eliciting the value of the variable that will be exceeded with that probability. This can be very tedious, specially when a large number of variables are involved. Pearson and Tukey, and later Perry and Grieg, have demonstrated that the mean and the variance of a random variable can be very reliably estimated from its CDF with the 0.05, 0.5, and the 0.95 fractiles.[5] This information can be very effectively used when one needs to elicit a large number of distributions, as in the case of this study. A modified form of the triangular distribution can be used to elicit the distribution by obtaining the 5 percentile (worst of 20 times), the mode (the most likely), and the 95 percentile (the best of 20 times) values of the variable from the decision maker. This information can be used in the formula mentioned above to compute the mean and the variance of the variable.

The triangular distribution, which is recognized as a good approximation for most situations (Sonka and Patrick; Hull), has some weaknesses. One is that while it is possible to elicit the parameters of the distribution from farmers, these responses do not imply that the farmers have a knowledge of the underlying distribution. Farmers' knowledge about the distribution is an implied assumption (Spetzler and von Holstein). Another limitation of the

---

[5] The formulae for this estimation are given in Chapter 3 of this dissertation.

trianagular distribution is that the parameters of the probability distribution are estimated only using three data points. Keefer and Bodily, as discussed earlier, report that a three point distribution is as good as a five point distribution. They also report that distribution parameters computed with three data points, using formulae 3.11 and 3.12, compare well with those computed with a large number of data points. Equations 3.11 and 3.12 produced distribution paremeters with the smallest percentage error.

2.4.5 Shortcomings of the Expected Utility Theory

Schoemaker (1982) argues that the validity of a model should be evaluated on based its purpose and objectives. This is important because models are used to express complex problems in a simple manner. Schoemaker (1982) identifies four purposes of the EUT, which are: *descriptive; predictive or positivistic; postdictive;* and *prescriptive or normative.*

The use of a model based on EUT to describe the behavior of decision makers under uncertainty calls for a test of the realism of the axioms and the decision making process. Dreze has provided evidence that the axioms can be violated in real life decision making. MacCrimmon's study shows that individuals do not behave as if they maximize expected utility. Another set of shortcomings is based on the individual's ability to structure problems in the framework of EUT [Schoemaker (1982)]. Several authors note the limitations of the cognitive abilities of the human mind to process a complex set of information such as those encountered in the application of EUT [Dreze; Kozielecki; Simon (1957), (1972); Day].

The positivistic use of the EUM assumes all observed human behavior is optimal. This use of the EUT requires correct modelling of the problem. The criticism of this approach is directed at the ambiguity of the term "correct modelling". The EUT cannot be refuted when used as a positivistic tool [Schoemaker (1982)].

The prescriptive or normative purpose of the EUT is to indicate the best set of alternatives among a finite set of feasible alternatives as the solution set of a problem. The criterion is then to choose the set of alternatives which maximizes the EU of the decision maker. This application of EUT, however, involves three qualifiers. The first is that the implementation of EUT as a normative tool involves collection of information based on hypothetical situations [Schoemaker (1982)]. The responses obtained from decision makers to apply the EUT may not be consistent with their behavior under actual situations. The second is that when prescriptions are made for market level decisions only the individuals who are at the margin need to be included. The problem then is to identify these individuals. The third is that EUT does not have provisions for including learning over time.

The dominant application of EUT in decision literature is as a predictive or positivistic tool [Schoemaker (1982)]. Use of EUT for this purpose enjoys the privilege of ignoring the validity of the assumptions and axioms as with any other tool used for positivistic applications [Friedman; Machlup]. A model is accepted as valid if it predicts well. The weakness of this approach is that the hypothesis tested under this application cannot be falsified in principle [Schoemaker (1982)].

Apart from these weaknesses of the EUT as an alternative theory for decision analysis, several weaknesses of the EUT can be noted at the implementation level. For instance, utility functions are estimated from information elicited from decision makers and their risk attitudes are derived from these functions. The risk attitudes and the properties of risk attitudes (decreasing, constant, or increasing) are properties of the utility functional form used for the study [Musser *et al.*; Buccola (1982a); Schoemaker (1982)]. Karmakar has reported that the probability levels used in eliciting the utility functions can influence the information obtained to fit the utility function.

Despite these shortcomings, the EUT is a popular theory in decision analysis because of its immense appeal as a theory [Dreze; Sinn; Fishburn (1970), (1982)] and will continue to be one until more appealing theories are developed [Schoemaker (1982)]. Following the early application of EUT in agriculture by Freund, several authors have applied and tested the theory among agricultural producers [Heady and Candler; Lin *et al.*; Wiens; Binswanger; Herath *et al.*; Wolgin; Moscardi and de Janvry]. These studies tested EUT as a predictive tool against profit maximizing models and concluded that EUT performs better. While it has to be admitted that this in no way means that EUT is the best theory available, it has proven to be better than the profit maximizing model. This study tests the EUT against a theory suggested by the critics of EUT, which falls into the broad group of theories of bounded rationality.

2.5 Theories of Bounded Rationality

Rationality refers to taking action consistent with goals, means, and constraints. Simon (1957) distinguishes between theories incorporating all the means and all the constraints, in a global sense, and theories incorporating limitations of a decision maker to process this global information on goals and means. Theories which include the limitations of a decision maker in processing information are called *Theories of Bounded Rationality* . For instance, a profit maximizing entrepreneur, faced with a demand function, production function, and a cost function, to be fully rational, is assumed to be able to embody these three functions in a profit function and derive the first order conditions, consequently producing what the calculations show as profitable levels of production.

One of the criticisms of the optimality models in general is the exclusion of decision costs [Radner (1972)]. This is especially true, for instance, where a large number of alternatives are possible for a given decision problem. Implementation of a full optimality model would entail obtaining information on all alternatives which in turn would involve considerable costs. On the human side of problem solving, even if complete preordering of prospects is possible, these prospects can only be compared in pairs (binary comparisons). It is now evident that it is not possible for a finite information processing system to generate solutions which are consistent with preordering of a set of viable alternatives [Kramer (1967)]. In this respect Roumasset (1979 p. 97) quotes Day:

> *Orderly processes of thought are not sufficient to explain action. They must be finite to lead to an act. Hence while the logic of choice has everything to do with binary comparisons, constructing a choice problem as a mathematical program may lead to a finite process of choice and hence from an existential point of view to be an essential approach to the understanding of rational behavior.*

Roumasset (1976, 1979) concludes that for small farm operators in developing countries full optimality models are inappropriate. Georgescu-Roegen (1958, 1971) arrive at a similar conclusion that farmers take a satisficing approach using simple rules of thumb rather than an optimizing approach due to their limited knowledge about the future and their limited ability to process this information in a decision process. The case for satisficing decision models can be summarized by Day's quote (p. 240): *"In other words, rational men do not behave according to models which smart men can't solve."*

2.5.1 The Rationale for the Theories of Bounded Rationality

The rationale for the Theories of Bounded Rationality is based on the nature of the decision environment, which includes the problem, the real world, and the decision maker. The characteristics of these components, which result in the decision maker acting in a satisficing manner rather than an optimizing manner, are [Simon (1982b), Kozielecki]:

1. **Cognitive process:** The human mind has an inherent limitation on its power to assimilate information.
2. **Incomplete information about alternatives:** This has two aspects. One is the information available on the number of alternatives. The other is the amount of information available on each alternative in the feasible set.
3. **Computational ability:** This refers to the computational capabilities and the efficiency of the existing technology to solve a given problem. Simon (1982a) questions the ability of the techniques available in solving optimization problems.
4. **Man's Computational Efficiency:** Not only is man's cognitive power limited, but also his thinking ability. Simon (1982b), claiming that man's thinking process is serial (one thing leading to another), asserts that the human mind cannot solve a problem to find an *optimal* solution. Rather, the limitations result in a satisficing sub-optimal solution.

Decision criteria which do not optimize, but stop searching when an adequate or satisficing solution is found, belong to the broad class of *Bounded Rationality models.* Bounded rationality models, therefore, result in satisficing behavior. Satisficing behavior in decision analysis describes a process where a decision maker, when faced with a situation calling for a decision, takes the following steps [Simon (1957)]:

1. Evaluate problem,
2. Set aspiration levels - levels of the objective function which will satisfy him,
3. Consider a limited number of alternatives, and
4. Choose the alternative or a set of alternatives which satisfies the aspiration level.

The arguments for the theory of Bounded Rationality center around the inclusion of the decision maker's aspirations [Kozielecki; March and Simon], and consider it as a theory which goes a step towards considering the decision process rather than culminating the analysis once an optimal solution is found [Roumasset, (1976)]. Rationality is the foundation of optimization models while bounded rationality emphasizes the decision process itself. Optimization thus is really an approximate optimization where the initial step is to reduce the complex problem into one which can be comprehended by the decision maker [Roumasset (1976)], and in some cases the decision analyst. Bounded rationality models retain the real world situation but search for a satisficing solution rather than an approximately best solution, implying good solutions as opposed to optimal solutions.

2.5.2 Modelling with the Theories of Bounded Rationality

Models based on the theories of bounded rationality may be grouped under two classes. One is called *Safety-First* and the other *cautious optimizing* [Roumasset (1976)]. Cautious optimizing places emphasis on how the decision maker adapts to changes and additional information [Day]. In other words, cautious optimizing has a time horizon and thus is dynamic in nature. The time horizon considered in these models, however, is very short in order to conform to a decision maker's cognitive abilities. Day and Singh have applied this principle to study the effect of technology on development.

Roy's work is usually regarded as the origination of the analysis in Safety-First models [Roumasset (1976)]. Arrow, however, credits Cramer (1930) and Marschak (1950) with first exposition of these principles. Pyle and Turnovsky identify three rules of thumb which fall into the broad category of Safety-First decision models and claim that all other rules can be treated as special cases of these. The Safety-First models are:[6]

1. Safety Principle [Cramer (1930), Marchak (1950), Roy (1952)].
2. Strict Safety-First Principle [Telser (1955), Charnes and Cooper (1959)].
3. Safety-Fixed Principle [Kataoka (1963), Turnovsky (1968)].

1. Safety Principle involves minimization of the probability that some objective function falls below a disaster or a regret level. This can be expressed as:

$$\min \alpha, \text{ where } \alpha = P(\pi < \bar{d}),$$

where, α is a probability level, π is the objective function, and $\bar{d}$ is an exogenous level of safety. The level $\bar{d}$, for instance, can be the minimum level of income required for subsistence. Robison *et al.* show that under normally distributed π, the rule is equivalent to finding a $\bar{d}$ which is furthest from π. Here $\bar{d}$ is exogeneous.

2. Strict Safety first Principle involves maximizing an objective function subject to a constraint of the form:

$$P(\pi < \bar{d}) \leq \bar{\alpha},$$

[6] The year of the work is given, which is not consistent with the notation in the rest of the dissertation, in order to attach a time frame to the development of thought on Safety-First decision rules.

where, $\bar{d}$ and $\bar{\alpha}$ are exogenous. This principle can be extended to a multi-objective case where π is maximized subject to:[7] $P(x > \bar{x}) \geq \bar{\alpha}$ $[\equiv P(x < \bar{x}) \leq \bar{\alpha}]$. In this type of formulation of the strict safety-first principle, x could either be an argument in the objective function or a constraint.

*3. **Safety-fixed principle*** is of the form:

$$\max d, \text{ subject to: } P(\pi < d) \leq \bar{\alpha}.$$

This principle maximizes d subject to a constraint that the probability of income being below a safety level d does not exceed a specified level of probability $\bar{\alpha}$.

2.5.3 Some Applications of Safety-First Models

MacLaren compares the safety-first models outlined above and the expected utility model to study the output response of a representative firm. When the probability constraint of the strict safety-first model was binding, the safety-first models and the expected utility model gave similar solutions. The solutions of the safety principle model were markedly different from those of the other models. The strict safety-first model without the chanced-constraint gave the same solution as the certainty model, and with the chanced-contraint gave solutions similar to the expected utility model. The results of the certainty model, in general, were different from the results of the uncertainty model.

Kennedy and Francisco discuss the use and the limitations of Tchebycheff's theorem in formulating the safety-first models. Their application to a representative firm showed that the models which use Tchebycheff's theorem without assuming any particular distribution on the net returns give conservative results compared with the results given by models which assume normality.

---

7 See Taylor and Zuhair for an example.

Boussard and Petit, studying the behavior of farmers in France with respect to changes in the price of irrigation water, report that farmers maximize net income while assuring that the probability of the net income falling below a fixed minimum is very low. This behavior is consistent with Roy's Safety-Principle.

Webster and Kennedy use a safety-first model to derive the trade-offs between expected income and a safety level of income with a probability attached to it. The results were used for predictive purposes.

2.6 Safety-First Versus Expected Utility

Selley compares three properties of several decision models, which are: whether the models penalize distributions skewed to the left; whether the models prefer more to less (monotonically increasing or not); and whether the models exhibit decreasing marginal utility.

The safety-first models with a disaster level less than the expected level of the objective function penalize skewness to the left. The other models do not discriminate against distributions which are skewed to the left. Expected utility models which use the exponential utility function and the quadratic function do not penalize skewness to the left.

Expected utility models with exponential and quadratic utility functions exhibit diminishing marginal utility. This property of the EUM, however, depends on the utility functional form used. For instance, a cubic utility function could exhibit increasing and diminishing marginal utility.

The safety-first models all prefer more to less, that is, they are monotonically increasing with respect to the argument of the utility function. In EU models this property again depends on the chosen functional form. For instance, if a quadratic function is chosen, the function is monotonic only up to a level of income less than $b/2c$.[8] It is even more difficult to determine

[8] In the quadratic function of the form: $f(x) = a + bx - cx^2$, the function has a maxima at $x = b/2c$.

this property with a function like the cubic utility function because it can have a maxima and a minima or point of inflection in the same function.

In a mathematical comparison of the expected utility model and the safety-first models, Selley has shown that maximizing a utility function of the form:

$$U = a + bx - \lambda \quad \text{for } x < d, \text{ and}$$
$$= a + bx \quad \text{for } x \geq d,$$

under the N-M axioms is equivalent to a safety-first problem.

2.7 Chapter Summary

Analyzing decision making involves the application of theories of decision making, axioms for these theorems, and the decision rules which result from the theory and the axioms. This chapter reviewed the theory of expected profit maximization, the expected utility hypothesis, and the theory of bounded rationality along with the related concepts applicable to these theories. The methods involved in empirically implementing these theories were highlighted. The theory of expected profit maximization and the theory of expected utility maximization were classified as optimizing models. The theory of expected profit maximization results in maximizing the mathematical expectation of the profit function while the theory of expected utility maximizes a function which embodies the decision maker's preferences and the beliefs concerning the outcome of risky prospects. Bounded Rationality models were classified as satisficing models. These satisficing models include the decision maker's aspirations and his limitations in analyzing a complex decision problem. The next chapter describes the implementation of these theories in a practical decision making situation, with special reference to minor export crop farmers in Sri Lanka.

...Mathematical analysis is as extensive as nature itself; it defines all perceptible relations, measures times, spaces, forces, and temperatures. Its chief attribute is clearness; it has no marks to express confused notions; it brings together phenomena the most diverse, and discovers the hidden analogies which unite them. ...it seems to be a faculty of the human mind destined to supplement the shortness of life and the imperfection of the senses; and what is still more remarkable, it follows the same course in the study of all phenomena; it interprets them by the same language, as if to attest the unity and simplicity of the plan of the universe, and to make still more evident that unchangeable order which presides over all natural causes.

J.B.J. Fourier. *The Analytical Theory of Heat.* Cambridge: The University Press, 1878, (p. 7-8).

Chapter 3

EMPIRICAL MODELS AND METHODS

3.1 Introduction

Once a research problem is identified and the objectives laid out, a theoretical framework needs to be outlined as a basis for explaining the observed phenomenon. The next step is to outline the procedure for integrating the theory with the problem in order to quantify the relationships among the variables in the study. This chapter outlines the application of the theory in an empirical setting and describes the several analytical techniques used in the study. The first part of the chapter describes the area of study and the various aspects of the surveys. The second part describes the models and the procedures used to evaluate these models.

3.2 The Surveys

Farm surveys were conducted in the districts of Kandy and Matale in the central province of Sri Lanka. The choice of these two districts as the area of study was justified in Chapter One.

The farmers were surveyed by experienced enumerators employed at the Department of Minor Export Crops on the recommendation of M.P. de Silva.[9] These enumerators were recommended because they serve as extension agents, and thus are familiar with the farming activities in the area and also because the farmers feel more comfortable talking to these enumerators than to strangers from the outside. The surveys were done between December 22, 1985 and February 16, 1986. The sample size was 240, with an equal number from each district. The first survey was conducted on all the farms with the farm as the unit of inquiry. The electoral voters' register was used as a sampling frame and the households were picked using simple random sampling. The questionnaire used for this survey is given in Appendix A.

The second stage of the survey was conducted among 30 farmers selected at random from the larger sample of 240 farmers interviewed in the first stage of the survey. The second stage of the survey included more detailed information on decision making activities concerning the the farm, with the chief decision maker as the unit of inquiry. This stage of the survey included subjective elicitation of utility functions, discount rates, and probability distributions. The parameters for the bounded rationality decision models were obtained from the second stage. A different set of enumerators was used for this survey, as discussed later in the chapter. The interview questionnaire used in the second survey is contained in Appendix A.

3.3 The Expected Utility Maximizing Model

As discussed in Chapter 2 of this dissertation, the expected utility maximizing model of this study can be expressed as:

$$E[U(\pi)] = \int_{\pi} U(\pi)\, f(\pi)\, \partial p, \tag{3.1}$$

[9] Head, Division of Economics, Department of Minor-Export Crops, Peradeniya, Sri Lanka.

where:

$U(\pi)$ is the utility function in net-returns, π,

$f(\pi)$ is the probability density function of π,

E is the expectation operator, and

$\int_\pi$ indicates mathematical integration over the domain of the variable π.

Under the N-M axioms, a decision maker will choose the prospect or a set of prospects which has the highest utility index, $E[U(\pi)]$. This utility index can be calculated with the expression in [3.1] using numerical computation. This computation needs two pieces of information, which are the utility function and the probability density function of net returns.

3.3.1 Elicitation and Estimation of Utility Functions

The choice of ELCE (Equally Likely risky prospect and finding its Certainty Equivalent) method to elicit utility functions was justified in chapter 2. This section outlines the method and the interview procedures.

3.3.2 Enumerators

Due to the difficulty involved in understanding and implementing the ELCE method, it was preferable to employ individuals who were familiar with the method to elicit the utility functions. Elicitation of the utility functions was part of the second survey discussed earlier in this chapter. Four graduate students at the Postgraduate Institute of Agriculture of the University of Peradeniya were trained to use the ELCE method. Following the initial training they practiced the method among their colleagues at the Institute. This was followed by a trial field interview of farmers under the author's supervision.

The first part of the questionnaire collected detailed information on the 30 selected farmers. The annual net family income of the farm during the previous year was part of the information collected. This annual income was used as the upper limit of the ELCE method because the decision maker will be familiar with that income, and hence will be able to respond more realistically to the questions regarding preferences to income. A twenty percent loss of income was assumed to be reasonable in a given year, thus the lower level of the ELCE method was an amount equal to negative twenty percent of the annual income.

3.3.3 The ELCE Method

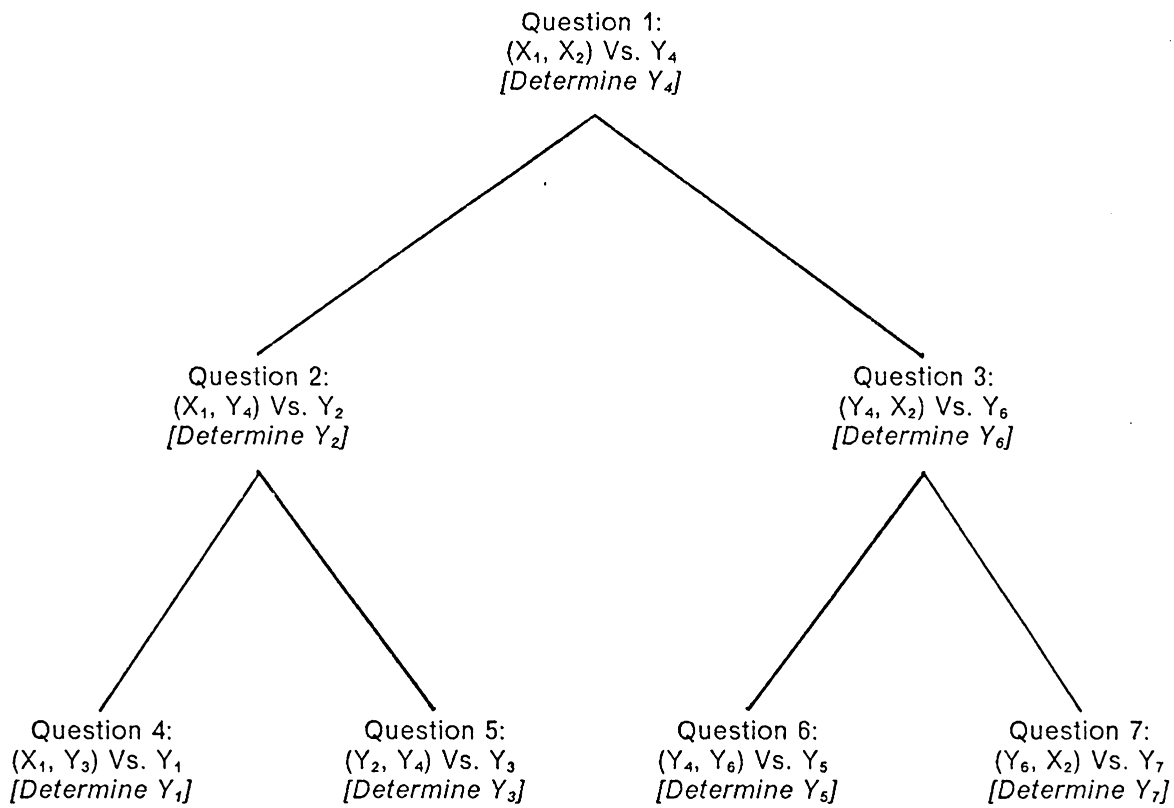
As the name implies, the ELCE method of eliciting utility functions elicits the agent's certainty equivalent (CE) of a prospect with equally likely risky outcomes. If an individual faced with a choice is indifferent between a sure income he is offered and a risky prospect, the sure amount is referred to as the individual's certainty equivalent of the risky prospect. For example, consider a risky prospect A with equally likely outcomes of Rs.5,000 and Rs.1,000. If an individual is indifferent between this prospect and a sure income of Rs.1,960, the individual's certainty equivalent of the prospect is Rs.1,960. Following this, the risk premium (RP) is:

$$E(A) - CE = RP$$

$$[.5(5000) + .5(1000)] - 1960 = Rs.1,040.$$

This implies that the individual will choose the risky prospect if he is paid Rs.1,040 or more. To facilitate the interview process, a scheme suggested by Anderson *et al.* (p. 72) was included in the survey instrument. This is given in Appendix A2 and is illustrated in figure 3.1. The CE's elicited from the farmers as given in figure 3.1 are represented in figure 3.2 in relation to a hypothetical utility function.

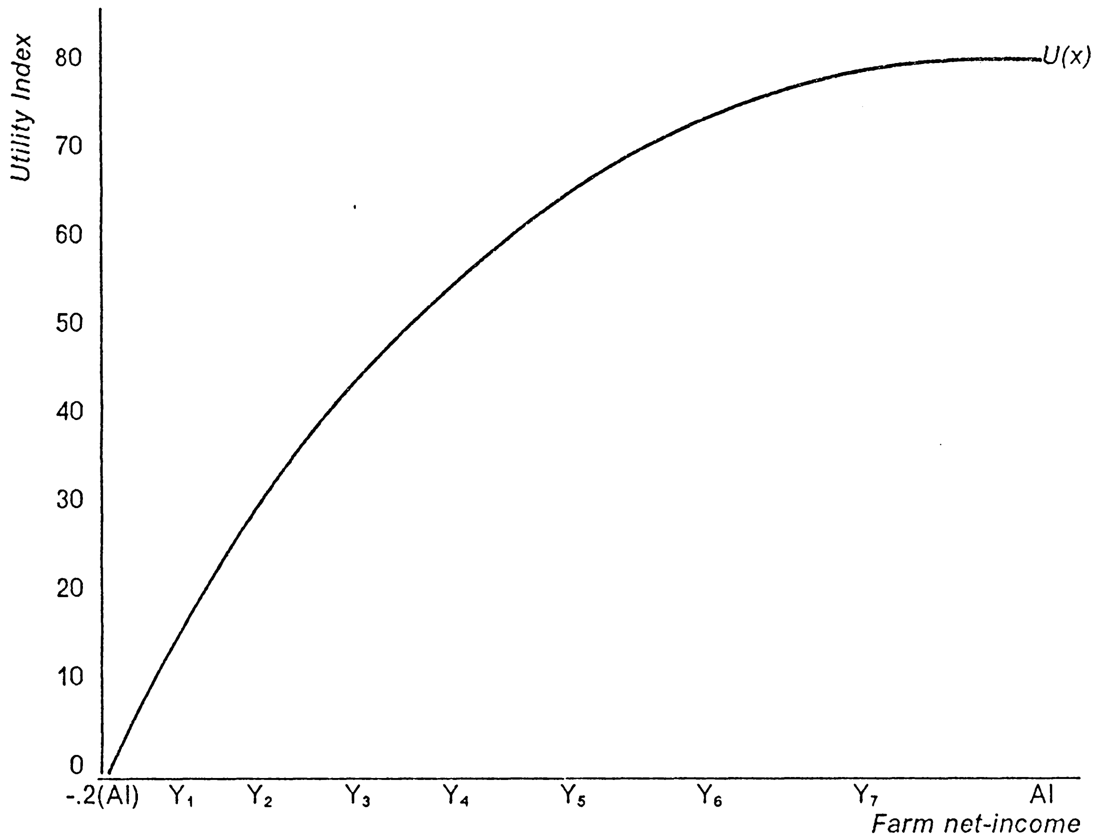
In figure 3.1 the variables inside each set of parentheses represent the outcomes of the lottery and the Y_i's represent the certainty equivalents of the lotteries. For example, in question 1, X_1 represents the negative twenty percent of the family net income for the previous year, X_2 represents the net annual income, and Y_4 is the certainty equivalent of a lottery with X_1 and X_2 as equally likely outcomes.



Check questions:

Question 8: is $(Y_3, Y_5) \equiv Y_1$
Question 9: is $(Y_2, Y_6) \equiv Y_1$
Question 10: is $(Y_1, Y_7) \equiv Y_1$

Figure 3.1: Schematic Representation of ELCE Method
(Source: Anderson, *et al.* p. 72)



NOTE:

Y_i 's are the certainty equivalents (CE), in Rupees, elicited from the farmers (See Figure 3.1).

AI is the annual income corresponding to a utility index of *80.*

-.2(AI) is the negative 20 percent of the annual income corresponding to a utility index of *0.*

Figure 3.2: A Typical Utility Function for a Risk Averse Decision Maker.

Figure 3.2 represents a typical concave utility function. This curve does not imply that the utility is maximum at 80 units. The utility indices on the vertical axis are arbitrary values, with a utility index of 0 representing a loss of twenty percent of annual income and an index of 80 representing the family net annual income. The indices 10 through 70 represent the certainty equivalents Y_1 through Y_7 respectively.

3.4 Utility Functional Forms

One of the important steps in analyzing decision making under the expected utility hypothesis is specifying and then estimating a suitable utility function. For this purpose, several functional forms have been suggested in theoretical literature and some of them have been used in empirical studies [Lin and Chang; Halter and Dean; Lin, Dean, and Moore; Musser *et al.*]. Researchers generally agree that utility functions should possess some desirable properties such as diminishing marginal utility and a decreasing absolute risk aversion coefficient [Pratt; Keeny and Raiffa; Roumasset (1976)]. Functional forms which result in a non-decreasing absolute risk aversion coefficient are clearly inappropriate for decision analysis. To circumvent this shortcoming, various other functional forms have been suggested [Lin and Chang]. In their evaluation of the functional forms, Lin and Chang criticize the forms usually studied because all of them require certain *a priori* assumptions on their specification. These two authors suggest a Box-Cox transformation as a means of determining the form of the function rather than assuming it. Despite the mathematical appeal of this transformation, Buccola (1982a) has demonstrated that the Box-Cox transformation is not consistent with Bernoullian decision theory. As demonstrated by Musser *et al.*, the chosen functional form is fundamental to the methodology as it could affect the classification of decision makers based on their risk attitudes. Musser *et al.* classified twelve subjects (graduate students) in their study, using the second order derivative of the utility function as a measure of risk aversion. The utility functions used were quadratic, semi-log ($U = a + b \ln x$), and non-linear ($U = a + bx^c$). The quadratic function classified three subjects as risk preferring and the rest as risk indifferent. The semi-log function classified all subjects as risk averse, and the non-linear function classified all subjects as risk indifferent.

This study will compare the classification of farmers based on their risk aversion coefficients given by three functional forms. The functional forms used are: the quadratic form (with increasing absolute risk aversion coefficient), the exponential form (with constant absolute risk aversion coefficient), and the cubic form (with decreasing and increasing absolute risk aversion coefficient).

Once the points on the individual's utility function are elicited by an appropriate method, the next step is to fit a curve to these points. Fitting a curve to a set of data involves two steps: one is the selection of a functional form and the other is a suitable measure to test how well the estimated equation fits the observed data, which is referred to as a test of goodness of fit. Regardless of the specific functional form chosen, certain desirable properties are sought in a functional form. The important ones are: the ease of estimating the parameters of the function, the ease with which the function can be mathematically manipulated to determine certain measures such as the expected value and the variance, and the behavior of the measures of risk aversion. Ideally, a utility function should exhibit decreasing relative risk aversion with respect to increasing wealth. The range of income level used is another factor which needs to be considered, particularly for the semi log forms, because the log of a negative number is not defined. Of the functional forms suggested in literature, the quadratic and the exponential are the most popular ones.

Analyzing a California farmer's marketing problem, Buccola (1982b) reports that quadratic and exponential functions give the same portfolio under the assumption of a normal distribution. But sometimes these two functions give the same solutions only when the risk aversion coefficients are the same.

Hanoch and Levy, in a theoretical comparison of the quadratic and the cubic functions, conclude that the cubic function has certain properties which are preferred to those of the quadratic function. These properties are:

1. The EU depends on the third moment of the distribution, skewness.

2. This added parameter results in greater flexibility and better approximates the general utility function.

3. Within certain restrictions on the coefficient, it is monotonically increasing.

4. It exhibits a decreasing degree of risk aversion at certain intermediate levels.

5. It allows for risk preference (convexity) at certain intervals of high returns.

The arguments for a cubic utility function, therefore, rest on the assumption of non-normal returns or non-zero skewness. Studies by Mendelbrot, and their extension by Fama, have shown that the skewness of the farm profit distribution is negligible; therefore, for all practical purposes, an assumption of a normal distribution is valid. The comparison of utility functional forms has so far been restricted to a study of classification of risk attitudes, except the study by Buccola (1982b) which compares the portfolios prescribed by the exponential and quadratic utility functions for a single farmer. This study will first compare the risk attitudes given by each of the functions chosen, and then will determine whether the ranking of prospects is independent of the functional form. If the functional form affects the ranking of prospects, choosing a functional form is fundamental to the methodology of expected utility analysis.

3.4.1 The Quadratic Utility Function

The quadratic utility function can be represented as:[10]

$$U = a + bx - cx^2, \qquad [3.2]$$

where, *a, b,* and *c* are constants. The second derivative of the function is *[-2c < 0],* implying diminishing marginal utility over the entire range of *x*, thus ruling out risk preferring behavior. The Arrow-Pratt risk aversion coefficient R_a is given by:

$$\frac{2c}{b - 2cx}. \qquad [3.3]$$

[10] In all the utility functional forms discussed, *U* will refer to the utility index and *x* to the monetary measure. In this dissertation the monetary measure will be net farm income in *Sri Lankan Rupees.*

The function [3.3] will remain positive for $x < (b/2c)$. Consequently, within this range of x, the quadratic function will exhibit increasing risk aversion, and for values $x > (b/2c)$ the function will exhibit decreasing risk aversion. The parameters of the quadratic function can be estimated by applying ordinary least squares (OLS), because it is linear in its parameters. The usual statistical tests such as the F-test and the t-test can be applied to test the significance of the model and the parameter estimates. Goodness-of-fit can be tested by the coefficient of regression, R^2.

3.4.2 *The Exponential Utility Function*

The exponential utility function can be represented as:

$$U = K - \theta e^{-\lambda x} \qquad K, \theta, \lambda > 0, \tag{3.4}$$

where, K and θ are parameters and e is the base of natural logarithms. The second derivative of the function is:

$$-\lambda^2 \theta e^{-\lambda x} < 0, \tag{3.5}$$

implying diminishing marginal utility. The risk aversion coefficient, R_a, is λ, which is positive and constant. The exponential utility function, therefore, exhibits constant risk aversion over all net returns.

Estimation of the Exponential Utility Function

The exponential utility function will be estimated by the method outlined by Buccola and French. The function given in equation [3.4] can be manipulated to give:

$$-U + K = \theta e^{-\lambda x} \tag{3.6}$$

which upon taking natural logarithms of both sides results in:

$$ln\,(K - U) = \ln\theta - \lambda x. \qquad [3.7]$$

In this form the function is linear in parameters and $ln\,(K - U)$ is regressed on x. To obtain the original parameters, θ is the antilog of the intercept term, and λ is the negative of the coefficient of x. The function in [3.7] is a monotonic but a non-linear transformation of the original function given in [3.4], and as Buccola and French note, this transformation is not a valid representation of utility under the N-M axioms. The alternative, therefore, is to estimate the original form using an appropriate method of estimating non-linear equations and to choose a set of (K, θ, λ) which minimizes the sum of squared error terms. Buccola and French suggest an alternative method involving two steps as:

1. Estimate different sets of (K, θ, λ) by regressing $\ln(K - U)$ on x. The different sets are estimated using several values of K.
2. Substitute estimated sets of (θ, λ) along with their associated K in the original function [3.6] and choose the set of (K, θ, λ) which gives the lowest sum of squared deviations for U defined as:

   $$SSE(U) = \sum_i (U_i - \hat{U}_i)^2,$$

   where, U_i's are the observed values of U, and $\hat{U}_i$'s are values of U predicted by the estimated equation for each x_i.

Because of the non-linearity of the function, the usual F-test and t-tests cannot be applied, but an R^2 can be computed as:

$$R^2 = 1 - \frac{\sum_i (\hat{U}_i - U_i)^2}{\sum_i (U_i - \bar{U})^2}. \qquad [3.8]$$

where $\bar{U}$ is the mean of the observed U_i's.

3.4.3 The Cubic Utility Function

The cubic utility function can be expressed as:

$$U = a + bx + cx^2 + dx^{3.} \qquad [3.9]$$

The marginal utility is given by: $b + 2cx + 3dx^2$, the sign of which depends on the sign and the magnitude of the parameters *b, c,* and *d*. The A-P risk aversion coefficient is:

$$R_a = -\left[\frac{2c + 6dx}{b + 2cx + 3dx^2}\right]. \qquad [3.10]$$

The R_a thus can be positive or negative depending on the parameter estimates.

The cubic utility function, when estimated without imposing any restrictions on the parameters, can give a range of risk attitudes. The cubic utility function is linear in parameters, and thus can be estimated by the OLS method.

3.5 Eliciting Probability Distributions

Probability distributions were elicited from growers concerning their beliefs about the prices and the yield of the minor export crops. As discussed in chapter 2, a modified form of the triangular distribution was used, where the 5, 50, and the 95 percentiles were elicited from the farmers. As demonstrated by Pearson and Tukey , and later by Perry and Grieg, a reliable estimate of the mean of a cumulative distribution is given by:

$$E(x) \cong 0.63(f_{0.05}) + (0.185)\,(f_{0.05} + f_{0.95}). \qquad [3.11]$$

Where: $f_{0.05}$ and $f_{0.95}$ are the 5^{th} and the 95^{th} fractiles of the distribution. For a symmetric distribution, Pearson and Tukey suggest a five-point approximation for the variance. Keefer and Bodily report that a three-point approximation is as good as a five-point approximation of the variance and suggest the following:

$$V(x) \cong [(f_{0.95} - f_{0.05}) / (3.29 - 0.1(\Delta/\sigma)^2)]^2. \qquad [3.12]$$

Where:

$$\Delta = f_{0.95} + f_{0.05} - 2f_{0.5}, \text{ and}$$

$$\sigma = (f_{0.95} - f_{0.05})/3.25.$$

The price and the yield were assumed to be independent of each other. That is, the price of a crop does not depend on the yield of the crop. Due to the large number of minor export crop growers in Sri Lanka, it is likely that a single farmer cannot influence the price. Similarly, Sri Lanka cannot influence the world price of the crops in the study because of the small contribution.

3.6 The Distribution of Net Returns

The net returns of an MEC farmer can be represented as:

$$\begin{aligned} \pi &= \sum_i TR_i - TC. \\ &= \sum_i p_i q_i - TC. \end{aligned} \qquad [3.13]$$

Where:

TR_i is the return from the i^{th} crop,

TC is the total cost for the farm unit, which is assumed non-random,

p_i is the price of the i^{th} crop, and

q_i is the output of the i^{th} crop.

The probability distribution of p_i is represented by $f(p_i)$ and the probability distribution of q_i is represented by $f(q_i)$. Then under the assumption of independence, the probability distribution of net returns from the i^{th} crop is given by:

$$f(TR_i) = f(p_i q_i) = f(p_i)\, f(q_i). \qquad [3.14]$$

The distribution of TR_i will be generated using Monte-Carlo simulation.

3.7 Subjective Discount Rates

The MEC farmer by delaying harvest, delays the cash flow from his farm. Thus, the farmer faces an opportunity cost for not receiving the income sooner. This opportunity cost is included in the decision over time as a discount rate. This discount rate is what is lost by delaying a cash flow. Under the assumption of a perfect capital market, the proxy for this discount rate is the market interest rate [Baumol]. For instance if the market interest rate is i per annum, the present value of a dollar received a year from now is $[1/(1+i)]$. Conversely, if a person invests $1/(1+i)$ dollars in the capital market at i annual interest rate, he will receive a dollar in a year. In real world investments, the return at the end of the investment may be uncertain. Baumol suggests adding a risk factor r to the interest rate for discounting future cash flows. The risk factor depends on the how risky the outcome is and is directly proportional to the risk. The discounting rate thus will be higher for a risky outcome given by i': $[1/(1+i+r)] < [1/(1+i)]$. The discount rate i' thus includes the time value of money and the risk effect. A decision maker may not always have access to a perfect capital market; and under such situations it is difficult to use a proxy for the discount rate. An alternative is to elicit the discount rate from the decision maker.

Subjective discount rates were elicited from each farmer by a method similar to the certainty equivalent method of eliciting utility functions. The decision maker was presented with a choice between two alternatives: Receive a sum of *Rs.A* today or a sum of *Rs.B* in n months, where $B > A$. The sum A is held constant and B is varied until indifference is reached between A and B. For instance, if A is preferred to B, B is increased by a small amount and then checked for indifference. At indifference then, the decision maker's present value of *Rs.B* received in n months time is *Rs.A*. The discount factor is then: $[A/B]$. In this study A was chosen to be Rs.1,000, and n as a month because the average period between harvests was about a month. The questions used for the elicitation of subjective discount factors are given in Appendix A2.

3.8 Monte-Carlo Simulation

Once the expected values and the variances of the price and the yield distribution have been obtained, these parameters can be used to simulate a density function for the price and yield. For this simulation a normal distribution was assumed. The choice of a normal distribution was justified earlier in the chapter. In the normal distribution the probability density of a random variable z is a function of its mean and its variance. A series of normal random deviates was generated which was used to generate random deviates specific to a given mean and its standard deviation of price and output. The distribution was truncated so that the lower value of the distribution was always equal to or greater than the lower value of the elicited distribution, because the actual price received by every farmer was higher than the lower value of the elicited distribution. Using this information, a series of TR_i and a corresponding series of $f(TR_i)$ was generated. With the distributions $f(TR_i)$, and the corresponding TR_i's a distribution for π was computed.

3.9 Classification of Farmers Based on the EUH Model

Earlier sections described how $U(\pi)$ will be determined empirically. This section describes how it will be used to test which harvesting strategy will give a higher $E(U)$ for a given set of $U(\pi)$, and $f(\pi)$

Let S_0 denote the strategy of harvesting the crop at maturity, and S_1 denote the strategy of harvesting the crop at a premature stage. Each strategy, then, has its own distribution for π, say π_0 for S_0 and π_1 for S_1. Then for each farmer in the sub sample two utility indices can be computed: U_0 for S_0; and U_1 for S_1. The results of EUM analysis can be used to classify farmers into two groups. For this classification consider two cases, each of which can result in two classifications:

Case 1: $U_0 > U_1$

a. If the observed strategy is S_0, then the farmer maximizes expected utility.

b. If the observed strategy is S_1, the farmer does not maximize expected utility.

Case 2: $U_1 > U_0$

a. If the observed strategy is S_1, then the farmer maximizes expected utility.

b. If the observed strategy is S_0, the farmer does not maximize expected utility.

3.10 The Bounded Rationality Model

Of the safety first models discussed in chapter two, those which fall in the groups of Safety-Principle and the Safety-Fixed principle do not consider the expected value of the objective function explicitly. With respect to these two principles, Roumasset (1976) argues that even a very small difference in the probability of disaster will be treated as an important criterion in choice, even if the less favored prospect has an expected value many times higher than that of the favored one. The safety principle is, thus, too restrictive in differentiating between two prospects. In the chance-constrained programming model (CCP) the disaster level $\bar{d}$ as well as the probability of disaster $\bar{\alpha}$ are both specified by the decision maker. Due to these specifications, it is possible for the CCP model not to satisfy all of the constraints and thus not give a solution.

With these general weaknesses of the Safety-Principle and the CCP, Roumasset suggests a combined version of safety first model, where two rules are ordered lexicographically as:

$$\begin{aligned} V(\pi) &\equiv 1 - \text{Max}\,[\bar{\alpha}, F_{\pi}(\bar{d})] \quad \text{(Probability of disaster)}, \\ W(\pi) &\equiv [V(\pi), E(\pi)] \quad \text{(Decision rule)}. \end{aligned} \qquad [3.15]$$

Where:

π is a vector of choice variables,

F_{π} is the cumulative distribution of π,

$E(\pi)$ is the expected value of π,

$\bar{d}$ is a disaster level, and

$\bar{\alpha}$ is a specified probability level.

This is called the Lexicographic Safety-First 1 (LSF_1). By this rule, the lexicographic ordering of $W(\pi)$'s, each prospect i resulting in a $W(\pi_i)$, depicts the preference of the individual. Roumasset (1976, p. 43) summarizes this decision rule as: *"Maximize expected value whenever the chance constraint is met, and minimize the probability of disaster when it is not."* Roumasset represents another combined version of CCP and Safety-fixed rule as:

$$V'(\pi) \equiv \text{Min}\,[\bar{d}, F_{\pi}^{-1}(\bar{\alpha})], \qquad [3.16]$$
$$W'(\pi) \equiv [V'(\pi), \mu],$$

where, μ is the expected value of π. Like the decision rule given in [3.15.], in equation [3.16.] lexicographic ordering of $W'(\pi)$'s represents the individual's preference ordering of π_i's. This model chooses prospects by minimizing the probability of disaster whenever the chance constraint is met and following the Safety-first principle when it is not. The rule in equation [3.16.] is called Lexicographic Safety First 2 (LSF_2). The two models, LSF_1 and LSF_2, thus first consider the disaster and then the level of profit. For the LSF preference models, Roumasset defines risk aversion to be directly related to $\bar{d}$ at a constant $\bar{\alpha}$, implying that risk aversion increases as $\bar{d}$ increases and decreases as $\bar{d}$ decreases when $\bar{\alpha}$ is constant.

The consequence of not meeting the specified disaster level is referred to as regret. In certain cases, not meeting the disaster level may result in total loss, while in certain cases it may not. For problems where regret is discrete (win or loose type), Roumasset recommends LSF_1. Failing to meet the quality requirements may be quoted as an example of bankruptcy, and where a particular standard in quality is not met, it could result in total loss. In peasant agriculture, it may be difficult to observe such a situation, and the regret is more likely to be on a continuum. For instance, a farmer might set his aspiration level at meeting family consumption expenses. Failing to meet these consumption expenses would not result in total death of the family, but certainly would result in discomfort. The degree of discomfort will depend on by how much the aspiration level was missed. For analyzing decision problems where the degree of regret is an important criterion Roumasset (1976) suggests the LSF_2 decision rule. For the problem identified in this study, LSF_2 is more appropriate.

The minimum amount of money required by each farmer to meet the daily expenses was considered to be an appropriate disaster level. For most farmers these elicited disaster levels were higher than the expected income, thus making it an inappropriate measure. As an alternative this study used the expected income calculated from the generated income deviates as the safety level. The LSF formulation of this study thus does not compute the probability of a disaster, rather a probability of a regret. The probability of a regret in this study is defined as the probability of missing the safety level.

3.10.1 The Safety-First Model for the MEC Farmer

The MEC farmer in Sri Lanka has to choose between harvesting the crop at mature stages of growth and harvesting at premature stages of growth. Delaying the harvest increases the output increases but there is an associated probability of losing a portion of the crop due to thievery and pest damages. This study will not distinguish between the nature of different kinds of loss, but will consider the total loss.

Let S_0 denote harvesting at the mature stage and S_1 denote harvesting at a premature stage; the farmer has to choose S_0 or S_1. Each alternative has its own mean profit and its distribution. Then from LSF_2 given by equation [3.16.]:

$$\text{For } S_0\text{:} \quad V'(\pi_0) \equiv \min\ [\bar{d},\ F_{\pi_0}^{-1}(\bar{\alpha})], \text{ and} \qquad [3.17]$$
$$W'(\pi_0) \equiv [V'(\pi_0),\ \mu_0].$$

$$\text{For } S_1\text{:} \quad V'(\pi_1) \equiv \min\ [\bar{d},\ F_{\pi_1}^{-1}(\bar{\alpha})], \text{ and}$$
$$W'(\pi_1) \equiv [V'(\pi_1),\ \mu_1].$$

By delaying harvest a farmer gets a crop of higher weight and better quality. But by delaying, the farmer loses utility due to time preference of money [Baumol.] If the income from mature harvest is denoted by π_0, this income will be discounted with θ as $\theta\pi_0$.

Specification of $\bar{d}$ and $\bar{\alpha}$

The regret level $\bar{d}$ and the allowable probability of avoiding the regret $\bar{\alpha}$ need to be specified for the LSF model. An appropriate regret level is the income necessary for subsistence. The subsistence level of income was elicited from each farmer by asking how much money is needed to meet monthly expenses. This amount is then multiplied by 12 to obtain the annual expenditure. The level of $\bar{\alpha}$ can be subjective and be elicited from the farmers. But Roumasset suggests that $\bar{\alpha}$ can be based on probability levels used as significant levels in statistical inference, and a value of 0.01 is reasonable. This implies that the probability of not meeting the regret level of income is 1%. An appropriate technique would be to plot various combinations of $\bar{d}$ and $\bar{\alpha}$ for each strategy on the same graph. These plots can be used to find:

a. solutions for situations under varying risk attitudes,

b. the sensitivity of the solution to changes in regret level or the confidence level, and

c. the percentage of the farmers in the population who use a particular strategy.

Solution Technique

The solution technique to compare S_0 and S_1 will follow Roumasset (1976, p. 56), outlined as:

Step 1: Compute the cumulative distributions for alternative S_0 and S_1 for a specified $\bar{d}$, denoted by $F_0(\bar{d})$ and $F_1(\bar{d})$.

Step 2: Order S_0 and S_1 based on a specified $\bar{\alpha}$

Step 3: Select the strategy which has the higher mean, μ_i.

Step 4: If neither S_0 or S_1 is found to be feasible in Step 2, apply LSF_1 or LSF_2 to select the preferred strategy.

The solution technique, therefore, can be solved by hand or with simple computer algorithms.

3.11 The Expected Profit Maximizing Model

In order to be consistent with the methods of analysis of the EUM and the bounded rationality decision models, a simple non-optimizing method will be used to analyze the Expected Profit Maximizing (EPM) model. At harvest, the only decision a decision maker has to make is when to harvest. Due to their perennial nature the composition of MEC plants on the field is predetermined. At harvest the farmer has to decide between harvesting at a premature stage of growth and harvesting at maturity. The net income from harvest at S_0 (harvest at maturity) is represented by:

$$\pi_0 = \sum_i p_{i,0}\, q_{i,0} - TC, \tag{3.18}$$

and the net income from harvest at S_1 (premature stage) is given by:

$$\pi_1 = \sum_i p_{i,1}\, q_{i,1} - TC. \tag{3.19}$$

Where:

π is the net income;

p_i is the price of the i^{th} product;

q_i is the quantity of the i^{th} product harvested;

TC is the total cost; and

the subscripts *0* and *1* refer to price, quantity, and net returns from S_0 and S_1 respectively.

Due to the time preference of money, when the decision is made at time *1* (pre-mature harvesting) the income from premature harvesting is compared with the income from mature harvesting discounted by the subjective discount rate. A decision maker, when faced with the decision, has to choose between π_0 and $\theta\pi_1$, where θ is the discount factor.

3.12 Qualitative Choice Model

Decision theoretic models explain behavior and show which one best predicts farmer behavior. This prediction is deterministic, based on the applied decision rule. In the decision theoretic models the relationship among the variables are specified. Certain models, such as EUM and EPM, base decisions on one variable, whereas models such as the mean-variance model and the safety-first models base decisions on two variables and lexicographic safety-first models base decisions on an ordered set of objectives.

An econometric model, on the other hand, estimates the relationship among the variables which can then be used to predict behavior conditional on a set of explanatory variables. The estimated function from an econometric model allows one to attach probabilities to the predictions. The models used in this study can, therefore, be compared with one another in terms of their predictive abilities.

When the determination of the effect of one or more variables on another variable or a set of variables is required econometric modelling is used. The four major steps in econometric modelling are:

1. Apply economic theory to a given situation and express a relationship among the chosen economic variables.
2. Express this economic relationship in a mathematical form, referred to as model building.
3. Estimate the magnitude of the relationships by applying mathematical and statistical techniques.
4. Use the estimated model for forecasting if necessary.

Models for prediction or forecasting can be classified into three groups. They are: time series models, single equation models, and multiple equation models. A time series model expresses the value of a variable as a function of time, such as population growth over time. These models could either be simple, where only time is included as a cause, or be complex and stochastic. The complex and stochastic models include the expectation of individuals in various forms, such as adaptive expectation and rational expectations. Single equation models explain a portion of the variation in the dependant variable with the variation in one or a group of independent variables. In the third group of models, called multi-equation models, one or several independent variables may be systematically related to each other. The estimation procedure involves several stages and are referred to as simultaneous system of equations. The coefficients will have to be estimated simultaneously.

Based on measurement, variables can be classified as continuous or discrete. A variable which can take any value on a line, such as the yield of a crop or the amount of rainfall, is called a continuous variable. A variable which can take only certain values on a line, such as the number of cows on a farm or the number of calves born during a month, is called a discrete variable. There are certain variables which can neither be measured on a continuous scale nor on a discrete scale. For example, if one is interested in studying the effect of farmers' participation in government programs on the output of certain crops, the independent variable is whether or not a farmer participates in the government program. The group of variables of this nature are called *qualitative choice variables.* When there are qualitative variables among the independent set, they are included as dummy variables and there is not much difference in the techniques used for the estimation of parameters.

Frequently, studies in agricultural economics use a qualitative dependant variable. For instance, if one is interested in studying the factors contributing to the farmer's decision to participate in a government program, the dependant variable is whether or not a farmer participates. Another example would be farmer's choice of varieties. In these two examples, the one regarding the government programs is called a *binary choice model,* because a choice has to be made between two alternatives, while the one regarding the varieties is called a *multiple choice model* because a single choice has to be made from more than two alternatives.

The MEC farmer in Sri Lanka has a binary choice with respect to harvesting: harvest prematurely or harvest at maturity. A binary choice model therefore, seems appropriate for a quantitative study of the factors contributing to this behavior. A binary choice model estimated from the sample can then be applied to the population from which it was drawn to predict behavior of other farmers. Even though actual observations will be included in the model as 0's and 1's, values predicted with the estimated equation may lie on a real line which can extend beyond the interval (0,1). The prediction equation, therefore, will not give enough information to predict behavior with perfect accuracy. A more reasonable application of the estimated equation is to predict the likelihood of a farmer harvesting the crop prematurely.

In the following sections the various types of available models will be discussed and a suitable model will be chosen. The chosen model will be discussed along with its estimation techniques and statistical tests. The model will then be applied to the harvesting behavior of MEC farmers in Sri Lanka. This chapter will develop the empirical model; the results will be discussed in the next chapter.

Three types of binary choice models have been used in the literature. They are: the linear probability model, the probit model, and the logit model.

3.12.1 The Linear Probability Model

The linear probability model can be expressed as [Pindyck and Rubinfeld]:[11]

$$Y_i = \alpha + X_i\beta + \varepsilon_i \qquad [3.19]$$

where:

Y_i is the binary choice variable for the i^{th} individual. Y_i equals 1 if the first choice is made and equals 0 if the second choice is made;

X_i is a row containing p explanatory variables;

β is a $p \times 1$ vector of parameter coefficients;

α is the intercept constant; and

ε_i is the i^{th} random error term $\sim iid\ N(0, \sigma^2)$.

[11] The rest of the discussion on qualitative choice models will use the notation described here.

The expected value of Y_i, $E(Y_i)$, is given by:

$$E(Y_i) = \alpha + \beta X_i. \qquad [3.20]$$

Recall that Y_i can be either 0 or 1. If the probability of $(Y_i = 1)$ is P_i, it follows that the probability of $(Y_i = 0)$ is $(1 - P_i)$. The expected value of Y_i can then be expressed as a mathematical expectation of the form:

$$E(Y_i) = 1(P_i) + 0(1 - P_i) = P_i. \qquad [3.21]$$

The estimated regression equation thus can be used to assign probability values to the prediction. The expectation of Y_i conditional on the X_i's is the probability this individual will select the first alternative. The individual β_{ij}'s represent the effect of a unit change in the j^{th} explanatory variable on the probability of the individual choosing the first alternative.

The parameters of the linear probability model can be estimated by the ordinary least squares method which gives unbiased and consistent estimates. When estimated by OLS, however, the model has some limitations. They are [Pindyck and Rubinfeld]:

1. The error terms are heteroscedastic resulting in loss of efficiency.
2. The error terms are not normally distributed. As a result the standard statistical tests can not be applied to the estimated parameters.
3. The predicted values can fall outside the interval (0,1). This results in biased predictions.

Alternate estimation techniques such as Generalized Least Squares (GLS), weighted least squares, and constrained mathematical optimization $(0 \leq \hat{Y}_i \leq 1)$ have been suggested. These techniques however do not rectify all the shortcomings of the linear probability model [Pindyck and Rubinfeld].

The predicted values falling outside the interval (0,1) is considered to be the most serious weakness of the linear probability model. This weakness can be overcome by transforming the original model, so that the transformed values of the predictions will fall within the range (0,1). Of the possible transformations, the popular ones are related to the normal probability model and the logistic probability model. Transformation with respect to the normal probability model is called a *probit model* while the transformtion with respect to the logistic probability model is called the *logit model* .

3.12.2 The Probit Model

In the probit probability model a new variable, Z_i , is defined as [Kmenta.]:

$$Z_i = \alpha + \beta X_i. \qquad [3.22]$$

The variable Z_i is only arbitrary and the prediction is based on whether the variable gets a high value or a low value in relation to a defined critical level $\bar{Z}_i$. Hanushek and Jackson demonstrate a close resemblance between the probit and the logit models. Amemiya has established a relationship between the estimates of the two models as:

$$1.6\ \hat{\beta}_{probit} \cong \hat{\beta}_{logit}, \qquad \text{implying} \qquad 2.56\ V(\hat{\beta}_{probit}) \cong V(\hat{\beta}_{logit}).$$

The probit model is criticized because it lacks theoretical justification [Pindyck and Rubinfeld]. This study will therefore use the logit model to analyze grower decisions.

3.12.3 The Logit Model

The logit model transforms the estimated function into a logistic probability model. The logistic cumulative distribution function is [Pindyck and Rubinfeld]:

$$F(Z_i) = \frac{1}{1 + e^{-Z_i}}, \qquad [3.23]$$

where, e is the base of natural logarithms. In the logit model P_i, which is the probability of the i^{th} individual choosing the first response, is expressed as a function of $(\alpha + \beta X_i)$, which is then substituted for Z_i in the logit model. The transformed logit model thus becomes:

$$P_i = F(Z_i)$$

$$F(Z_i) = F(\alpha + \beta X_i) \qquad [3.24]$$

$$P_i = F(Z_i) = F(\alpha + \beta X_i) = \frac{1}{1 + e^{-(\alpha + \beta X_i)}}.$$

To demonstrate the simple nature of the logit model, equation 3.24 can be expressed as:

$$P_i = \frac{1}{1 + e^{-Z_i}}, \qquad [3.25]$$

which can be manipulated to give:

$$e^{Z_i} = \frac{P_i}{1 - P_i}. \qquad [3.26]$$

Taking the natural logarithm of both sides results in:

$$Z_i = \ln\left[\frac{P_i}{1 - P_i}\right]. \qquad [3.27]$$

Substituting from equation [3.24] gives the appealing relationship:

$$\ln\left[\frac{P_i}{1 - P_i}\right] = Z_i = \alpha + \beta X_i, \qquad [3.28]$$

where, the dependant variable is the logarithm of the ratio of the probability that a particular event will occur (particular choice will be made) to the probability that the event will not occur (particular choice will not be made). Thus the dependant variables can be interpreted as the logarithm of the odds that a particular choice will be made. The properties of the logit model are:

1. The distribution is symmetric about 0.

2. The variance is $\pi^2/3$, where, $\pi = 22/7$.

3. The slope of the derivative is the greatest at $P = 0.5$. This implies that the greatest impact of the explanatory variable on the probability of choosing a given alternative will be at the midpoint of the distribution. The tails of the distribution are flat implying that large changes are necessary in the explanatory variable to affect the probability of choice.

Estimation of Parameters

The parameters of the logit model can be estimated by applying ordinary least squares (OLS) procedure on equation [3.28.]. But, if in equation [3.28.] P_i is equal to either one or zero, the logarithm of the expression $P_i/(1 - P_i)$ is not defined. One way to overcome this is to group the observations on some characteristics of the explanatory variables. This, however, is possible only if the studied sample is large. For smaller samples the maximum likelihood method of estimating the coefficients seems more appropriate. Estimation by the method of maximum likelihood assumes that each individual estimation is independent of each other. In maximum likelihood estimation, the chosen estimates of the population parameters are those which maximize the probability of obtaining such a sample from the population. Estimating population parameters by the method of maximum likelihood involves three steps [Pindyck and Rubinfeld]:

1. construct the likelihood functions,
2. derive the first order conditions with respect to each parameter to be estimated, and
3. solve the first order conditions for the estimates of each parameter.

The method of maximum likelihood assumes independence among estimates.
From equation [3.24.], the logit model can be expressed as:

$$P_i = \frac{1}{1 + e^{-(\alpha + \beta X_i)}}.$$

For sample size N with n_1 responses to one choice and n_2 responses to the other choice, and $n_1 + n_2 = N$, the likelihood function is then given by:

$$P_i = L = P(Y_i, \dots, Y_N | Z) = P(Y_1 | Z), P(Y_2 | Z), \dots, P(Y_N | Z).$$

If the observations are ordered such that the first n_1 observations have $Y = 0$, then the likelihood function can be re-written as:

$$L = [F(Z_1), \dots, F(Z_n),] \; [(1 - F(Z_{n_1+1})), \dots, (1 - F(Z_N))]. \qquad [3.29]$$

Using the information that the probability of choosing the second alternative is 1 minus the probability of choosing the first alternative, equation [3.29.] can be reduced to:

$$\prod_{i=1}^{N} P_i^{Y_i} (1 - P_i)^{(1 - Y_i)}. \qquad [3.30]$$

The log-likelihood function is then given by taking logarithms of equation [3.30.], which is:

$$\log L = \sum_{i=1}^{n_1} \log P_i + \sum_{i=n_1+1}^{N} \log (1 - P_i). \qquad [3.31]$$

By substituting equation [3.28.] in equation [3.31.] the first order conditions for maximum *log L* can be derived, which are non-linear. Of the procedures available for estimating parameters of non-linear equations, the method of maximum likelihood is preferred because the estimators are consistent and efficient asymptotically, and the estimators are asymptotically normal [Pindyck and Rubinfeld]. The method of maximum likelihood will be used to estimate the parameters in this study.

Tests of Significance

The second property of the maximum likelihood estimators, asymptotically normal estimators, can be used to carry out *t*-tests on the estimated parameters [Pindyck and Rubinfeld]. To test the significance of the logit model, the chi-square (χ^2) distribution is used instead of the *F*-test. For the χ^2-test define the likelihood ratio as:

$$\lambda = \frac{L_0}{L_{max}},$$

where, L_0 is the value of the likelihood function with all parameters except the intercept set equal to zero, and L_{max} is the value of the likelihood function at its maximum. The function:

$$-2 \log \lambda = -2(\log L_0 - \log L_{max}),$$

follows a χ^2-distribution with k degrees of freedom, where k is the number of parameters of the regression equation excluding the constant.

Goodness of Fit

Three goodness-of-fit tests will be conducted on the estimated equation. They are [Pindyck and Rubinfeld]:

1. McFadden's R^2 which is equal to $(1 - \lambda)$ Recall that $\lambda = L_0 / L_{max}$. When L_{max} approaches L_0, implying the unconstrained function does no better than the constrained function, λ approaches 1 and R^2 approaches 0. When L_{max} increases, on the other hand, R^2 approaches 1. Therefore, the closer the value of McFadden's R^2 to 1 the better the fit of the estimated equation to the sample data.

2. An analog to R^2 as in regular regression. As in regular regression the total sum of squares, TSS, and the error sum of squares, ESS, can be defined for a sample of size N as:

$$TSS = \sum_{i=1}^{N} (Y_i - \bar{Y})^2, \quad \text{and} \quad ESS = \sum_{i=1}^{N} \hat{\varepsilon}_i^2,$$

where, $\bar{Y}$ is the mean of the observed dependant variable. With these two measures the $\hat{R}^2$ is defined as:

$$\hat{R}^2 = 1 - \frac{ESS}{TSS}, \qquad [3.32]$$

which is the proportion of the variation in the independent variables which is explained by the variation in the independent variables. Morrison, and later Neter and Maynes, have argued that $\hat{R}^2$ calculated this way very rarely gives values close to one, because the possible upper limit is less than one.

3. A third method which will be used in this study is based on the number of correct predictions made by the estimated equations. Using the estimated equations the index for Z is computed which is then used in the original cumulative distribution function to predict the probabilities P_i for each individual. Amemiya, and later Morrison, have suggested that if $P_i > 0.5$ it is appropriate to select the alternative which has a value of 1 in the original observation. The maximum proportion of correct classifications of outcomes is given by [Morrison; Westin]:

$$P(c) = \int_0^{.5} (1 - p)\, f(p)\, \partial p \quad + \int_{.5}^{1} p\, f(p)\, \partial p. \qquad [3.33]$$

where, *p(c)* is the maximum proportion of correct specification and *f(p)* is either the beta probability density function or the S_β density function, and *p* is the proportion of correct predictions.

3.12.4 The Logit Model as Applied to MEC growers

Based on the observation that some of the MEC farmers in Sri Lanka practice premature harvesting of their crops, a logit model can be used to determine whether this behavior can be predicted with levels of probability conditional on certain characteristics of the farmer. The explanatory variables in the model include characteristics of the farm decision maker, such as the age and the level of education; the characteristics of the farming environment, such as the size of the farm and the number of crops on the farm; total family income; and the size of the household.

It is reasonable to assume that a decision maker's personal characteristics will enter the decision process, and hence influence the decision. A decision maker with a higher education will tend to harvest the crop at a mature stage because the farmer will be able to understand the implications of premature harvesting, and the advantages of harvesting the crop at a mature stage. The hypothesized direction of the effect of education on harvesting behavior is, therefore, positive, This implies that, the higher the level of education of the decision maker the lower the probability of harvesting the crop at premature stage.

Studies have shown that risk averse behavior is directly related to age; that is as one gets older the degree of risk aversion increases (Moscardi and de Janvry). Inclusion of age in the model has two purposes. First is to provide evidence for or against the findings, and second is to test the hypothesis that the age of a decision maker influences harvesting behavior. If risk aversion is directly related to age, then as one gets older one becomes more risk averse. If a farmer considers mature harvesting a risk the probability of premature harvesting will have a positive relationship with age.

It is reasonable to assume that risk aversion decreases with increasing income as implied by theory (Arrow; Pratt). The level of income can have a direct impact on the probability of premature harvesting. As the level of income increases premature harvesting practiced due to reasons such as immediate money needs can decrease. Also, with a higher income a farmer will be able practice better management for the crop. The hypothesized sign on the income variable is, therefore, negative.

The harvesting seasons of the crops in the study do not coincide with each other; the seasons are staggered over a year. If immediate money needs is the most important reason for premature harvesting, the number of crops on a farm can have a negative effect on the probability of premature harvesting. If thievery or pest damage, or both, are important reasons, then the number of crops can have a positive effect on premature harvesting because as the number of crops increases, so do the problems from them.

The size of the household is a good indicator of the demand for income of the family. As the size of the household increases, the probability of premature harvesting would increase. On the other hand, as the size of the household increases the labor supply would increase. This increased supply of labor can be used in several ways, such as increased management and increased protection against thievery. The sign on the family size variable can, therefore, be either positive or negative.

The size of the farm is a good indicator of farm income. The total land owned and operated by a farmer in the sample is composed of two types of land; which are highland and lowland. Highland is referred to land which grows regular crops and lowland refers to land which grows wetland rice. Wetland rice is the commonest form of rice grown in Sri Lanka. Because rice is the staple food of Sri Lanka it is reasonable to assume that a farmer would pay extra attention to rice. This extra attention demanded by rice could divert the attention from rest of the farm towards rice production. Also, rice demands a more than an average amount of management, especially the high yielding newer varieties. The land variables, highland and lowland can, thus, have impacts in the opposite direction. To capture these impacts it is appropriate to use the ratio of lowland to total land operated by the farmer as the land variable. If the income effect is higher than the input demand effect the estimate on the land variable will be positive. On the other hand, if the input demand effect is higher the sign on the land variable could be negative.

3.12.5 The Empirical Model

The empirical form of the logit model used in the study can be represented as follows:

$$\log \frac{P_i}{1 - P_i} = Y_i = \alpha_0 + \sum_{j=1}^{k} \beta_j X_j + \varepsilon_i$$

Where, P_i is the probability that a farmer will harvest his crop pre-maturely, α_0 is the constant for the intercept, β_j is the coefficient of the j^{th} independent variable, Y_i is the i^{th} independent variable, and ε_i is the random error term. The model can be written in estimation form as:

$$\begin{aligned} Y_i = \ & INT + \beta_1 NUM + \beta_2 AGE + \beta_3 EXFM + \beta_4 NCROP \\ & + \beta_5 TTI + \beta_6 RLND + \beta_7 EDU1. \end{aligned} \qquad [3.34]$$

Where:

Y_i is the dependant qualitative choice variable where, Y_i equals 1 if the individual harvests the crops prematurely, and equals 0 if the individual does not harvest the crop at premature stages;

β_i's are the coefficients to be estimated;

INT is a constant for the intercept;

NUM is the size of the household;

AGE is the age of the head of the household, in years;

EXFM is the farming experience of the head of the household;

NCROP is the number of minor export crops grown by the farmer;

TTI is the total farm income;

RLND is the ratio of lowland to total land; and

EDU1 is the education variable which is equal to 1 if the years of schooling of the head of the household is less than 6 years, and equal to 0 if not.[12]

3.13 Chapter Summary

This chapter explained in detail the methods used in the study. The utility functional forms were discussed and the three functional forms chosen for the study were justified. The decision theoretic models and their solution techniques were explained. The decision theoretic models will be used as descriptive models to predict farmer behavior. A qualitative choice model was explained which will be used to explain behavior and attach probabilities to the predictions conditional on certain explanatory variables. The next chapter will first present summary statistics from the surveys and then discuss the results from the decision theoretic and the qualitative choice models.

---

[12] Preliminary models were estimated with various education variables. The model with this formulation gave the highest significant relation of education variable to harvesting behaviour.

Complete realism is clearly unattainable, and the question whether a theory is realistic "enough" can be settled only by seeing whether it yields predictions that are good enough for the purpose in hand or that are better than predictions from alternative theories.

Milton Friedman. *Essays in Positive Economics.* Chicago: Chicago University Press. 1953. (p: 41).

Chapter 4

Results and Discussion

4.1 Introduction

This chapter presents the results of the various analyses of the study. Initially, the characteristics of families, farmers, and farms in the study sample are described based on the survey data. This is followed by a discussion of the estimates of the utility functions, the Arrow-Pratt risk aversion coefficients, and the classification of the farmers' risk attitudes.

The results of the first objective are discussed next, which is *"to determine the reasons for the practice of premature harvesting."* This is followed by a discussion on the second objective of the study: *"to determine the relationship between the behavior and socio-economic characteristics of the farmer."* The second objective was approached with a logit probability model expressing the logarithm of the odds that a farmer would harvest the crop at a mature stage as a function of: age; farming experience; the education of the farmer; the number of members in the household; the ratio of lowland to total land of the farm; the number of minor export crops grown by the farmer; and the total family income.

The results of the models developed to explain farmer behavior are discussed next. The performance of each model is discussed individually with respect to its ability to explain farmer behavior. The preference ordering prescribed by the various utility functions were not consistent implying that the utility function chosen to analyze decisions can influence the ranking of prospects. This property of the utility functions, which is of paramount importance to the methodology of expected utility analysis, is discussed next. The last section of this chapter compares the performance of the various models analyzed in predicting farmer behavior and their sensitivity to changes in discount rates. The sensitivity of the LSF model to changes in expected income is also analysed.

4.2 Summary of Farm Family Characteristics

The summary of survey results relevant to this discussion is given in Appendix B. This discussion will focus primarily on the family and farmer characteristics; farm characteristics; and the harvesting behavior of the households. This information is given in order to give the reader an idea about the structure of a minor export crop farm in Sri Lanka.

4.2.1 Family Characteristics

The summary of family characteristics is given in table B.1. The average family size of the surveyed households is about five members with a range of one to ten. The family income had a very wide range of Rs.59,500.00 with a mean of Rs.11,288.13. The minimum annual household income is Rs.500.00 and the highest income for the sample was Rs.60,000.00. The standard deviation of annual income was Rs.11,193.55. Of the 240 households in the study, 89 percent had a male as the head of the household (HOH).

The age of the HOH ranged from 32 years to 71 years with a mean of 54.2 years. The average age of a minor export crop farmer is thus almost the retirement age from government services, which is 55 years. The level of education had a wide range from six HOH's with no schooling at all to one with a Ph.D. The average level of education is 9-10 years of schooling. The group with 9-10 years of education was also the mode and the median, with 114 farmers (47.5 percent). Grade 10 is considered to be a natural breaking point of formal education, at which point all students in the country take a common examination conducted by the government Department of Examination. Only those interested in higher education, if they qualify on the examination in grade 10, enter grade 11. Most students entering grade 11 do so with the aim of entering one of the country's eight universities. Admission to a university is gained based on the performance on a competitive examination at the end of grade 12 and on the basis of the districts from which they take the examination.

Experience in farming of the HOH ranged from 0 to 55 years with a mean of 16.41 years. Off-farm work of the HOH ranged from 0 to 60 years with a mean of 8.38. Thus, on average, a MEC farmer has more experience on-farm than off-farm. The total land owned and operated by the surveyed farmers ranged from 0.12 acres to 19.8 acres with a mean of 2.49 acres. The average area of highland owned ranged from 0.12 acres to 19 acres with a mean of 2.04 acres. Lowland describes land which can grow rice as a wet crop in standing water. The sample had 87 farms (36 percent) with lowland. For the farmers with lowland, the acreage ranged from 0.125 to 8.0 acres with a mean of 1.24 acres. A large proportion of farms do not grow rice and when they do, it is grown in a small area.

The number of minor export crops ranged from 1 to 5 with a mean of about 3. Thirty farms (12 percent) had some kind of animal as indicated in table B.2. Poultry was the most popular, raised on 25 farms, while 20 farms had cattle and seven farms had goats.

4.2.2 Farming Decisions

The summary of information on farming decisions is given in table B.3. Farming decisions involve factors such as timing of planting, deciding which crops to plant, and other day to day farming decisions. The HOH made the farming decisions on 218 (90.8 percent) farms, the wife of the farmer made the decisions on 16 (6.7 percent) farms, and the eldest child made the farming decisions on 6 (2.5 percent) farms.

Decisions made on harvesting of the MEC's followed a similar pattern. The HOH made the decisions about harvesting of MEC's on 216 (90 percent) farms, the wife made the decisions on 17 (7.1 percent) farms, and the eldest child made the decisions on 7 (2.9 percent) farms.

4.2.3 *Farm Labor*

The summary on farm labor is given in table B.4. A majority of the farms met all their labor requirements with family labor. Nearly a third of the farms (36.25 percent) hired additional labor to meet farm labor requirements. The activities for which labor is hired were: land preparation (24.5%); soil conservation, such as cutting drains , building and maintaining ridges (22.8%); fertilizer application (22.8%); weeding (19.17%); planting (8.3%); irrigation (2.5%); and pruning (2.5%).

4.2.4 *Harvesting Practices of MEC*

The information on harvesting practice is summarized in tables B.5 and B.6. All but four farmers reported that they are aware of the stage of maturity of the minor export crops. In the sample 56 (23.33 percent) of the farmers reported that they practice premature harvesting. The knowledge about the stage of maturity, therefore, does not seem to influence premature harvesting. Seventy three percent of the farmers reported that grading the crop does not affect the income received from the crop, implying that there is not much incentive to grade the crop. Fifteen percent of the farmers reported that harvesting activities of MEC's affected their off-farm activities, and about seventeen percent of the farmers reported that off-farm activities affected their harvesting activities on the farm.

4.2.4.1 Method of Disposal

Table B.6 gives the information on the disposal of minor export crops by the farmers surveyed. A very small number of farmers dispose of their crop while on the tree. This is a practice where the crop is sold while it is still on the tree. The buyer and the farmer assess the crop, negotiate a price based on an estimated yield, and the buyer harvests the crop. A slightly higher number of farmers sell their crop when it is still fresh, without drying the crop. This method was practiced by: 10 for cocoa, 18 for coffee and pepper, 3 for nutmeg, and none for cardomom. Selling the crop green implies no grading. A large portion of the farmers sold their crop after drying it. This involves varying degrees of processing for certain crops such as fermenting and removing the pulp around the beans for cocoa; removing the seed coat and washing of coffee beans; and opening the fruit and separating the mace from the seed for nutmeg. The number of farmers who sold their crop after processing and drying were: cocoa (92), coffee (193), pepper (169), cardomom (4), and nutmeg (31).

A large portion of the farmers sell their crop ungraded, the grading for these crops takes place along the marketing channel on its way to the exporter. The number of farmers who sold their crop ungraded were: cocoa (88), coffee (189), pepper (166), cardomom (2), and nutmeg (32). Only a small portion of the farmers sold their crop graded. Grading by the farmers, however, does not mean that this grading conforms to the standards of the exporters. It is very likely that almost all the crops purchased by the exporters are graded once again [Gunasekara; Rambukwella]. The percentage of farmers selling their crop graded are: cocoa 14 percent, coffee 10 percent, pepper 11 percent, cardomom 50 percent, and nutmeg 5 percent. A majority of the farmers, then, sell their crop dry and ungraded.

4.3 Reasons for Premature Harvesting

Only 56, (23%), farmers reported that they practiced premature harvesting. The farmers' responses to the reasons for premature harvesting are given in table 4.1. As hypothesized based on observation [M.P. de Silva; Tennakoon], fear of theft, immediate money needs, and pest damages were reported as the more important reasons for prematurely harvesting the crops. Among these, fear of theft was ranked as the most important reason by 24 farmers, out of a total of 49, who responded with fear of theft as one of the reasons for prematurely harvesting the crop. Forty-six farmers gave immediate money needs as one of the reasons for premature harvesting, of which 22 found this to be the most important reason. Pest and disease problems was ranked as the number one reason by 8 farmers out of a total of 29. Three other reasons for premature harvesting were reported by eight farmers. They are: insignificant difference in the prices of mature and immature products (reported by three

Table 4.1: Reasons for Premature Harvesting

Reasons	Rank 1	2	3	4	Total	Percent. of Total
1. Fear of theft	24	15	10	0	49	88
2. Immediate money needs	22	16	8	0	46	82
3. Pest and Diseases	8	14	17	2	29	52
4. Insignificant difference in prices	1	2	0	0	3	5
5. Demand by merchants	0	2	1	0	3	5
6. Harvest premature only when price is high	1	0	1	0	2	4
Total[1]	56	49	37	2		

[1] This row gives the number of farmers who harvest their crops prematurely for number of reasons corresponding to the number in the second row of the table heading. For instance, 56 farmers gave at least one reason for harvesting the crop prematurely, 49 farmers gave at least two reasons, and so on.

farmers), demand for the product regardless of maturity (reported by three farmers), and those who harvest prematurely only when the price of the product is high, so that the farmers do not lose much income by selling the premature product. Two directors of produce brokering agents interviewed for the study strongly believe that the excess demand for the products in the world market has a strong influence on the behavior of the farmers [Gunasekara; Rambukwella]. This excess demand which is first felt by the exporters is transferred down the marketing channel to the farmers. The farmers respond by harvesting the crop available at the time, unless they can meet the demand with whatever is stored from the previous season.

This section presented the reasons given by the farmers for harvesting their crops at a premature stage. The following section discusses the estimates of the logit model proposed in chapter 3. The objective of this analysis is to explain the behavior of premature harvesting with certain farmer characteristics and socio-economic variables.

4.4 Results of the Logit Model

The estimation results for the logit model are given in table 4.2. This estimated model was proposed in Chapter three of this dissertation and the variables included in the model were justified. The data used to estimate the logit function are given in Appendix C. The dependant variable of the estimated logit model is the logarithm of the odds that a farmer will harvest the crop at a premature stage. Unlike the linear model, the estimated partial regression coefficients of the logit model have no direct interpretation. Specifically, the estimate of a parameter does not mean that the odds will increase by the value of the coefficient when the corresponding explanatory variable increases by a unit. A valid interpretation is that a unit change in the explanatory variable changes the logarithm of the dependant variable. The dependant variable is $\ln[P/(1-P)]$, where, P is the probability of a farmer harvesting the crop at a premature stage. For instance, in the estimated equation the variable *RLND* (ratio of lowland to total land) has a coefficient of 5.1068. It follows then:

Table 4.2: Estimates of the Logit Model

Variable	Estimate	Change in probability[1]	*t*-statistic
INTERCEPT	1.3072		0.71027
NUM (family size)	0.01158	0.7512D-4	0.10037
AGE (age of farmer)	0.006177	0.4008D-4	0.21060
EXFM (experience in farming)	0.003314	0.2151D-4	0.20736
NCROP (number of MEC)	0.29975	0.1945D-4	1.1378
TTI (total farm income)	-0.0007399	-0.4801D-5	-6.1381***
RLND (ratio of lowland to total land)	5.1068	0.0331	3.4234**
EDU1 (variable on education =1 if years of education < 6 =0 otherwise)	1.7956	0.0117	2.3349*

Test Statistics:

Log of likelihood for the binomial model ($\ln L_0$):	-130.39
Log of likelihood function at its maximum ($\ln L_{max}$):	-65.69
Value of likelihood ratio $[-2(\ln L_0 - \ln L_{max})]$:	129.39***
Goodness-of-fit (McFadden's R^2)	0.5038
Goodness-of-fit (R^2 = 1 - ESS/TSS)	0.5046
Number of correct predictions	215
Percentage of correct predictions	89.58

*** Significant at the 0.001
** Significant at the 0.01
* Significant at the 0.05

[1]Estimated at sample mean, D-4 indicate 10^{-4}, and D-5 indicate 10^{-5}.

$$\Delta \ln \left[\frac{P}{1-P}\right] = 5.1068\ \Delta\ \text{RLND}.$$

Using the relationship $\Delta \ln x \cong \Delta x/x$, the expression $\Delta \ln[P/(1-P)]$ can be written as [Pindyck and Rubinfeld]:

$$\Delta \ln \frac{P}{1-P} \cong \left[\frac{1}{P} + \frac{1}{1-P}\right]\Delta P = \frac{1}{P(1-P)}\Delta P.$$

When Δ RLND = 1, the above expression can be manipulated to give:

$$\Delta P \cong 5.1068[P(1-P)].$$

This implies that the change in the probability due to a change in an explanatory variable is a function of the probability at which the change is evaluated. A single value cannot be assigned to express the impact of a change in an explanatory variable on the probability. However, a reasonable point at which to estimate the change in the probability of premature harvesting due to changes in the explanatory variables is the sample mean. The estimates of the change in probability at sample mean are given in table 4.2. The sign on the parameter estimates, however, can be interpreted directly. A positive sign on an estimate implies a direct relationship between this variable and the probability of premature harvest. Specifically, an increase in the value of an explanatory variable with a positive estimate will increase the odds of an average farmer harvesting the crop at a premature stage and an increase in the value of an explanatory variable with a negative estimate will decrease the odds of an average farmer harvesting the crop at a premature stage. This type of interpretation, however, has to consider the desired level of significance.

Table 4.2 shows that the variables NUM, AGE, EXFM, NCROP, RLND, and EDU1 have positive estimates for their regression coefficients. This implies that increases in the value of these variables will increase the odds of an average farmer harvesting the crop at a premature stage. However, only the coefficients for TTI, RLND, and EDU1 were significantly different from zero at the 0.001, 0.01, and 0.05 level of significance, respectively. Some of these signs can be explained relatively easier than the others. The variable NCROP (number of MEC's grown by the farmer) has a positive sign. This was the sign hypothesized in chapter 3 because as the number of crops increase, so do some of the problems associated with them, such as the problem of theft and the incidence of pests. A similar explanation can be given for the signs on the land variable, RLND (ratio of lowland to total land). Rice is the most important food crop in Sri Lanka, hence, it is reasonable to assume that farmers would pay extra attention to rice and strive for a high output. Rice, especially if it is one of the the new improved varieties, is a crop which demands high levels of inputs [Herath *et al.*], particularly inputs purchased from the market, such as chemicals and fertilizer. This high demand for inputs in turn demands ready cash. Recall that one of the reasons cited for the practice of premature harvesting is immediate money needs, to meet day-to-day expenses. The estimate on this variable is significant at the 0.01 level. The ratio of lowland to highland thus plays an important role in farmer behavior.

It is reasonable to assume that with experience a farmer would exercise better management, and hence the sign on the variable EXFM (farming experience) would be negative. The sign on the estimated coefficient is, however, positive implying that an experienced farmer has a higher probability of harvesting the crop at premature stage than a farmer with less experience. A reasonable explanation for this behavior is that with experience a farmer becomes aware of possible problems. This behavior of experienced farmers may be the result of a precautionary nature; a means of preventing a problem.

The age of the farmer has a positive impact on the probability of premature harvesting. This implies that as the age of the farmer increases the probability of a farmer harvesting the crop at a premature stage also increases. Moscardi and de Janvry have shown risk aversion to have a positive relationship with age. The behavior exhibited by the MEC growers is then consistent with this finding. As the age increases, a farmer's aversion to risk may increase, resulting in an increased tendency to harvest the crop at a premature stage.

The number of members in the household, represented by the variable NUM, had a positive impact on the probability of premature harvesting. As the size of the household increases so does the household expenditure. As the household expenditure increases, especially with households without any off-farm income, premature harvesting may be practiced to meet the day-to-day expenses.

The education variable, EDU1 (where: EDU1 = 1 when the level of education is less than 6 years, and = 0 when the level of education is more than 6 years) had an estimate of 2.3349 which is significant at the 0.05 level. This implies that this level of education has a significant impact on the harvesting behavior of farmers as hypothesized. Education of the farmer has an influence on a farmer's ability to understand and comprehend extension information, presented verbally by extension agents or the information in extension publications.

The estimate on the income variable TTI was -0.0007399 which was significant at the 0.001 level. The negative sign on this variable implies that as the net income from the farm increases, the probability of the farmer harvesting the crop at premature stages decreases. The higher income solves the problem of immediate money needs. A higher income also implies that problems with pests can be controlled by taking precautionary measures, which could either be achieved with higher use of labor or with a higher use of chemicals.

At the sample mean, *ceteris paribus*, RLND has the largest impact on the probability of premature harvesting. Specifically, a one unit change in the ratio of lowland to total land would change the probability of premature harvesting by about 0.03. Similarly, educating farmers to a level higher than that of grade six would decrease the probability of premature harvesting by about 0.01. Increasing the level of income by a rupee would have only a small impact on the probability, while increasing the income by a thousand rupees would decrease the probability of premature harvesting by 0.004.

The value of the likelihood ratio was 129.391 with nine degrees of freedom. This is significant at the 0.001 level of significance based on a χ^2-test. This significance implies that the overall model will predict harvesting behavior of farmers better than a random 50-50 guess. The goodness-of-fit test based on McFadden's R^2 is 0.5038, and the R^2 based on the definition of R^2 (1 - ESS/TSS) is 0.5046. These numbers imply that more than 50 percent of the variation in the harvest behavior of the farmers in the sample can be explained by the estimated logit function. Considering the characteristically low value for R^2 of logit models, it is reasonable to conclude that the model fits the data well. The estimated equation made 215 correct predictions out of a total of 240, which is almost a 90 percent correct prediction.

4.4.1 Policy Implications of the Logit Function

This section will discuss the the policy implications of the logit model with respect to the variables with significant estimates. An important and an essential assumption underlying the following discussion is that premature harvesting is an unfavorable practice. The evidence for this assumption will be established in the sections on the results of the decision theoretic models. The policy measures suggested in this section are only proposals and prior to implementing them in reality each policy needs to be evaluated with respect to its costs and the potential benefits.

Of the explanatory variables which were significant in the logit model, the variables on education lend themselves to more convenient manipulation by policy measures. These policy measures should be directed at increasing the level of education of the MEC growers. The mean age of the sample, 52.5 years, indicates that on the average a MEC farmer has long passed the age of formal education, and any attempt to increase the level of education of these farmers has to be done through the extension services. Extension policies need to be directed at teaching the farmers the implications of premature harvesting and the measures which can be adopted to minimize the risks of letting the crop mature on the tree, such as appropriate pest control measures.

Direct impact on the ratio of lowland to the total land is beyond the control of simple policy measures; this can be achieved through serious land reform policies. The implication of this variable on the behavior of the farmers, however, can be reasonably addressed with certain simpler micro-level policies. The problem of high cash demand for inputs by rice, which is hypothesized to influence premature harvesting, can be ameliorated by providing subsidies for inputs and consumption credit during the cultivation season which can be paid back after the harvest.

The implications of the estimate on the income variable are, however, broader than those of the two variables discussed above in this section. Policy measures to increase the income of the household can be achieved in at least two ways. One way to increase the household income is to increase employment opportunities for the household. This option however forms part of the national policies. At the micro level, household income can be increased by promoting rural industries. A second approach is to increase the income from the other agricultural products grown by the farmer. This can be achieved by improving the benefit/cost relationships for the farmer by providing input subsidies and price supports for the product. However, the cost of these policies to increase income could be greater than the benefits of reduced premature harvesting.

4.4.2 Conclusions

The logit probability model of the MEC growers to predict harvesting behavior of farmers showed that household income, low levels of education, and the ratio of lowland to total land were significantly related to harvesting behavior. Based on test statistics, the model is significant in predicting behavior. The model correctly predicted nearly 90 percent of the sample observations.

4.5 Computations of Components of Decision Models

The analysis of the decision models, as noted in chapter 3, requires several components to be calculated, such as the parameters of price and output distributions, the subjective discount rates, and the estimates of the utility functions. This section will discuss the results of these computations.

4.5.1 Price and Output Distributions

The price and output distributions elicited from each farmer are given in Appendix D with the budget for each farmer and are summarized in table 4.3. All the distributions elicited from the farmers showed a wide range. The range of the price distribution was, however, narrower than that of the output. This is partly because the output distribution represents the farmers' belief about the output for the entire farm as a unit of production. The farm was taken as a unit of production, instead of a unit area, because the crops in the study are all grown in a mixed type of garden. Any land unit chosen is bound to contain more than one crop, making it difficult to represent the output of a crop by land area. The distributions will be discussed in terms of premature and mature harvests and within each group the distributions for each crop will be discussed separately.

Each farmer, regardless of the harvesting behavior, was asked to give his or her beliefs about the price and output distributions for mature harvesting as well as for premature harvesting for each crop. The beliefs were elicited as explained in chapter 3. For each farmer the parameters of the subjective distribution, mean and the variance, were computed using the equations [3.11] and [3.12]. These parameters were grouped, first by harvesting behavior and then by crop. For each of the groups the mean, the standard deviation, and the coefficient of variation were computed and are reported in table 4.3. In table 4.3. the values under "Mean" and "Standard Deviation" refer to the mean and the standard deviation of the parameters of the individual's subjective distribution.

Cocoa had the narrowest range for the price distribution of Rs.30.0 per kg with a coefficient of variation (CV) of 30.035. Pepper had a range of Rs.68.47 with a CV of 41.761. Coffee had the widest range and the largest CV of the three crops with Rs.112.88 for the range and 60.95 for the CV. Based on this finding, an average MEC farmer in Sri Lanka considers coffee to be the riskiest of the three crops in terms of price variability. Of the 30 farmers in the sample, 29 had coffee, 21 had pepper, and 10 had cocoa.

Table 4.3: Summary of Parameters of Subjective Distributions

	Mean	Standard Deviation	Minimum Value	Maximum Value	C.V.[1]
	MATURE HARVESTING				
COCOA					
Mean price	29.66	8.91	21.47	51.47	30.03
S.D.[2] of price	11.34	4.07	6.61	18.91	35.89
Mean output	36.79	48.39	2.29	139.95	131.54
S.D. of output	22.25	29.85	2.26	82.98	134.17
COFFEE					
Mean price	38.36	23.38	5.63	118.50	60.949
S.D. of price	17.65	10.51	3.51	49.06	59.540
Mean output	19.11	29.45	0.19	145.90	154.136
S.D. of output	9.21	13.05	0.48	57.80	141.624
PEPPER					
Mean price	39.83	16.63	8.18	76.65	41.761
S.D. of price	15.14	7.55	3.04	28.36	49.866
Mean output	32.57	58.13	2.29	274.00	178.427
S.D. of output	14.48	25.68	1.23	121.58	177.301
	PREMATURE HARVESTING				
COCOA					
Mean price	21.62	5.80	15.55	31.85	26.833
S.D. of price	7.98	4.77	3.44	17.18	59.820
Mean output	27.11	32.23	1.93	94.05	118.881
S.D. of output	12.97	16.69	1.21	47.28	128.692
COFFEE					
Mean price	27.91	17.99	3.48	84.80	64.454
S.D. of price	12.21	8.34	2.48	42.54	68.325
Mean output	9.69	9.69	0.18	35.90	100.006
S.D. of output	5.97	8.35	0.44	42.55	139.912
PEPPER					
Mean price	27.24	12.62	8.48	51.47	46.318
S.D. of price	11.73	6.96	1.32	31.11	59.369
Mean output	32.67	54.83	1.93	246.25	167.904
S.D. of output	13.56	21.68	0.94	76.97	159.855

[1]C.V. is the coefficient of variation
[2]S.D. is the standard deviation

For the premature harvesting strategy (strategy-P) the range for the price distribution was narrower than that of the mature harvesting strategy (strategy-M), but the CV's were comparable. The mean price of coffee ranged from Rs.15.55 to Rs.31.85 per kg. with a CV of 26.83; the price of cocoa ranged from Rs.3.48 to Rs.84.80 with a CV of 64.45; and the mean price of pepper ranged from Rs.8.48 to Rs.51.475 with a CV of 46.32.

Even though the mean output of the crops cannot be compared, because of the reason explained earlier, it is reasonable to compare the corresponding CV's between strategy-M and strategy-P. The CV's for the output were generally higher for the mature crop than for the premature crop. This observation bears evidence for loss of crop due to theft and pest damages. The longer the crop is left on the tree the higher is the risk of losing a portion of the crop, as believed by the farmer. This expressed belief about the output of the crop for a given farm is thus consistent with the reasons given by the farmers for harvesting the crop at premature stages. The higher C.V expressed for the output of the crop for Strategy-M is likely in part due to the expected crop loss associated with delays in harvesting. The higher CV's obtained for the price of a mature crop is also due to a wider variation of the crop in terms of the grades of the crop, as compared to a premature crop which will have a narrower variation in the quality because of the lower level of maturity.

4.5.2 Subjective Discount Rates

Table 4.4 gives the monthly subjective discount rates elicited from the farmers.[1] In this table A_0 represents the amount of money offered at the time of interview. The farmers, as another alternative, were offered a sum higher than A_0, let it be B_1, to be received a month from the time of the interview. The farmers were told that they were guaranteed to receive these sums of money. This assurance was necessary to ensure that the farmers would not increase the time preference for money due to uncertainty about the future outcome. If a farmer preferred

---

[1] Subjective discount rates were elicited for one month, three months, and for one year. The survey results showed that the average time lag between premature and mature harvesting is about a month. For discounting the income from MEC for Strategy-M the market discount rate was used.

Table 4.4: Subjective Monthly Discount Rates

Farmer number	A_0	A_1	Discount Factor
19	1000	2000	0.500000
24	1000	1250	0.800000
26	1000	1050	0.952381
34	1000	1700	0.588235
35	1000	1400	0.714286
36	1000	1500	0.666667
38	1000	1025	0.975610
39	1000	7500	0.133333
40	1000	1750	0.571429
42	1000	1650	0.606061
52	1000	1100	0.909091
62	1000	1450	0.689655
64	1000	1100	0.909091
66	1000	1325	0.754717
69	1000	1125	0.888889
72	1000	1200	0.833333
95	1000	1100	0.909091
96	1000	1500	0.666667
103	1000	1025	0.975610
113	1000	1225	0.816327
162	1000	1100	0.909091
168	1000	1700	0.588235
170	1000	2500	0.400000
182	1000	1275	0.784314
186	1000	1500	0.666667
195	1000	1850	0.540541
196	1000	1050	0.952381
199	1000	1100	0.909091
201	1000	1100	0.909091
204	1000	2250	0.444444

Summary Statistics:

	With Farmer 39	Without Farmer 39[1]
Mean	0.732	0.753
Std. Deviation	0.203	0.171
Minimum	0.133	0.400
Maximum	0.976	0.976
Coefficient of Variation	27.709	22.769

[1]Summary statistics were reported with the data of farmer 39 deleted because his A_1 value was an outlier.

B_1 to A_0, B_1 was reduced in small steps until the farmer expressed indifference between B_1 and A_0. If a farmer preferred A_0 to B_1, B_1 was increased in small steps until indifference was expressed between A_0 and B_1. Column A_1 in table 4.4 gives the values of B_1 at the point of indifference. The discount rates were computed by dividing A_0 by A_1, and are given in the last column of the table. These discount rates represent the present value of a rupee received in a months time. For instance, for farmer number 24 the present value of a rupee received in a months time is 0.8 rupees. The other values in the last column of the table have identical interpretation for the other farmers.

The discount rates ranged from 0.976 to 0.1333 with a mean of 0.732. This implies that on the average the present value of a rupee received in a month's time is 0.732 rupees. Farmer number 39 had a very low discount rate implying a high time preference for money. The mean discount rate excluding farmer number 39 was 0.753. Because of this wide range in the elicited discount rates, the market discount rate of 15% was used to discount the future income from mature harvesting. The sensitivity of the solution obtained using the market interest rate was analyzed using the elicited discount rate as well as several discount rates ranging from 0 to 0.5.

4.5.3 Computation of Income Distributions

The distribution of net income for each farmer was computed as follows:

1. The distribution of income from MEC was computed from the subjective price and output distributions elicited for each crop a farmer grows.
2. For the computation of net incomes from the mature harvesting strategy, the net income from MEC were discounted using the market discount rate. The income from the premature harvesting strategy was not discounted because the time of premature harvesting is considered as the period at which a farmer evaluates the strategies of mature and premature harvesting. At this time the farmer uses an

appropriate decision rule, presumably one of the rules analyzed in this study, and chooses the one with a higher value for the rule.

The income from sources other than MEC is assumed to be non-stochastic. This is because most of the off-farm income is received as salary or retirement income. A few farmers received their off-farm income by off-farm labor. Because of few layoffs, the income from off-farm labor can be assumed to be non-stochastic. In addition to off-farm income, some farmers produced food crops. The major crops grown by a typical farmer in the study sample were rice and vegetables; one farmer had a large extent of tobacco. Rice has a government price support scheme which guarantees a fixed price. Demand for rice in Sri Lanka is assured because it is the staple food of Sri Lanka and the country is yet to achieve full self sufficiency. The output of rice can be assumed to be reasonably stable in the study area because of the climatic conditions which assure adequate moisture for growing rice. Tobacco cultivation in Sri Lanka is supported by the private tobacco industry which provides the necessary inputs for the crop including extension service. The company contracts to buy the crop after harvest. Tobacco, thus, faces minimal risk in terms of income for the grower. The income from other crops for the farmers in the sample make up a small proportion of the total net income. For an average MEC grower in the study area, most of the income variation is due to the MEC.

Computation of Income Distribution from MEC

The income distribution for the i^{th} farmer was computed as follows:

$$TI_{ij} = YOTHER_i + YMEC_{ij}, \quad \text{for the premature harvesting strategy, and}$$

$$TI_{ij} = YOTHER_i + \alpha\ YMEC_{ij}, \quad \text{for the mature harvesting strategy.}$$

Where:

TI_{ij} is the j^{th} deviate of total income,

$YOTHER_i$ is the annual income from sources other than MEC's;

$YMEC_{ij}$ is the j^{th} deviate of total income from MEC's; and

α_i is the market discount factor.

The distribution of income from MEC were computed as follows:

$$YMEC_i = \sum_{k=1}^{n} [MNP_k + (PS_k \times z_i)]^*[QM_k + (QS_k \times z_k)].$$

Where:

PS_k is the standard deviation of the subjective distribution of price for the k^{th} crop;

MNP_k is the mean of the subjective distribution of price for the k^{th} crop;

QS_k is the standard deviation of the subjective distribution of output for the k^{th} crop;

QM_k is the mean of the subjective distribution of output for the k^{th} crop; and

z_k is a random deviate from a standard normal distribution.

MNP_k, PS_k, QM_k, and QS_k were computed from the elicited triangular distributions using formulae 3.11 and 3.12. One thousand deviates of z_k and z_i were generated using the GGNML subroutine (FORTRAN) of the International Mathematics Subroutine Library (IMSL) at the Virginia Tech Computing Center.[2] These deviates were used in another FORTRAN program to compute the various values used for the analysis, such as the probability of loss, expected income, and the utility indices. A complete listing of this FORTRAN source code is given in Appendix F of this dissertation.

4.6 Estimates of the Utility Functions

This section discusses the estimates of the utility functions. As explained in chapter 3, the ELCE method was employed to elicit the certainty equivalents used to estimate the utility functions. The certainty equivalents used for the estimation are given in Appendix C. For each farmer, three different utility functions were estimated. They are: the exponential utility function, the quadratic utility function, and the cubic utility function. The exponential utility

---

[2] Document number MT01, User Services Department, Virginia Tech Computing Center, Virginia Tech, Blacksburg, Virginia.

function (EUF) has a constant risk aversion coefficient, the quadratic utility function (QUF) has an increasing risk aversion coefficient, and the cubic utility function (CUF) can have an increasing or a decreasing risk aversion coefficient. The differences in the properties of the utility functions formed the basis for selecting them for the study.

The estimates of the utility functions are given in tables 4.5, 4.6, and 4.7. These tables give the estimates of the parameters of the functions and their standard errors. The quadratic utility functions (QUF) and the cubic utility functions (CUF) were estimated by applying the OLS technique while the exponential utility functions (EUF) were estimated by the method of maximum likelihood (ML). For the exponential functions a set of parameters (K, θ, and λ) was determined for each function which minimized the sum of squares of the error terms (SSE) as explained in chapter 3. These estimates were used as the starting values in the ML method. The R^2 values reported for the EUF were calculated using the expression for R^2 given in equation 3.8.

For the EUF the Arrow-Pratt risk aversion coefficient (A-P R_a) is given by λ, which is a parameter estimated in the function. Table 4.5 shows that the estimates of λ were significant at least at the 0.05 level for all the farmers. For 15 farmers the coefficients were significant at the 0.001 level and for 10 farmers the estimates were significant at the 0.01 level. For the QUF and CUF the risk aversion coefficients are non-linear functions of the utility function parameters, as given in equations 3.3 and 3.10 in chapter three. For this reason, determining the distribution of the risk aversion coefficients and thus determining the level of significance is very difficult. This study will not determine the level of significance of the risk aversion coefficients for the QUF and the CUF.

The main purpose of the utility functions in the expected utility model is to compute the integral $E[U(\pi)]$ explained in section 3.3 (equation 3.1). To obtain an accurate estimate of this integral the important property of the estimated function is the goodness-of-fit given by R^2. For the quadratic utility function the adjusted-R^2 ranged from 0.80 to 0.99, corrected to two

Table 4.5: Estimates of the Exponential Utility Functions.[1]
$(U = K - \theta e^{-\lambda x})$

Farmer Number	K	θ	λ	Adjusted R-Square
19	86.190 *(11.000)******	49.993 *(12.212)****	0.0000527 *(0.00001354)****	0.87
24	90.232 *(13.239)******	59.676 *(14.801)****	0.0004045 *(0.00012158)****	0.92
26	172.10 *(23.519)******	167.12 *(23.218)******	0.00019760 *(0.00003608)******	0.99
34	145.38 *(29.423)******	127.46 *(29.676)****	0.00033224 *(0.00009778)****	0.99
35	108.59 *(14.754)******	88.344 *(15.354)******	0.00036092 *(0.00008471)******	0.97
36	124.12 *(21.173)******	104.63 *(21.611)******	0.00011053 *(0.00002942)****	0.98
38	105.70 *(15.959)******	84.889 *(16.734)******	0.00029795 *(0.00008230)****	0.95
39	236.10 *(1.2482)******	223.92 *(1.3678)******	0.00001611 *(0.00000101)******	0.97
40	258.76 *(2.1933)******	251.28 *(2.2652)******	0.00012613 *(0.00001415)******	0.91
42	268.33 *(1.3839)******	251.66 *(1.4003)******	0.00010392 *(0.00000748)******	0.96
52	95.498 *(12.138)******	69.938 *(13.191)******	0.00009431 *(0.00002288)****	0.94
62	84.189 *(8.3159)******	43.555 *(9.1761)****	0.00005919 *(0.00001210)****	0.91
64	89.026 *(1.4446)******	61.012 *(1.5705)******	0.00047985 *(0.00006107)******	0.92
66	119.79 *(38.948)****	100.50 *(39.888)**	0.00001732 *(0.00000884)**	0.89
69	216.85 *(2.3714)******	204.16 *(2.3644)******	0.00011673 *(0.00001591)******	0.89

*** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level.
[1]Figures in parenthesis are the standard errors.

... continued

Table 4.5: Estimates of the Exponential Utility Functions.[1] (*continued...*)

Farmer Number	K	θ	λ	Adjusted R-Square
72	360.58 *(3.5966)****	359.48 *(3.3380)****	0.00022695 *(0.00003484)****	0.86
95	135.70 *(22.922)****	117.30 *(23.260)****	0.00005872 *(0.00016550)***	0.92
96	87.914 *(9.3154)****	54.596 *(10.395)****	0.00027857 *(0.0000600)***	0.91
103	104.09 *(16.970)****	81.318 *(18.007)****	0.00062817 *(0.00018006)***	0.95
113	123.89 *(35.601)***	95.388 *(36.964)**	0.00008684 *(0.00003913)**	0.95
162	117.15 *(26.826)***	102.40 *(27.285)**	0.0035684 *(0.001307)**	0.93
168	81.881 *(2.0375)****	70.011 *(2.2486)****	0.00046407 *(0.00003001)****	0.99
170	329.38 *(1.0749)****	317.63 *(1.0522)****	0.00007983 *(0.00000356)****	0.98
182	114.82 *(1.2542)****	94.955 *(1.2552)****	0.00007236 *(0.00000586)****	0.97
186	239.21 *(1.3457)****	225.80 *(1.3629)****	0.00007145 *(0.00000478)****	0.96
195	103.31 *(9.8984)****	80.865 *(10.453)****	0.0013662 *(0.00023899)****	0.97
196	137.99 *(46.496)***	122.51 *(46.865)**	0.00015313 *(0.00007534)**	0.98
199	85.626 *(6.1648)****	49.479 *(7.0440)****	0.00033195 *(0.00005244)****	0.96
201	91.779 *(12.043)****	64.304 *(13.328)****	0.00017842 *(0.00004663)****	0.90
204	96.917 *(20.561)***	72.777 *(22.079)***	0.0025354 *(0.00099457)**	0.89

*** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level.
[1]Figures in parenthesis are the standard errors.

Table 4.6: Estimates of the Quadratic Utility Functions.[1]
($U = a + bx + cx^2$)

Farmer Number	a	b	c	Adjusted R-square
19	34.9372	0.0031410	-4.067(10^{-8})	0.86***
	*(3.6149)****	*(0.0005244)****	*(0.9540*(10^{-8}))**	
24	28.9825	.0247494	-2.8922(10^{-6})	0.90***
	*(3.2532)****	*(0.0036403)****	*(0.8297*(10^{-6}))*	
26	5.0425	0.0322646	-2.4725(10^{-6})	0.99***
	*(1.0029)***	*(0.0017085)****	*(0.5785*(10^{-6}))**	
34	17.6902	0.042172	-5.6322(10^{-6})	0.98***
	*(1.4015)****	*(0.0031796)****	*(1.7943*(10^{-6}))*	
35	19.4502	0.0325886	-4.2443(10^{-6})	0.97***
	*(1.9972)****	*(0.0029415)****	*(0.9228*(10^{-6}))**	
36	19.0366	0.0116308	-4.9693(10^{-7})	0.98***
	*(1.7680)****	*(0.009805)****	*(1.3493*(10^{-7}))**	
38	19.7890	0.0261879	-2.7593(10^{-6})	0.95***
	*(2.6016)****	*(0.0029433)****	*(0.6824*(10^{-6}))**	
39	12.1654	0.0033222	-8.723(10^{-9})	0.96***
	*(2.5852)***	*(0.0005031)****	*(25.553*(10^{-9}))	
40	7.1733	0.0134393	8.5195(10^{-6})	0.93***
	(4.0763)	*(0.0088782)*	*(4.6470*(10^{-6}))	
42	16.5393	0.0247031	-5.292(10^{-7})	0.95***
	*(2.8584)****	*(0.0051000)****	*(22.692*(10^{-7}))	
52	24.2160	0.0068000	-1.9982(10^{-7})	0.94 ***
	*(2.5842)****	*(0.0007658)****	*(0.4409*(10^{-7}))**	
62	39.4021	0.0031198	-4.034(10^{-8})	0.91***
	*(2.9832)****	*(0.0004063)****	*(0.722*(10^{-8}))***	
'64	26.1123	0.0314817	-4.1589(10^{-6})	0.93***
	*(2.7291)****	*(0.0037809)****	*(0.8271*(10^{-6}))**	
66	18.5683	0.0017850	-1.200(10^{-8})	0.85***
	*(4.6451)***	*(0.0003634)***	*(0.670*(10^{-8}))	
69	12.3851	0.0244405	-1.4153(10^{-6})	0.84***
	(5.6703)	*(0.0061772)***	*(1.7685*(10^{-6}))	

*** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level.
[1]Figures in parenthesis are the standard errors.

... continued

Table 4.6: Estimates of the Quadratic Utility Functions.[1] (*continued...*)

Farmer Number	a	b	c	Adjusted R-square
72	1.3935	0.0187206	$80.112(10^{-6})$	0.92***
	(5.1554)	*(0.0222572)*	$(28.204(10^{-6}))^{**}$	
95	18.0848	0.0773727	$-20.333(10^{-6})$	0.98***
	*(1.4062)****	*(0.0055575)****	$(5.438(10^{-6}))^{**}$	
96	31.7597	0.0171879	$-1.2303(10^{-6})$	0.92***
	*(2.7303)****	*(0.0021138)****	$(0.2243(10^{-6}))^{***}$	
103	21.8275	0.0519547	$-11.247(10^{-6})$	0.94***
	*(2.6633)****	*(0.0061177)****	$(3.119(10^{-6}))^{*}$	
113	28.1332	0.008397	$-2.9370(10^{-7})$	0.94***
	*(2.6906)****	*(0.0010546)****	$(1.4248(10^{-7}))$	
162	13.8111	0.374323	$-498.87(10^{-6})$	0.92***
	*(3.6960)***	*(0.0562187)****	$(182.66(10^{-6}))^{*}$	
168	12.2274	0.0239682	$-1.7912(10^{-6})$	0.98***
	*(1.5327)****	*(0.0012371)****	$(0.1298(10^{-6}))^{***}$	
170	11.8694	0.023707	$-2.532(10^{-7})$	0.98***
	*(1.9074)****	*(0.0030593)****	$(11.4639(10^{-7}))$	
182	19.1953	0.006851	$-1.778(10^{-7})$	0.96***
	*(2.2261)****	*(0.0007075)****	$(0.5436(10^{-7}))^{*}$	
186	13.0852	0.0131412	$3.6606(10^{-7})$	0.97***
	*(2.4348)****	*(0.0024613)*	$(6.4601(10^{-7}))$	
195	21.6525	0.110614	$-51.442(10^{-6})$	0.98***
	*(1.3956)****	*(0.0072825)****	$(8.369(10^{-6}))^{***}$	
196	14.7322	0.019621	$-1.3006(10^{-6})$	0.90***
	*(4.1198)***	*(0.003464)****	$(0.6613(10^{-6}))$	
199	34.2273	0.0177899	$-1.4163(10^{-6})$	0.96***
	*(1.9015)****	*(0.0014978)****	$(0.1836(10^{-6}))^{***}$	
201	25.7206	0.0127194	$-6.5550(10^{-7})$	0.90***
	*(3.3063)****	*(0.0018392)****	$(1.4927(10^{-7}))^{**}$	
204	22.5934	0.199211	$-164.13(10^{-6})$	0.80**
	*(5.1158)***	*(.0454056)***	$(66.85(10^{-6}))^{*}$	

*** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level.
[1]Figures in parenthesis are the standard errors.

Table 4.7: Estimates of the Cubic Utility Functions[1]
($U = a + bx + cx^2 + dx^3$)

Farmer Number	a	b	c	d	Adjusted R-square
19	25.692 *(3.013)******	0.004345 *(0.000411)******	$1.604(10^{-7})$ *($5.053(10^{-8})$)**	$-3.779(10^{-12})$ *($9.453(10^{-13})$)*	0.96***
24	20.964 *(6.805)**	0.023651 *(0.003533)******	$7.466(10^{-6})$ *($7.886(10^{-6})$)*	$-1.997(10^{-9})$ *($1.513(10^{-9})$)*	0.91**
26	4.933 *(1.098)****	0.033692 *(0.00351)******	$-3.928(10^{-5})$ *($3.110(10^{-6})$)*	$3.433(10^{-10})$ *($7.190(10^{-10})$)*	0.99***
34	16.824 *(1.765)******	0.039720 *(0.004366)******	$5.572(10^{-7})$ *($7.564(10^{-6})$)*	$-2.391(10^{-9})$ *($2.834(10^{-9})$)*	0.98***
35	17.081 *(1.674)******	0.028879 *(0.002512)******	$2.981(10^{-6})$ *($2.813(10^{-6})$)*	$-1.730(10^{-10})$ *($6.552(10^{-10})$)**	0.98***
36	16.412 *(1.745)******	0.010128 *(0.000981)******	$5.916(10^{-7})$ *($4.760(10^{-7})$)*	$-1.056(10^{-10})$ *($4.511(10^{-11})$)**	0.98***
38	15.892 *(1.912)******	0.022375 *(0.002067)******	$3.935(10^{-6})$ *($1.975(10^{-6})$)*	$-1.232(10^{-9})$ *($3.560(10^{-10})$)****	0.98***
39	10.227 *(2.740)****	0.002799 *(0.000589)****	$1.067(10^{-7})$ *($8.392(10^{-8})$)*	$-4.107(10^{-12})$ *($2.864(10^{-12})$)*	0.97***
40	12.257 *(3.623)****	0.022841 *(0.007532)**	$-2.127(10^{-5})$ *($1.247(10^{-5})$)*	$1.228(10^{-8})$ *($4.949(10^{-9})$)**	0.96***
42	17.912 *(3.651)****	0.028435 *(0.007786)****	$-6.337(10^{-6})$ *($9.108(10^{-6})$)*	$1.625(10^{-9})$ *($2.460(10^{-9})$)*	0.94***
52	18.734 *(2.660)******	0.006042 *(0.000594)******	$3.464(10^{-7})$ *($1.994(10^{-7})$)*	$-2.604(10^{-11})$ *($9.401(10^{-12})$)**	0.97***
62	34.085 *(3.711)******	0.004002 *(0.000569)******	$8.722(10^{-8})$ *($6.658(10^{-8})$)*	$-2.323(10^{-12})$ *($1.207(10^{-12})$)*	0.94***
64	22.586 *(2.824)******	0.029792 *(0.003187)******	$3.187(10^{-6})$ *($3.701(10^{-6})$)*	$-1.421(10^{-9})$ *($7.042(10^{-10})$)*	0.96***
66	8.511 *(5.864)*	0.001322 *(0.000354)****	$6.406(10^{-8})$ *($3.518(10^{-8})$)*	$-1.109(10^{-12})$ *($5.069(10^{-13})$)**	0.91**
69	0.343 *(4.604)*	0.014050 *(0.004517)**	$1.849(10^{-5})$ *($5.514(10^{-6})$)*	$-4.378(10^{-9})$ *($1.192(10^{-9})$)****	0.95***

*** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level.
[1]Figures in parenthesis are the standard errors.

... continued

Table 4.7: Estimates of the Cubic Utility Functions[1] (... *continued*)

Farmer Number	a	b	c	d	Adjusted R-square
72	3.690	0.026580	2.471(10^{-5})	5.342(10^{-8})	0.90**
	(9.142)	(0.034574)	(1.771(10^{-4}))	(1.682(10^{-7}))	
95	16.576	0.070734	1.179(10^{-5})	-2.211(10^{-8})	0.99***
	(1.545)***	(0.006363)***	(2.017(10^{-5}))	(1.348(10^{-8}))	
96	28.275	0.017633	8.351(10^{-7})	-2.082(10^{-10})	0.94***
	(3.160)***	(0.001868)***	(1.241(10^{-6}))	(1.235(10^{-10}))	
103	16.904	0.044539	2.037(10^{-5})	-1.252(10^{-8})	0.97***
	(2.993)**	(0.005743)***	(1.419(10^{-5}))	(5.538(10^{-9}))*	
113	22.226	0.0080051	7.107(10^{-7})	-9.456(10^{-11})	0.95***
	(4.820)**	(0.001011)***	(7.147(10^{-7}))	(6.614(10^{-11}))	
162	8.063	0.241151	1.932(10^{-3})	-6.132(10^{-6})	0.98***
	(1.811)**	(0.032834)***	(4.384(10^{-4}))**	(1.090(10^{-6}))**	
168	11.743	0.028600	-4.052(10^{-6})	1.897(10^{-10})	0.99***
	(1.267)***	(0.002496)***	(1.120(10^{-6}))**	(9.360(10^{-11}))	
170	11.585	0.023278	7.481(10^{-7})	-3.006(10^{-10})	0.98***
	(2.411)**	(0.003811)***	(4.488(10^{-6}))	(1.294(10^{-9}))	
182	16.140	0.005898	2.382(10^{-7})	-2.309(10^{-11})	0.98***
	(2.446)***	(0.000771)***	(2.221(10^{-7}))	(1.206(10^{-11}))	
186	13.655	0.013946	-4.384(10^{-7})	1.391(10^{-10})	0.96***
	(3.102)**	(0.003524)**	(2.410(10^{-6}))	(3.988(10^{-10}))	
195	20.538	0.104874	-1.211(10^{-5})	-3.341(10^{-8})	0.98***
	(1.638)***	(0.008512)***	(3.383(10^{-5}))	(2.791(10^{-8}))	
196	7.780	0.015004	5.474(10^{-6})	-1.046(10^{-9})	0.98***
	(1.972)**	(0.001545)*	(1.167(10^{-6}))**	(1.760(10^{-10}))***	
199	33.887	0.017782	-1.199(10^{-6})	-2.377(10^{-11})	0.96***
	(2.715)***	(0.001635)***	(1.133(10^{-6}))	(1.224(10^{-10}))	
201	19.966	0.012436	1.134(10^{-6})	-1.359(10^{-10})	0.96***
	(2.829)***	(0.001186)***	(5.882(10^{-7}))	(4.407(10^{-11}))	
204	14.120	0.190579	5.094(10^{-4})	-9.246(10^{-7})	0.86**
	(6.076)*	(0.037810)**	(3.510(10^{-4}))	(4.759(10^{-7}))	

*** significant at 0.001 level; ** significant at 0.01 level; * significant at 0.05 level.
[1]Figures in parenthesis are the standard errors.

decimal places.[3] With the exception of one function, which was significant at 0.01 level (farmer number 204), all the other functions were significant at the 0.001 level, based on an *F*-test.

For the cubic utility functions, the adjusted-R^2 ranged from 0.86 (farmer number 204) to 0.99 (several farmers). The functions fitted were significant at the 0.01 level for four farmers and at 0.001 for the rest of the farmers. For the EUF the adjusted-R^2 ranged from 0.86 (farmer number 72) to 0.99 (several farmers).

Comparing the R^2 across functions, the CUF gave the highest adjusted-R^2 for 16 farmers and the EUF for 5 farmers. For four farmers all three functions gave the same adjusted-R^2, for three farmers the CUF and the EUF gave the higher adjusted-R^2, and for one the QUF and the EUF gave the higher adjusted-R^2. The next section discusses the A-P R_a derived from these functions and the classification of farmers based on these coefficients.

4.6.1 Farmer Risk Attitudes

The Arrow-Pratt (A-P) risk aversion coefficient, R_a, was computed for each farmer using equations [3.3] and [3.10]. The R_a, when computed with the exponential utility function, is independent of the level of income, while for the quadratic and the cubic utility functions the R_a is a function of income. To study the change with income, if any, in the risk attitude of farmers, the R_a was computed at the mean income and the annual income. The mean income for this computation was the mean of the income variable used the estimation of the individual utility functions, therefore it is the mean of the certainty equivalents used to estimate the individual utility functions. Farmer risk attitudes are discussed under mean income and under annual income. The risk aversion coefficients are given in table 4.8 and the risk attitude classifications are given in table 4.9.

---

[3] R^2 reported for the utility functions have been adjusted for the number of parameters estimated for each function, hence adjusted-R^2

Table 4.8: Arrow-Pratt Absolute Risk Aversion Coefficients

Farmer number	*Exponential*	*Quadratic* Mean income	*Quadratic* Annual income	*Cubic* Mean income	*Cubic* Annual income
19	0.00005270	0.0000314	-0.000052	-0.0000273	-0.000065
24	0.00040450	0.0002923	-0.001559	-0.0001453	-0.000918
26	0.00019760	0.0001910	0.000284	0.0002057	0.000086
34	0.00033224	0.0003250	0.000608	0.0002270	0.002784
35	0.00036092	0.0003438	0.003458	0.0001235	-0.002010
36	0.00011053	0.0001079	0.000312	0.0000322	-0.001552
38	0.00029795	0.0002793	0.022107	0.0000282	-0.001204
39	0.00001611	0.0000055	0.000006	0.0000006	0.000276
40	0.00012613	-0.0005170	-0.000346	-0.0018647	-0.001169
42	0.00010392	0.0000448	0.000049	0.0001436	-0.000464
52	0.00009431	0.0000764	-0.000508	-0.0000104	-0.000254
62	0.00005919	0.0000306	-0.000046	-0.0000190	-0.000061
64	0.00047985	0.0003431	-0.000939	0.0000325	-0.000884
66	0.00001732	0.0000172	0.000068	-0.0000078	-0.000094
69	0.00011673	0.0001366	0.000207	-0.0000631	-0.001790
72	0.00022695	-0.0015813	-0.001091	-0.0022678	-0.001813
95	0.00005872	0.0006515	0.001423	0.0003576	0.038248
96	0.00027857	0.0001787	-0.000332	0.0000035	-0.000385
103	0.00062817	0.0005613	0.009114	-0.0000190	-0.002614
113	0.00008684	0.0000817	0.000219	-0.0000263	-0.000822
162	0.00356840	0.0035835	0.019934	-0.0007416	-0.018145
168	0.00046407	0.0002165	-0.000376	0.0004030	-0.000980
170	0.00007983	0.0000219	0.000023	0.0000293	0.000189
182	0.00007236	0.0000663	0.000234	0.0000154	-0.000630
186	0.00007145	-0.0000505	-0.000044	-0.0000493	-0.000158
195	0.00136620	0.0012160	0.013310	0.0008111	-0.011474
196	0.00015313	0.0001708	0.000515	-0.0000146	-0.001094
199	0.00033195	0.0001954	-0.000375	0.0001722	-0.000391
201	0.00017842	0.0001341	-0.000323	-0.0000283	-0.000322
204	0.00253540	0.0021626	-0.010734	-0.0007770	-0.006289

Table 4.9: Classification of Risk Attitude Based on A-P Risk Aversion Coefficients

Farmer number	Exponential	Quadratic Mean income	Quadratic Annual income	Cubic Mean income	Cubic Annual income
19	A	A	P	P	P
24	A	A	P	P	P
26	A	A	A	A	A
34	A	A	A	A	A
35	A	A	A	A	P
36	A	A	A	A	P
38	A	A	A	A	P
39	A	A	A	A	A
40	A	P	P	P	P
42	A	A	A	A	P
52	A	A	P	P	P
62	A	A	P	P	P
64	A	A	P	A	P
66	A	A	A	P	P
69	A	A	A	P	P
72	A	P	P	P	P
95	A	A	A	A	A
96	A	A	P	A	P
103	A	A	A	P	P
113	A	A	A	P	P
162	A	A	A	P	P
168	A	A	P	A	P
170	A	A	A	A	A
182	A	A	A	A	P
186	A	P	P	P	P
195	A	A	A	A	P
196	A	A	A	P	P
199	A	A	P	A	P
201	A	A	P	P	P
204	A	A	P	P	P

NOTE: A = risk averse ($R_a > 0$)
P = risk prefering ($R_a < 0$)

4.6.1.1 Mean income

As hypothesized in theory, the exponential utility function (EUF) classified all farmers as risk averse, $R_a > 0$. The R_a, as given by λ, ranged from 0.00001611 (farmer number 39) to 0.0035684 (farmer number 162).

The quadratic utility function (QUF) classified 27 farmers as risk averse and three farmers as risk preferring. For the risk averse farmers, the R_a ranged from 0.0000055 (farmer number 39) to 0.0035835 (farmer number 162). The lowest and the highest R_a from the QUF at mean income correspond to the same farmers in the EUF. For the risk preferring farmers the R_a ranged from -0.0000505 (farmer number 186) to -0.0015813 (farmer number 72).

The cubic utility function (CUF) classified 15 farmers as risk averse and 15 farmers as risk preferring at mean income. The R_a for risk averse farmers ranged from 0.0000006 (farmer number 39) to 0.0008111 (farmer number 195). Note that the same farmer had the lower level of risk aversion with all three functions. Also the three farmers classified as risk preferring by the QUF were classified as risk preferring by CUF. For the risk preferring farmers the R_a ranged from -0.0000078 to -0.0022678.

4.6.1.2 Annual Income

In the EUF the R_a is constant over income. The QUF classified 17 farmers as risk averse and 13 farmers as risk preferring. The three farmers who were classified as risk preferring at the mean income were classified as risk preferring at the annual income. However, more farmers were classified as risk preferring by QUF at annual income than at mean income. For the risk averse the R_a ranged from 0.000006 (farmer number 39) to 0.022107 (farmer number 38). For the 17 farmers classified as risk averse at both mean as well as annual income, two had decreasing R_a , the others had increasing risk aversion. For the risk preferring farmers, the R_a ranged from -0.000044 (farmer number 186) to -0.010734 (farmer number 204).

The CUF classified five farmers as risk averse and 25 farmers as risk preferring at annual income. For the risk averse the R_a ranged from 0.000086 (farmer number 26) to 0.038248 (farmer number 95). For the risk preferring farmers the R_a ranged from -0.000061 (farmer number 62) to -0.018145 (farmer number 162). Four of the risk averse farmers were classified as exhibiting increasing risk aversion, while one farmer exhibited decreasing risk aversion.[4]

Of the risk preferring farmers, two farmers exhibited increasing risk aversion. The CUF, therefore, classified 24 farmers as exhibiting decreasing risk aversion.

For the farmers whose risk attitude changes from risk aversion to risk preference it is then possible, mathematically, to find an income at which the farmer is risk neutral. The risk attitude of farmers, when determined with QUF and CUF, is a function of the income at which the R_a is computed rather than the parameters of the utility function. The question then is what income level to use to compute the R_a.

Musser *et al.* used the mid point of the income scale to estimate the risk aversion coefficients. With this they were able to compare across the sample, because all the subjects in their study had the same income level. When the income across the sample is not equal, the mean of the sample can lie above the income level of certain elements in the sample making the estimated coefficients unrealistic. The other alternative is to use the mid-point in the income scale of each individual in the sample. The third alternative is to use the mean of the elicited certainty equivalents. Because the estimated risk aversion coefficients can vary with the income level chosen to estimate it, it is reasonable to estimate the coefficient at the income level appropriate to the decision under consideration.

The study by Wiens showed that small farmers had a risk aversion coefficient of 0.091 and the larger farms 0.0085. In a recent study of the sorghum producers in the Texas Coastal Bend, Sriramaratnam found the risk aversion coefficient to lie between 0.000002 and 0.000037. The risk aversion coefficients estimated in this study fall in a range broader than those

[4] For farmers classified as risk averse at both mean and annual income, a higher (lower) R_a at annual income is considered as increasing (decreasing) risk aversion. For farmers classified as risk preferring at both mean and annual income, a higher (lower) $-R_a$ at annual income is considered as increasing (decreasing) risk preference. Increased risk preference can be considered as decreased risk aversion. Also, risk aversion at a lower level of income and risk preference at a higher level of income is considered to be decreasing risk aversion.

estimated in the studies mentioned above.[5] This study supports Wiens' view that it is appropriate and realistic to use empirically estimated risk aversion coefficients.

4.6.2 Utility Functions and Risk Neutrality

The ability of a utility function to allow for risk neutrality can be considered as a favorable property. It is pertinent to note that the A-P R_a for a risk neutral individual is zero. For the EUF this implies that $\lambda = 0$. When $\lambda = 0$ the EUF becomes $U = K - \theta$, which in turn implies that utility is constant over all levels of the argument of the utility function; a utility function is therefore not needed.

For the QUF R_a is given by $2c/(b-2x)$, which can be zero only if $c=0$. But in the quadratic utility function when $c=0$ the function is linear. The QUF, therefore, cannot give a risk neutral A-P risk aversion coefficient. Statistically, if the estimate for c is not different from zero, at a desired level of significance, then it is valid to assume that the function is not significantly different from a linear function, provided the other estimates are significant. If the estimate for c is not significant, then the function is linear for all practical purposes. Theoretically, then, a quadratic utility function cannot give a zero A-P risk aversion coefficient.

The A-P risk aversion coefficient for the cubic utility function is given by $-[(2c + 6dx)/(b + 2cx + 3dx^2)]$, which is equal to zero only when

$$2c + 6dx = 0. \qquad [4.1]$$

Because of the number of variables in expression 4.1, analyzing the CUF for the possibility of a zero R_a is more complicated than that for the QUF. This expression has the argument of the utility function as a variable, and hence, the point at which the risk aversion coefficient is evaluated could determine the risk attitude classification of a decision maker. For instance, when $x = -c/3d$ the expression 4.1 is equal to zero, and hence the risk aversion coefficient

[5] Note that the risk aversion coefficients compared were estimated with different currency units.

is equal to zero. With respect to the other arguments of equation 4.1, a zero A-P risk aversion coefficient will result when: $c = -dx$, or $d = -c/3x$.

Besides these relationships among c, d, and x which can result in a zero risk aversion coefficient, the desired accuracy of the R_a in terms of the number of decimal points considered can result in a zero R_a. For instance, in Table 4.8, farmer number 39 has a risk aversion coefficient of 0.0000006 when evaluated at the mean income using the CUF. If a decision analyst specifies the accuracy of the risk aversion coefficients at six decimal points this coefficient will be zero and the farmer will be classified as risk neutral. The observations made in this section thus further attest to the need for the development of a generalized utility function which does not impose restrictions on its properties with respect to risk aversion coefficients.

4.7 Decision Theoretic Models

This section discusses the results of the various decision models used by this study to predict farmer behavior. In order to refresh the mind of the reader, this discussion will begin by presenting a summary of the decision theory models used in this study and their respective decision rules.

Decision model	*Decision Rule*
1. Expected Profit Maximization	Choose the alternative with the maximum expected profit
2. Lexicographic Safety First	Choose the alternative that has the lowest probability of a regret. If the probabilities are the same, then choose the one with a higher net income.
3. Expected Utility Maximization	Choose the alternative with the highest expected utility.

The result of each model is discussed separately and then the models are compared with each other. In the following discussion Strategy-M refers to mature harvesting and Strategy-P refers to premature harvesting. Initially the results of the estimates of the utility function, A-P risk aversion coefficients, and the classification of farmers' risk attitude are discussed.

4.7.1 Expected Profit Maximization

Table 4.10 gives the expected income for the sample. The mean income for mature harvesting was Rs.7308.63 and it was Rs.6873.84 for the premature harvesting strategy. Thus premature harvesting results in loss of income for an average MEC farmer. For all the farmers in the sample the expected income from mature harvesting was greater than that from the premature harvesting. Evidently, a majority of the MEC farmers lose income when they harvest their crop at a premature stage. For strategy-M the expected profit ranged from Rs.125.0 (farmer 195) to Rs.44,541.80 (farmer 66) and for Strategy-P it ranged from Rs.77.10 (farmer 95) to Rs.44,187.40 (farmer 66). The range for Strategy-M is therefore higher than that for Strategy-P across the sample. All the farmers who harvested their crop at a premature stage have forgone a higher income by not harvesting at mature stage. The expected profit maximization theory, therefore, does not provide evidence for the harvesting strategy to be motivated by expected profit.

4.7.2 Safety First Model (LSF)

The results of the LSF model are given in table 4.10. For the mature harvesting strategy the probability of a regret ranged from 0.528 (farmer 52) to 0.635 (farmer 35) with a mean of 0.563. For the premature harvesting strategy the probability of a regret ranged from 0.536 (farmer 52) to 0.653 (farmer 38) with a mean of 0.565. On the average, mature harvesting strategy, therefore, has a lower probability of a regret. In the sample 17 farmers had a lower probability of regret for Strategy-M and the rest had a lower probability for Strategy-P.

Table 4.10: Target Income, Expected Income, and the Probability of Regret

Farmer number	Reported income	Mature harvesting Expected income	Mature harvesting Prob. of regret	Premature harvesting Expected income	Premature harvesting Prob. of regret
19	58750	28632.6	0.557	27984.0	0.542
24	4922	4397.8	0.561	3887.6	0.580
26	2990	988.4	0.563	800.8	0.550
34	2090	1387.2	0.565	829.6	0.553
35	3550	2270.0	0.635	2217.9	0.623
36	8500	2046.4	0.591	1938.1	0.578
38	4700	4211.1	0.622	4157.2	0.653
39	22775	18815.4	0.550	17564.2	0.560
40	2100	1913.8	0.555	1587.1	0.548
42	2740	1815.3	0.577	1379.2	0.581
52	18985	18348.4	0.528	18197.6	0.536
62	60600	14691.9	0.542	11537.5	0.552
64	4850	3839.1	0.569	3717.1	0.562
66	59580	44541.8	0.557	44187.4	0.556
69	3800	3751.7	0.561	3722.6	0.561
72	7990	3892.4	0.550	3385.5	0.573
95	1250	125.0	0.564	77.1	0.577
96	10015	4967.2	0.565	5339.5	0.577
103	2200	1550.7	0.553	1040.6	0.554
113	9720	10493.6	0.570	9770.7	0.574
162	325	234.0	0.583	206.6	0.581
168	9350	8831.3	0.540	8770.1	0.534
170	2920	758.8	0.546	118.1	0.547
182	14995	15537.4	0.542	15359.1	0.539
186	4600	1162.7	0.560	456.1	0.563
195	1000	241.8	0.552	135.1	0.551
196	5600	4762.4	0.542	4496.6	0.542
199	8940	8068.5	0.602	7985.6	0.576
201	12790	6759.0	0.543	5247.8	0.563
204	712	223.5	0.552	118.7	0.555
Mean	11777.97	7308.63	0.563	6873.84	0.565

Table 4.11: Indices of Expected Utility

Farmer number	Exponential M	Exponential P	Quadratic M	Quadratic P	Cubic M	Cubic P
19	75.126	74.744	91.595	91.055	192.910	190.120
24	80.136	77.833	81.825	81.451	99.079	108.206
26	34.155	29.237	34.071	29.113	34.225	29.349
34	64.754	48.623	65.052	48.796	66.088	48.791
35	69.630	68.904	71.521	70.838	77.690	76.899
36	40.656	39.656	40.742	39.703	38.706	37.492
38	81.481	81.094	81.114	80.956	87.764	88.316
39	70.688	67.330	71.581	67.824	73.282	70.065
40	61.237	53.015	64.753	50.164	68.155	44.951
42	59.622	50.105	59.486	49.524	59.320	49.497
52	83.099	82.923	81.704	81.782	85.316	86.441
62	65.696	61.425	76.228	69.191	104.218	88.281
64	79.319	78.757	85.545	85.619	103.110	104.229
66	73.316	73.032	74.246	73.994	96.512	96.373
69	85.084	84.637	84.147	83.745	81.987	82.935
72	31.480	27.678	20.920	16.965	21.045	17.646
95	19.255	18.928	27.358	23.899	25.563	22.100
96	72.562	72.735	82.560	80.274	102.004	94.479
103	72.882	61.441	74.379	63.227	84.799	70.311
113	85.474	83.032	83.767	82.090	74.113	79.730
162	72.628	68.116	73.922	69.791	90.926	86.075
168	80.711	80.679	84.159	84.633	79.004	78.913
170	30.336	14.693	29.688	14.656	29.546	14.367
182	83.878	83.532	82.520	82.400	77.720	78.900
186	31.127	20.518	29.055	19.240	29.572	19.894
195	41.715	33.983	41.867	33.859	41.731	33.339
196	78.832	76.421	78.536	76.607	89.318	90.428
199	82.163	82.070	85.509	85.939	86.710	87.239
201	72.317	66.342	81.286	74.038	112.684	96.195
204	55.197	42.952	58.377	43.827	71.340	42.435

M = Mature harvesting strategy
P = Premature harvesting strategy

4.7.3 Expected Utility Maximizing Model

Table 4.11 gives indices of expected utility for the three utility function analyzed under respective harvesting strategies. These indices represent a measure of the expected utility derived from each strategy by each farmer.

For the EUF the index ranged from 19.255 (farmer 95) to 85.479 (farmer 113) for Strategy-M and from 14.693 (farmer 170) to 84.637 (farmer 69) for Strategy-P. The Strategy-M, therefore, has a narrower range for the utility index than that of Strategy-P. The utility index for Strategy-M was higher than that of Strategy-P for 28 farmers, was lower for two farmers.

For the QUF the utility indices ranged from 20.920 (farmer 72) to 91.225 (farmer 19) for Strategy-M and from 14.658 (farmer 170) to 91.055 (farmer 19) for Strategy-P. The range of the utility indices for Strategy-P was wider than that of Strategy-M. The QUF ranked Strategy-M higher for 26 farmers and lower for four farmers.

For the CUF the utility indices ranged from 21.045 (farmer 72) to 192.910 (farmer 19) for Strategy-M and it ranged from 14.367 (farmer 170) to 190.120 (farmer 19) for Strategy-P. Strategy-P therefore has a wider range for the utility indices than that for Strategy-M. The CUF ranked Strategy-M higher for 11 farmers and lower for 19 farmers. The CUF, thus, favored the premature harvesting strategy for the largest number of farmers.

This result then demonstrates that different utility functional forms can have different preference ordering of the same set of prospects. This reversal of ranking by the different utility functions will be discussed in the following section where the performance of the three decision models are compared with respect to their ability to predict the behavior of farmers.

4.7.4 Comparison of Decision Models

Table 4.12 gives the behavior predicted by the various models compared against the observed behavior. Table 4.13 gives the summary of the predictions including the number of predictions that were consistent with the observed behavior.

Table 4.12: Observed and Predicted Behavior

Farmer number	Observed behavior	Predicted behavior EPM	LSF	EUF	QUF	CUF
19	M	M*	P	M*	M*	M*
24	M	M*	M*	M*	M*	P
26	P	M	P*	M	M	M
34	P	M	P*	M	M	M
35	M	M*	P	M*	M*	M*
36	M	M*	P	M*	M*	M*
38	M	M*	M*	M*	M*	P
39	M	M*	M*	M*	M*	M*
40	M	M*	P	M*	M*	M*
42	P	M	M	M	M	M
52	M	M*	M*	M*	P	P
62	M	M*	M*	M*	M*	M*
64	M	M*	P	M*	P	P
66	M	M*	P	M*	M*	M*
69	M	M*	M*	M*	M*	P
72	M	M*	M*	M*	M*	M*
95	M	M*	M*	M*	M*	M*
96	P	M	M	P*	M	M
103	M	M*	M*	M*	M*	M*
113	M	M*	M*	M*	M*	P
162	M	M*	P	M*	M*	M*
168	M	M*	P	M*	P	M*
170	M	M*	M*	M*	M*	M*
182	P	M	P*	P*	M	P*
186	P	M	M	M	M	M
195	M	M*	P	M*	M*	M*
196	M	M*	M*	M*	M*	P
199	M	M*	P	M*	P	P
201	P	M	M	M	M	M
204	P	M	M	M	M	M

M = Mature harvesting
P = Premature harvesting
EPM = Expected Profit Maximization
LSF = Lexicographic Safety First
EUF = Exponential utility function
QUF = Quadratic utility function
CUF = Cubic utility function
* = correct prediction

Table 4.13: Summary of Performance of the Decision Models

Decision Model	Mature Harvesting	Premature harvesting	Indifferent	Correct predictions
Expected Profit	30	0	0	22
LSF	17	13	0	15
Expected Utility:				
EUF	28	2	0	25
QUF	26	4	0	19
CUF	21	19	0	15
Observed	22	8	0	

EPM Expected Profit Maximization
LSF Lexicographic Safety First
EUF Exponential utility function
QUF Quadratic utility function
CUF Cubic utility function

As shown in table 4.13, the EUF model made the largest number (25) of predictions that were correct. The EPM was close second with 21 correct predictions. The QUF model made the third highest number of predictions with 19. The CUF and the LSF models each made 15 correct predictions.

As mentioned earlier, the utility functions exhibited a considerable number of reversals of ranking. This implies that if the EUF model prefers Strategy-M for a farmer it is not necessary that all other utility functions give the same preference order. Some of the functions can reverse the preference order.

Table 4.14 summarizes the number of rankings reversed by a decision model with respect to the ranking given by another model. For instance, 13 rankings made by the EPM model were reversed by the LSF model, and 16 of the rankings made by the CUF model were reversed by the QUF model. As discussed under the section on the results of the estimates of the utility functions and the classification of risk attitudes, the CUF had a higher R^2 for a larger number of farmers implying a better fit of the function to the data. In predicting farmer behavior, however, the CUF made the least number of correct predictions. It is therefore evident that a better fit of a utility function does not guarantee a better performance in predicting behavior. Despite its weakness of constant risk aversion coefficient, the EUF made the largest number of correct predictions among the three utility functions. The results of this study show that the performance of a utility function in predicting behavior under uncertainty does not depend on the desirable properties of a utility function, such as decreasing risk aversion coefficient and the provision for a utility function to exhibit risk prefering and risk averse behavior. Buccola compared the EUF and the QUF and reported that these functions prescribed the same portfolio for the representative decision maker studied. The present study does not provide conclusive evidence for the better performance of one utility function over another in predicting behavior in general. It does, however, provide evidence that the choice of a utility function is of paramount importance to the methodology of expected utility theory. The properties of the utility function are not correlated to the performance of the function in predicting farmer behavior. The results of this study suggest that it is advisable to

Table 4.14: Reversal of Preference Rankings

	EPM	LSF	EUF	QUF
LSF	13			
EUF	2	13		
QUF	4	10	16	
CUF	9	17	9	7

EPM Expected Profit Maximization
LSF Lexicographic Safety First
EUF Exponential utility function
QUF Quadratic utility function
CUF Cubic utility function

employ several utility functions and to choose the one with the best performance until adequate evidence is provided to favor certain utility functions over others in predicting farmer behavior.

4.7.5 Sensitivity Analysis

The sensitivity of the models were analyzed with respect to the discount factors and with respect to changes in the expected income. The sensitivity of the models with respect to changes in the discount rate is given in table 4.15. The discount rate used in the sensitivity analysis ranged from 1.0 (undiscounted) to 0.5 (a fifty percent discount rate), in increments of five percent including the elicited discount rates. The LSF, EUF and the CUF models made the highest number of correct predictions at a discount rate of 15 percent which is the market discount factor. The EPM model made a higher number of correct predictions at higher discount rates. The QUF model did not follow any pattern with the discount rates.

The sensitivity of the LSF model was analyzed with respect to changes in the expected income, with the safety level held constant. As seen in table 4.16 the model is sensitive to changes in the expected income. Even a ten percent change in the expected income, in either direction, would improve the predictions made made by this model as much as six correct predictions. Any decrease in the expected income below ten percent does not change the performance of the model. Increasing the expected income by up to 30 percent improves the number of correct predictions of the model to 26.

4.8 Chapter Summary

This chapter presented the results of the various analysis of the study. Fear of theft and immediate money needs were reported as the primary reasons for the practice of premature harvesting. The logit probability model estimated to explain this behavior indicated the farm

Table 4.15: Performance of the Models at Various Discount Factors

Discount factor	*EPM* M	P	C	*LSF* M	P	C	*EUF* M	P	C	*QUF* M	P	C	*CUF* M	P	C
Undiscounted	30	0	22	16	14	14	30	0	22	26	4	18	21	9	15
Elicited	23	7	22	17	13	15	23	7	23	21	9	19	17	13	14
0.95	30	0	22	16	14	14	30	0	24	26	4	18	21	9	15
0.90	30	0	22	16	14	14	30	0	24	26	4	18	21	9	15
0.85	30	0	22	17	13	15	29	1	25	26	4	19	21	9	15
0.80	28	2	23	17	13	15	28	2	25	25	5	19	21	9	15
0.75	28	2	23	17	13	15	28	2	25	24	6	20	22	8	15
0.70	26	4	21	17	13	15	26	4	23	24	6	20	19	11	14
0.65	22	8	20	17	13	15	22	8	20	20	10	18	18	12	14
0.60	20	10	18	17	13	15	20	10	18	20	10	10	19	11	15
0.55	18	12	16	17	13	15	18	12	17	19	11	17	18	12	15
0.50	15	15	23	17	13	15	15	15	12	17	13	16	16	14	12

M = Mature harvesting
P = Premature harvesting
EPM = Expected Profit Maximization
LSF = Lexicographic Safety First
EUF = Exponential utility function
QUF = Quadratic utility function
CUF = Cubic utility function
C = correct prediction

Table 4.16: Sensitivity of LSF Model to Changes in Expected Income

Percent change in expected income	Premature	Prediction Mature	Correct
-50	7	23	21
-40	7	23	21
-30	7	23	21
-20	7	23	21
-10	7	23	21
Basis	*13*	*17*	*15*
+10	9	21	21
+20	5	25	25
+30	4	26	26
+40	3	27	26
+50	2	28	26

income, the ratio of lowland to total land, and the level of education to influence harvesting behavior.

The classification of farmers' risk attitude varied with the functional form. The exponential function classified all the farmers as risk averse, and the risk aversion coefficients were independent of the level of income at which it is evaluated. The quadratic utility function classified a majority of farmers as risk averse and a few as risk preferring and exhibited increasing risk aversion. The cubic utility function classified almost half the number of farmers as risk preferring and the other half as risk averse. Both, the quadratic and the cubic functions classified a larger number of farmers as risk averse at the annual income than at the mean income.

Of the decision theoretic models compared, the expected utility model with the exponential utility function described farmer behavior better than the other models compared in this study. The CUF and the safety-first models made the least number of correct predictions. It is, therefore, evident that the expected utility theory performs better than the expected profit maximizing model and the safety-first model. The results of all the models were sensitive to changes in the discount rate. The LSF model was sensitive to changes in the expected income.

If our conclusions are robust- if they are not changed materially by substituting one or another variant of the behavioral model for the classical model- we will gain confidence in our predictions and recommendations; if the conclusions are sensitive to such substitutions, we will use them warily until we can determine which micro theory is the correct one.

Herbert A. Simon. "Rational Decision Making in Business Organizations." *Amer. Econ. Rev.* 69(1979): 493-513. (p: 509) Nobel Prize Lecture, December 8, 1978. Stockholm, Sweden.

Chapter 5

Summary, Conclusions, and Implications

5.1 Introduction

This chapter summarizes the study and its conclusions, and draws relevant implications. The chapter ends with some suggestions for future research, both with respect to the problem as well as with respect to the methodology.

5.2 Summary of the Methodology of the Study

This study involved one of the fast growing industries of Sri Lanka in terms of the potential for earning foreign exchange. The study problem was premature harvesting of these crops by the growers. The problem was identified as a result of observations and opinions expressed by the extension agents and government officials in the Department of Minor Export Crops in Sri Lanka. It was hypothesized that farmers practiced premature harvesting because of risk faced by them and immediate money needs. Based on preliminary interviews with officials in the government departments and brokering agents, the problems contributing to this behavior were identified as fear of theft, immediate money needs, and problems with pests. The specific objectives of the study were to answer the following questions:

1. Why do minor export crop growers harvest their crops at premature stages?
2. Can their behavior be explained with an econometric qualitative choice model? and
3. Can their behavior be described with one of the decision theoretic models:
    a. Expected Profit Maximization,
    b. Expected Utility Maximization, and
    c. Safety-First.

The first question was answered by asking the farmers, directly, the reasons for harvesting the crop at premature stages. The second question was answered by estimating a logit probability model with the harvesting decision as the dependant variable and some socio-economic factors of the household as explanatory variables. The third question was answered by comparing farmers' actual behavior with the harvesting strategy prescribed by the decision models. The methodology of the study is summarized in figure 5.1.

5.3 Conclusions

This section will summarize the major conclusions of the study under respective objectives.

5.3.1 Objective 1:

Of the 240 farmers interviewed in the first survey, 56 farmers (23.3 percent of the sample) reported that they harvest their crop at premature stages. According to the farmers, fear of theft is the most important problem influencing this behavior. Immediate money needs as a reason for premature harvesting is a close second. Pest and disease damage was cited by a minority of farmers to be an important problem.

Problem:	The behavior of premature harvesting of perennial cash crops.
Objectives:	1. Determine the reasons for the behavior. 2. Explain the behavior with a logit probability model with socio-economic factors as explanatory variables. 3. Describe behavior with an appropriate decision theoretic model.
Tested theories:	1. Expected Profit Maximization 2. Expected utility maximization, using the exponential, quadratic, and the cubic utility functions. 3. Safety-first
Methods used:	1. Statistical methods for computing frequencies and distribution parameters. 2. Econometric estimation of the logit model and the utility functions, 3. Simulation of net returns from minor export crops, 4. Numerical computation of expected income, probability of a disaster, and the utility indices.

Figure 5.1: Schematic Representation of the Methodology of the Study

5.3.2 *Objective 2:*

The explanatory variables used to predict the probability of premature harvesting of a farmer were: household size, age of the farmer in years, experience in farming, number of minor export crops, total household income, ratio of lowland to the total farming land, and education. Education of the farmer, ratio of lowland to total land, and the total family income were found to be significantly related to the harvesting behavior of the farmers. The logit model correctly predicted the behavior of nearly 90 percent of the farmers in the sample.

5.3.3 *Objective 3:*

Of the three decision theoretic models used, the expected utility model with the exponential utility function made the largest number of correct predictions, followed by the expected profit maximizing model. The quadratic utility function made the third largest number of correct predictions followed by the cubic utility function and the safety-first model.

The minor export crop growers in Sri Lanka, therefore, aim at maximizing their expected utility than either expected profits or minimizing the probability of expected income falling below a safety level. The results also suggest that farmers' utility functions are better approximated by exponential utility functions than the quadratic or the cubic functions. The results of this study support the conclusions of the studies which have shown the expected utility theory to better explain farmer behavior than profit maximization. The studies reported so far were concerning resource allocation behavior. This study shows that harvesting behavior also can be explained with the expected utility theory.

The poor performance of the safety-first model cannot be generalized to mean these models do not explain or correctly predict farmer behavior. One of the reasons for the poor performance of the safety-first model may be the way the study specified the safety level.

5.4 Implications

The implications of the study will be discussed with respect to the problem studied and with respect to the methodology and methods of the study.

5.4.1 The Study Problem

The results of the study show that fear of theft and immediate money needs to meet household expenses are the more important reasons for the behavior of premature harvesting. The estimates of the logit model, combined with the results of the decision model suggest that policy measures directed at influencing this behavior should be aimed at education and the income levels of the farmer. The farmers need to be educated about the implications of premature harvesting.

The income level can be influenced by policies directed at the price of MEC's or other crops. Policy measures on crops other than the MEC's are beyond the scope of the Department of Minor Export crops. The price of minor export cops is largely handled by the private sector, which has been the case for a long period. Any measures taken to bring this industry under total government control will be met with stiff opposition.

In view of the favorable features of the free-market system, this study does not recommend a complete involvement of the government in the industry. Rather, the government could act as a catalyst to the system; as an agency to provide the supporting services. One of the services suggested by the study is to encourage quality control on the minor export crops. This quality control would need to be implemented with the cooperation of the exporters and the large volume traders. The government could request, or make mandatory, that the brokers and the exporters include only mature produce in their transactions.

5.4.2 *Methodology*

This study suggests that expected utility maximization better explains farmer behavior than the other two decision models considered. This finding strengthens the evidence provided by several authors that agricultural producers are motivated by expected utility maximization rather than expected profit maximization or satisfying a safety level of income.

The other important contribution made by this study is evidence that a utility functional form can reverse the preference ranking of another functional form. One previous study has compared the ranking of the exponential utility function and the quadratic utility function [Bucolla]. The study, with one representative farm, did not find any difference in the portfolio prescribed by the two utility functions. The present study has demonstrated that the choice of a utility function is an important aspect of the methodology of expected utility theory. Although the study showed the EUF to predict better than the QUF and CUF, the evidence is not conclusive for the performance of one function over the other. The only conclusive evidence is that utility functions can reverse the ordering of prospects and, very likely, portfolio analysis with different utility functions could result in different portfolios. The importance of choosing an appropriate utility function cannot be over emphasized. For instance, if this study had used only the quadratic utility function the results would have shown the expected profit maximization model to perform better than the expected utility maximizing model.

5.5 Suggestions for Future Research

The discussion in the previous section highlighted some of the more important implications of the study problem and the methodology. The following section suggests some possible studies based on the above discussion.

5.5.1 The Study Problem

For most farmers in the sample of the second survey, premature harvesting resulted in lower estimated income than mature harvesting. In order to give the policy makers an idea of the magnitude of economic loss due to premature harvesting, the extent of loss in income needs to be estimated, both at the farm level as well as at the national level. This would involve detailed record keeping by farmers and by the Chief Collector of Customs.

In a general sense, the MEC sector needs many benchmark and preliminary studies. Some of the suggested studies are: price determination, relationship between the world prices and the local prices, demand projections for the crops, quantification of the potential contribution of the MEC industry to economic development, and the role of price information in the decision making of farmers. These are some of the analytical studies. The MEC sector also needs more fundamental studies, such as a study on the structure of the industry.

5.5.2 Methodology

In order to increase the reliability, and possibly the predictive power of the decision models, the farmers' beliefs about the prices and the outputs should be compared with actual prices and actual output. Such a study will show whether farmers consistently overestimate, or underestimate the expected prices and outputs and their variability. If such a behavior is detected with some degree of significance, a correction factor for such discrepancies can be built into decision models.

Because of the problems discussed in in chapter 4, this study did not use the directly elicited safety level for the analysis on safety-first behavior. Many authors have noted the importance of using a realistic safety-level. This study suggests a need for research to determine realistic safety levels, or a way to determine the safety levels used by farmers.

More research is needed on directly elicited utility functions. The need for a generalized utility function has arisen several times in this study. Expected utility analysis needs a utility function that will be consistent with classification of risk attitudes, and be consistent with the ranking of prospects.

BIBLIOGRAPHY

Agroskills. *The Minor-Export Crop Sector: A Study of Policies, Organizations, Producers, and Incentives.* Colombo, Sri Lanka: Agroskills Ltd., 1985.

Amemiya, T. "Qualitative Response Models: A Survey." *J. Econ. Lit.* 19(1981): 1483-1536.

Anderson, J. R., J. L. Dillon, and J. B. Hardaker. *Agricultural Decision Analysis.* Ames, Iowa: Iowa State University Press, 1977.

Arrow, K.J. *Essays in the Theory of Risk Bearing.* Chicago: Markham Publishing Co., 1971.

Arrow, K.J., and L. Hurwicz. "An Optimality Criterion for Decision Making under Ignorance." In C.F. Carter and J. L. Ford (Eds.) *Uncertainty expectations in Economics: Essays in Honor of G.L.S. Schakle.* Blackwell, England: Oxford University Press, 1972.

Barker, R. *"Economic Aspects of High Yielding Varieties of Rice with Special Reference to National Rice Policies."* IRRI Report, Food and Agriculture Organisation of the United Nations, Study Group on Rice, Thirteenth Session, Manila, Philippines, March, 1969.

Baron, David P. "On the Utility Theoretic Foundations of Mean-Variance Analysis." *Journ. of Fin.* 32(1977): 1683-97.

Battra, R., and A. Ullah. "Uncertainty in Production and the Competitive Firm." *South. Econ. Journ.* 46(1979): 489-501.

Baumol, W.J. *Economic Theory and Operations Analysis.* Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1977.

Bernoulli, D., "Speciman Theoriae noval de mensura sortis." *Commentarri Academiae Scientiarum Imperialis Petropolitanae.* 5(1738): 175-92. Translated in: Sommer, L., "Expositions of a new Theory on the Measurement of Risk." *Econometrica.* 22(1954): 23-36.

Bessler, D.A. "Subjective Probability." In P.J. Barry (Ed.) *Risk Management in Agriculture.* Ames, Iowa: Iowa State University Press, 1984, pp. 43-52.

Binswanger, H.P "Attitudes Towards Risk: An Experimental Measurement in Rural India." *Amer. J. Agr. Econ.* 62(1980): 395-407.

Blau, R.A. "Stochastic Programming and Decision Analysis: An Apparent Dilemma." *Mgt. Sci.* 21(1974): 271-76.

Borch, K.H., *The Economics of Uncertainty.* Princeton: Princeton University Press, 1968.

Boussard, J-M. "A Model of the Behavior of Farmers and its Application to Agricultural Policies." *Eur. Econ. Rev.* 2(1971): 436-61.

Boussard, J-M., and M. Petit. "Representation of Farmers' Behavior under Uncertainty with a Focus-Loss Constraint." *Journ. Farm Econ.* 49(1967): 869-80.

Buccola, S.T. "Specification of Bernoullian Utility Function in Decision Analysis: Comment." *Ag. Econ. Res.* 34(1982a): 19-21.

Buccola, S.T. "Portfolio Selection under Exponential and Quadratic Utility." *West. J. Ag. Econ.* 7(1982b): 43-51.

Buccola, S.T., and B.L. French. "Estimating Exponential Utility Functions." *Ag. Econ. Res.* 30(1978): 37-43.

Bunn, D.W. *Applied Decision Analysis.* New York: McGraw Hill, 1984.

Central Bank of Ceylon. *Review of the Economy 1984.* Colombo, Sri Lanka: Central Bank of Ceylon, 1984.

Ceylon. *The Draft Agricultural Development Plan, 1971-1977.* Ceylon: Ministry of Agriculture and Food, 1971.

Ceylon. *Sessional Paper no. XVIII.* Government of Ceylon, Tea Commission, 1968

Ceylon. *The Short-Term Implementation Programme.* Ceylon: The Department of National Planning, 1962.

Ceylon. *The 10-Year Plan* Ceylon: National Planning Council, Government of Ceylon, 959.

Ceylon. *The Agricultural Plan* Ceylon: Ministry of Agriculture and Food, Government of Ceylon, 1958.

Charnes, A., and W.W. Cooper "Chance constrained Programming." *Mgt. Sci.* 6(1959):73-79.

Chen, J.T. "Quadratic Programming for Least Cost Feed Formulations under Probabilistic Protein Constraints." *Amer. J. Agr. Econ.* 55(1973): 175-83.

Cocks, K.D. "Discrete Stochastic Programming." *Mgt. Sci.* 15(1968): 72-79.

Colson, G., and M. Zeleny. *Uncertain prospects Ranking and Portfolio Analysis under the Conditions of Partial Information.* Cambridge, Massachusetts: Oelgeschlager, Gunn & Hain, 1979.

Cramer, H. "On the Mathematical Theory of Risk." In *Forsakringsaktiebolaget Scandias Festskrft.* Stockholm: Centraltryckeriet, 1930, pp. 7-84.

Cyert, R.M. and J.G. March. *A behavioral Theory of the Firm* Englewood Cliffs: Prentice-Hall Inc., 1963.

Dao, D.M., "On the Formulation of Risk Constraints for Linear Programming: Comment." *J. Agr. Econ.* 30(1979): 195-6.

Day, R.H. and I.J. Singh, "A Dynamic Model of Regional Agricultural Development." *Int. Reg. Sci. Rev.* 1(1975): 27-48.

Day, R.H. "Rational Choice and Economic Behavior." *Theory and Decision* 1(1971): 229-51.

DMEC *Administrative Report of the Director for 1973* Sri Lanka: Department of Minor-Export Crops, 1974.

De Finnetti, B. "La Prevision: Ses Lois Logiques, Ses Sources Subjective." *Ann. Int. H. Poincare.* 7(1937): 1-68. Translated into English in: H.E. Kyburg and H.E. Smokler (Ed) *Studies in Probability.* New York: John Wiley and Sons, 1964, pp. 93-158.

de Silva, C.R. *Ceylon under British Occupation 1795-1833: Its Political, Administrative and Economic Development.* Vol. I. 1942.

de Silva, M.P. Personal Communication. November, 1985- February, 1986. Head, Agricultural Economics Division, Department of Minor-Export Crops, Peradeniya, Sri Lanka.

de Silva, M.P. and W.H.E. Premaratne. "Evaluation of Delpitiya Mixed Crop Model" Economics Unit, Department of Minor Export Crops, Peradeniya, April, 1985.

Dillon, J.L., and J.R. Anderson. "Allocative Efficiency, Traditional Agriculture, and Risk." *Amer. J. Agr. Econ.* 53(1971): 26-32.

Dillon, J.L., and P.L. Scandizzo. "Risk Attitudes of Subsistence Farmers in North East Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60((1978): 425-35.

Dillon, J.L. "Decision Theory: Outline and Problems." In J. A. Roumasset *et al.* (Eds.) *Risk, Uncertainty, and Agricultural Development.* New York: Agricultural Development Council, 1979, pp. 23-38.

Dillon, J.L. "An Expository Review of Bernoullian Decision Theory: Is Utility Futility?" *Rev. Mktg. Agric. Econ.* 39(1971): 3-80.

Domencich, T., and D. McFadden. *Urban Travel Demand: A Behavioral Analysis.* Amesterdam: North-Holland, 1975.

Domotor, Z. *Probabilistic Relational Structures and Their Applications.* Technical Report 144, Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, California, 1969.

Dreze, J.H. "Axiomatic Theories of Choice, Cardinal Utility, and Subjective Probability: A Review." In J.H. Dreze (Ed.) *Allocation under Uncertainty: Equilibrium and Optimality.* New York: John Wiley and Sons, 1974.

Fama, E.F. "Mandelbrot and the Stable Paretian Hypothesis." *J. of Business.* 36(1963): 420-9.

Fishburn, P.C. *The Foundations of Expected Utility.* Dordrecht, Holland: D. Reidel Publishing Co., 1982.

Fishburn, P.C. *Utility Theory for Decision Making.* New York: John Wiley and Sons, 1970.

Fishburn, P.C. "Weak Qualitative Probability on Finite Sets." *Ann. Math. Stat.* 40(1969): 2118-26.

Fishburn, P.C. *Decision Value and Theory.* New York: John Wiley and Sons, 1964.

Food and Agriculture Organization, Rome, Italy. Personal Communication, April, 1985.

Fourier, J.B.J., *The Analytical Theory of Heat.* Cambridge: The University Press, 1878.

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

Friedman, M. *Essays in Positive Economics.* Chicago: University of Chicago Press, 1953.

Georgescu-Roegen, N. *The Entropy Law and the Economic Process.* Cambridge, Massachusetts: Harvard University Press, 1971.

Georgescu-Roegen, N. "The Nature of Expectations and Uncertainty." In J. Bowman (Ed.) *Expectations, Uncertainty, and Business Behavior*. New York: Social Science Research Council, 1958, pp. 11-29.

Gottinger, H.W. *Coping with Complexity.* Dordrecht, Holland: D. Reidel Publishing Co., 1983.

Great Plains Agricultural Council. *Proceedings of Research Conference on Risk and Uncertainty in Agriculture.* North Dakota Agric. Expt. Station Bulletin, 400, 1955.

Gunasekera, A. Personal Communication. Director/Marketing, John Keells Ltd., Colombo, Sri Lanka. February, 1986.

Hadley, G. *Nonlinear and Dynamic Programming.* Reading: Addison-Wesley Publishing Co. Inc., 1964.

Hagen O., and F. Wenstop (Eds.) *Progress in Utility and Risk Theory* Dordrecht, Holland: D. Reidel Publishing Co., 1983.

Halter, A.N., and R. Mason. "Utility Measurement for Those Who Need to Know." *West. J. Ag. Econ.* 3(1978): 99-109.

Halter, A.N., and G.W. Dean. *Decision under Uncertainty with Research Applications.* Cincinnati: South-Western Publishing, 1971.

Hanf, C-H., and G. Schiefer. (Eds.) *Consideration and Modelling of Risk in the Agribusiness Sector.* Kiel: Kieler Wissenschaftsverlag Vauk, 1981.

Hanoch, G., and H. Levy. "Efficient Portfolio Selection with Quadratic and Cubic Utility." *J. of Business.* 43(1970): 181-9.

Hanushek, E.A., and J.E. Jackson, *Statistical Methods for Social Scientists.* New York: Academic Press, 1977

Hathurusinghe, C. Personal Communication. Agrarian Research and Training Institute, Colombo, Sri Lanka. February, 1986.

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

Henderson, J.H., and R.E. Quandt. *Microeconomic Theory: A Mathematical Approach.* New York: McGraw Hill, 1981.

Herath, H.M.G, J.B. Hardaker, and J.R. Anderson. "Choice of Varieties by Sri Lanka Rice Farmers: Comparing Alternative Decision Models." *Amer. J. Agr. Econ.* 64(1982): 87-93.

Hey, J.D. *Uncertainty in Microeconomics.* New York: New York University Press, 1979.

Hildreth, C., "What do we know about Agricultural Producers' Behavior under price and yield instability." *Amer. J. Ag. Econ.* 59(1977): 898-902.

Hogarth, R.M. "Cognitive Process and the Assessment of Subjective Probability Distribution." *J. Amer. Stat. Assoc.* 70(1975): 271-89.

Horowitz, Ira. *Decision Making and the Theory of the Firm.* New York: Holt, Rinehart and Winston, Inc., 1970.

Horstein I.N., and J. Milnor. "An Axiomatic Approach to Measurable Utility." *Econometrica* 21(1953): 291-7.

Hull, J.C. "Obtaining Probability Distributions for the Evaluation of Investment Risk." *Management Accounting.* 54(1976): 349-351.

Hull, J., P.G. Moore, and H. Thomas. "Utility and Its Measurement." *J Royal Stat. Assoc.* Ser. A 136(1973): 226-47.

Intriligator, M.D. *Mathematical Optimization and Economic Theory.* Englewood Cliffs: Prentice-Hall Inc., 1971.

Just, R.E. "An Investigation of the Importance of Risk in Farmer's Decisions." *Amer. J. Agr. Econ.* 56(1974): 14-25.

Kataoka, S. "A Stochastic Programming Model." *Econometrica.* 31(1963): 181-96.

Kahneman, D., and A. Tversky. "Subjective Probability: A Judgement of Representativeness." *Cog. Psych.* 3(1972): 430-54.

Kahneman, D., and A. Tversky. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica.* 47(1979): 263-91.

Karmarkar, U.S. "Subjectively Weighted Utility: A Descriptive Expansion of the Expected Utility Model." *Org. Beh. Hum. Perf.* 21(1978): 61-72.

Keefer, D.L., and S.E. Bodily, "Three-Point Approximations for Continuous Random Variables." *Mgt. Sci.* 29(1983): 595-609.

Keeny, R.L., and H. Raiffa. *Decisions with Multiple Objectives.* New York: John Wiley and Sons, 1976.

Kennedy, J.O.S., E.M. Francisco. "On the Formulation of Risk Constraints for Linear Programming" *J. Agr. Econ.* 25(1974): 129-45.

Kennedy, J.O.S., E.M. Francisco. "On the Formulation of Risk Constraints for Linear Programming: Reply." *J. Agr. Econ.* 30(1979): 197.

Kerlinger, F.N. *Foundations of Behavioural Research.* New York: Holt, Rinehart, and Winston Inc., 1973.

Kim, C. S., J. F. Yanagida, and R. L. Shane. *Alternative Approaches to Risk and Uncertainty in Evaluating Optimal Firm Behavior.* Division of Agricultural and Resource Economics, University of Nevada, Reno. January, 1981.

King, R.P., and L.J. Robison. "An Interval Approach to the Measurement of Decision Maker Preference." *Amer. J. Ag. Econ.* 63(1981): 510-20.

Knight, F.H. *Risk, Uncertainty and Profit.* Boston: Houghton Mifflin Company, 1921.

Kozielecki, J. *Psychological Decision Theory.* Dordrecht, Holland: D. Reidel Publishing Co., 1981.

Kraft, C.H., J.W. Pratt, and A. Seidenberg. "Intuitive Probability on Finite Sets." *Ann. Math. Stat.* 30(1959): 408-19.

Kramer, R.A., W.T. McSweeny, and R.W. Stavros. "Soil Conservation with Uncertain Revenues and Input Supplies." *Amer. J. Agr. Econ.* 65(1983): 694-702.

Kramer, G. "An Impossibility Result Concerning the Theory of Decision Making." Cowles foundation Discussion Paper. No. 218, 1967.

Krantz, D.H., R.D. Luce, P. Suppes, and A. Tverskey. *Foundations of Measurement.* Vol. I. New York: Academic Press, 1971.

Kuhn, H.W. (Ed.) *Proceedings of the Princeton Symposium on Mathematical Programming.* Princeton: Princeton University Press, 1970.

Kuznets, S. "Economic Growth and the Contribution of Agriculture." In C.K. Eicher and L.W. Witt. (Eds.) *Agriculture in Economic Development.* New York: McGraw Hill, 1964.

Levy, H and H.M. Markowitz. "Approximating Expected Utility by a Function of Mean and Variance." *Am. Econ. Rev.* 69(3): 308-17. June 1979.

Lin, W., and H.S. Chang. "Specification of Bernoulian Utility Functions in Decision Analysis." *Ag. Econ. Res.* 30(1978): 30-6.

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

Lindley, D.V. *Making Decisions.* London: John Wiley and Sons, 1971.

Low, A.R.C. "Decision Making under Uncertainty: A Linear Programming Model of Peasant Farmer Behavior." *J. Agric. Econ.* 25(1974): 311-22.

Luce, R.D., and P. Suppes. "Preferences, Utility, and Subjective Probability." In R.D. Luce *et al.* (Eds.) *Handbook of Mathematical Psychology.* Vol. III. New York: John Wiley and Sons, 1965, pp. 249-410.

Luce R.D., and H. Raiffa. *Games and Decisions.* New York: John Wiley and Sons, 1957.

Machlup, F. "Theories of the Firm: Marginalist, Behavioral, Managerial." *Am. Econ. Rev.* 57(1967): 1-33.

MacCrimmon, K.R., "Descriptive and Normative Implications of Decision Theory Postulates." In K.H. Borch and J. Mossin (Eds.) *Risk and Uncertainty: Proceedings of a Conference.* New York: Macmillan, 1968, pp. 3-23.

MacLaren, D. "The Output Response of the Risk Averse Firm: Some Comparative Statics for Agricultural Policy." *J. Agr. Econ.* 34(1983): 45-56.

Magnusson, G. *Production under Risk: A Theoretical Study.* Uppsala: Almqvist and Wiksells. 1969.

March, J.G., and H. A. Simon. *Organizations.* New York: John Wiley and Sons, 1958.

Marchak, J. "Rational Behavior, Uncertain Prospects, and Measurable Utility." *Econometrica* 18(1950): 111-41.

Markowitz, H. *Portfolio Selection.* New York: John Wiley and Sons, 1959.

Marschak, J. "Actual Versus Consistent Decisions." *Behavioral Science.* 9(1964): 103-10.

McInerney, J.P. "Maximin Programming - An Approach to Farm Planning under Uncertainty." *J. Agric. Econ.* 18(1967): 279-90.

McInerney, J.P. "Linear Programming and Game Theory Models: Some Extensions." *J. Agric. Econ.* 20(1969): 269-78.

Mendelbrot, B. "The Variation of Certain Speculative Prices." *J. of Business.* 36(1963): 394-419.

Merril, W.C. "Alternative Programming Models Involving Uncertainty." *J. Farm. Econ.* 47(1965): 595-610.

Meyer, J. "Choice among Distributions." *J. Econ. Theory.* 14(1977): 326-36.

Morrison, D.G. "Upper Bound for Correlations between Binary Outcomes and Probabilistic Predictions." *Journ. Amer. Stat. Assoc.* 67(1972): 68-70.

Moscardi, E., and A. de Janvry. "Attitudes Toward Risk Among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977): 710-16.

Mosher, A.T. *Getting Agriculture Moving.* New York: Praeger Publishing Company, 1966.

Murphy, A.H., and R.L. Winkler. "Reliability of Subjective Probability Forecasts of Precipitation and Temperature." *Applied Stat.* 26(1977): 41-7.

Musser, W.N., M.E. Wetzstein, S.Y. Reece, L.M. Musser, P.E. Varca, and C.C.J. Chou "Classification of Risk Preferences with Elicited Utility Data: Does the Functional Form Matter?" *West. J. Agr. Econ.* 9(1984): 322-28.

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

Naslund, B. *Decisions under Risk: Economic Applications of Chance-constrained Programming.* Stockholm: The Economic Research Institute, Stockholm School of Economics, 1967.

Neter, J., and E.S. Maynes. "On the Appropriateness of the Correlation Coefficient with a 0,1 Dependant Variable." *Journ. Amer. Stat. Assoc.* 65(1970): 501-9.

Newbery, D.M.G., and J.E. Stiglitz. *The Theory of Commodity Price Stabilization: A Study in the Economics of Risk.* Oxford: Clarendon Press. 1981.

Nieuwoudt, W. L., J. B. Bullock, and G. A. Mathia. "An Economic Evaluation of Alternative Peanut Policies." *Amer. J. Agr. Econ.* 58(1976): 485-495.

Officer, R.R., and J.R. Anderson. "Risk Uncertainty and Farm Management Decisions." *Rev. Mktg. Ag. Econ.* 36(1968): 3-19.

Officer, R.R., and A.N. Halter. "Utility Analysis in a Practical Setting." *Amer. J. Agr. Econ.* 50(1968): 257-277.

Payne, J.W. "Task Complexicity and Contingent Processing in Decision Making: An Information Search and Protocol Analysis." *Org. Beh. Hum. Perf.* 16(1976): 366-87.

Pearson, E.S., and J.W. Tukey. "Approximate Means and Standard Deviations Based on Distances between Percentage Points on Frequency Curves." *Biometrica.* 52(1965): 533-46

Perry, C., and I.D. Grieg. "Estimating the Mean and Variance of Subjective Distributions in PERT and Decision Analysis." *Mgmt. Sci.* 21(1975): 1477-80.

Pope, R.D., and R.A. Kramer. "Production Uncertainty and Factor Demands for the Competitive Firm." *South. Econ. Journ.* 46(1979): 489-501.

Pratt, J.W. "Risk Aversion in the Small and in the Large." *Econometrica.* 32(1964): 122-36.

Preston, M.G., and P. Baratta. "An Experimental Study of the Auction Value of an Uncertain Outcome." *Amer. J. Psychol.* 61(1948): 183-93.

Pyle, D.H., and S.J. Turnovsky. "Safety-First and Expected Utility Maximization in Mean-Standard Deviation Portfolio Analysis. *Rev. Econ. Stud.* 52(1970): 75-81.

Pindyck, R.S., and D.L. Rubinfeld. *Econometric Models and Economic Forecasts.* New York: McGraw Hill, 1981.

Quirk, J.P., and R. Saposnik. "Admissability and Measurable Utility Functions." *Rev. Econ. Stud.* 29(1962): 140-46.

Radner, R. "Existence of Equilibrium of Plans, Prices, and Price Expectations in a Sequence of Markets." *Econometrica.* 40(1972): 289-303.

Radner, R. "Mathematical Specification of Goals for Decision Problems." In M.W. Sheely and G.L. Bryan (Eds.) *Human Judgements and Optimality.* New York: John Wiley and Sons, 1964, pp. 178-216.

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

Raiffa, H. *Decision Analysis: Introductory Notes on Choice under Uncertainty* Reading, Massachusetts: Addison-Wesley. 1970.

Rahman, S.A., and F.E. Bender. "Linear Programming Approximations of Least Cost Feed Formulations under Probabilistic Protein Constraints." *Amer. J. Agr. Econ.* 53(1971): 612-18.

Rambukwella, K. Personal Communication. Director, Bartleets Ltd., Colombo, Sri Lanka. February, 1986.

Ramsey, F.P. "Truth and Probability" In F.P. Ramsey, *The Foundations of Mathematics and other Logical Essays.* New York: Harcourt, Brace, and Co., 1931. Reprinted in H.E. Kyburg and H.E. Smokler (Eds.) *Studies in Subjective Probability.* New York: John Wiley and Sons, 1964, pp. 61-92.

Ratti, R., and A. Ullah. "Uncertainty in Production and the Competitive Firm." *South. Econ. Journ.* 42(1976): 703-10.

Rescher, N. *The Coherence Theory of Truth.* Blackwell, England: Oxford University Press. 1970.

Roberts, F.S. *Measurement Theory.* Reading, Massachusetts: Addison-Wesley Publishing Company, 1979.

Robison, L.J., P.J. Barry, J.B. Kliebenstein, and G.F. Patrick. "Risk Attitudes: Concepts and Measurement Approaches. In P.J. Barry (Ed.) *Risk Management in Agriculture.* Ames, Iowa: Iowa State University Press, 1984.

Rothschild, M., and J.E. Stiglitz, "Increasing Risk I: A Definition." *Journ. of Econ. Theory.* 2(1970): 225-43.

Roumasset, J.A. "Introduction and the State of Arts." In J.A. Roumasset *et al* (Eds.), *Risk, Uncertainty, and Agricultural Development.* New York: Agricultural Development Council, 1979.

Roumasset, J.A. *Rice and Risk: Decision Making among Low Income Farmers.* Amsterdam: North-Holland Publishing Company, 1976.

Roy, A.D. "Safety First and the Holding Assets." *Econometrica.* 20(1952): 431-49.

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

Savage, L.J. "Elicitation of Personal Probabilities and Expectations" *J. Am. Stat. Assoc.* 66(1971): 783-801.

Savage, L.J. *The Foundations of Statistics.* New York: John Wiley and Sons, 1954.

Schoemaker, P.J.H. "The Expected Utility Model: Its Variants, Purposes, Evidence, and Limitations." *J. Econ. Lit.* 20(1982): 529-63.

Schoemaker, P.J.H. *Experiments on Decisions under Risk: The Expected Utility Hypothesis* Boston, Massachusetts: Martinus Nijhoff Publishing, 1980.

Schultz, T.W. *Transforming Traditional Agriculture.* Chicago: The University of Chicago Press, 1983.

Scott, D. "Measurement Models and Linear Inequalities." *J. Math. Psychol.* 1(1964): 233-247.

Scott, J.T., and Chester B. Baker. "A Practical Way to Select an Optimal Farm Plan under Risk." *Amer. J. Agr. Econ.* 54(1972): 657-60.

Selly, R. "Decision Rules in Risk Analysis" In P.J. Barry (Ed.) *Risk Management in Agriculture.* Ames, Iowa: Iowa State University Press, 1984.

Sengupta, J.K. *Stochastic Programming - Methods and Applications.* New York: American Elsevier Publishing Co. Inc., 1972.

Silverberg, R. *The Stochastic Man.* New York: Fawcet, 1975.

Simon, H.A. *Models of Bounded Rationality (Vol. 1): Economic Analysis and Public Policy.* Cambridge, Massachusetts: The MIT Press, 1982.

Simon, H.A. *Models of Bounded Rationality (Vol. 2): Behavioral Economics and Business Organizations.* Cambridge, Massachusetts: The MIT Press. 1982

Simon, H.A. "Rational Decision Making in Business Organizations." *Amer. Econ. Rev.* 69(1979): 493-513.

Simon, H.A. *The New Science of Management Decision.* New York: Harper and Brothers, 1960.

Simon, H.A. *Models of Man: Social and Rational.* New York: John Wiley and Sons,, 1957.

Sinn, H.W. *Economic Decisions under Uncertainty.* Amsterdam: North-Holland, 1983.

Sonka, S.T. and G.F. Patrick. "Risk Management and Decision Making in Agricultural Firms." In P.J. Barry, (ed.), *Risk Management in Agriculture.* Ames: Iowa State University Press, 1984

Spetzler, C.S. and C.-A.S. Stael von Holstein. "Probability Encoding in Decision Analysis." *Management Science.* 22(1975): 340-358.

Sposito, V.A. *Linear and Non-Linear Programming.* Ames, Iowa: Iowa State University Press, 1975.

Sri Lanka. *Economic and Social Statistics of Sri Lanka* Central Bank of Ceylon, 7(1984).

Sri Lanka. *Administrative Report of the Director* Department of Minor Export Crops, 1981.

Sri Lanka. *Highland Crops and Livestock Statistics* Department of Census and Statistics, 1980.

Sri Lanka. *The Five Year Plan 1972-76.* Sri Lanka: Ministry of Planning and Employment. 1972.

Sriramaratnam, S. "Texas Coastal Bend Grain Sorghum Producer's Fertilizer Decisions Under Uncertainty." Unpublished Ph.D. Dissertation. Texas A&M University, 1985.

Stigum, B.P., and F. Wenstop (Eds.) *Foundations of Utility and Risk Theory with Applications.* Dordrecht, Holland: D. Reidel Publishing Co., 1983.

Suppes, P., and M. Zanotti. "Necessary and Sufficient Conditions for Existence of a Unique Measure Strictly Agreeing with a Qualitative Probability Ordering." *J. Phil. Logic.* 5(1976): 431-8.

Taylor. D.B., and S.M.M. Zuhair. "Chance Constrained Programming: A Simple way to Introduce Risk in a Linear Programming Model." *J. Amer. Soc. Fm. Mang. and Rural Appraisers.* 50(1986): 43-7.

Telser, L. "Safety-First and Hedging." *Rev. econ. Stud.* 22(1955): 1-16.

Turnovsky, S.J. "Stochastic demand and the theory of the firm." Discussion Paper No. 96, Department of Economics, University of Pensylvania, Philadelphia, 1968.

Tennakoon, S.T. Personal Communication. November, 1985- February, 1986. Deputy Director/ Technical, Department of Minor-Export Crops, Peradeniya, Sri Lanka.

Theil, H. "Some Reflections on Static Programming Under Uncertainty." *Weltwirtschaft.* 87(1961): 124-38.

Thomas, W., L. Blakeslee, L. Rogers, and N. Whitlesley. "Separable Programming for Considering Risk in Farm Planning." *Amer. J. Agr. Econ.* 54(1972): 260-66.

Thomson, K.J., and P.B.R. Hazell. "Reliability of Using the Mean Absolute Deviation to Derive Efficient E-V Farm Plans." *Amer. J. Agr. Econ.* 54(1972): 503-6.

Tintner, G., and J.K. Sengupta. *Stochastic Economics: Stochastic Processes, Control, and Programming* New York: Academic Press, 1972.

Tsaing, S.C. "The Rationale of the Mean-Standard Deviation Analysis, Skewness, Preference, and Demand for Money." *Am. Econ. Rev.* 62(1972): 354-71.

Vadja, S. *Probabilistic Programming.* New York: Academic Press, 1972.

Van de Panne, C., and W. Popp. "Minimum Cost Cattle Feed under Probabilistic Protein Constraints." *Mgt. Sci.* 9(1963): 405-30.

Von Neumann, J., and O. Morgenstern. *Theory of Games and Economic Behavior.* Princeton, New Jersey: Princeton University Press, 1953.

Webster, J.P.G., and J.O.S. Kennedy. "Measuring Farmers' Trade-offs between Expected Income and Focuss-Loss Income." *Amer. J. Agr. Econ.* 57(1975): 97-105.

Westin, R.B. "Predictions from binary choice models." *Journ. of Econometrics.* 2(1974): 1-16.

Wharton, C.R. Jr., *Risk, Uncertainty, and the Subsistence Farmer: Technological Innovation and Resistance to Change in the Context of Survival.* Joint Session of the American Economic Association and Association for Comparative Economics. Chicago, December, 1968.

White, D.J. *Decision Methodology: A Formalization of the OR Process.* London: John Wiley and Sons, 1975.

Wiens, T.B. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." *Amer. J. Agr. Econ.* 58(1976): 629-635.

Wijnands, J. "Farm Planning with the Risk Crop Seed Potatoes: A Comparison and an application of Methods of Risk Programming." In C.H. Hanf and G. Schiefer (Eds.), *Consideration and Modelling of Risk in the Agribusiness Sector* Keler Wissenschaftsverlag Vauk, 1981.

Winkler, R.L. "Probabilistic Prediction: Some Experimental Results." *J. Am. Stat. Ass.* 66(1971): 675-85.

Winkler, R.L., and A.H. Murphy. "Good Probability Assessors." *Journ. App. Meterology* 7(1968): 751-58.

Winkler, R.L. "The Assessment of Prior Distributions in Bayesian Analysis." *J. Am. Stat. Ass.* 62(1967): 776-800.

Winter, S.G. "Satisficing, Selection, and the Innovative Remnant." *Quart. J. Econ.* 85(1971): 237-61

Wolgin, J.M. "Resource Allocation and Risk: A Case Study of Small-holder Agriculture in Kenya." *Amer. J. Agr. Econ.* 57(1974): 622-630.

Young, D.L. "Risk Concepts and Measures for Decision Analysis." In P.J. Barry (Ed.) *Risk Management in Agriculture.* Ames, Iowa: Iowa State University Press, 1984.

Young, D.L. "Risk Preferences of Agricultural Producers: Their Use in Extension and Research." *Amer. J. Agr. Econ.* 61(1979): 1063-1070.

Young, D., W. Lin, R. Pope, L. Robison, and R. Selly. "Risk Preferences of Agricultural Producers: Their Measurement and Use." In Risk Management in Agriculture: Behavioral, Managerial and Policy Issues, Proceedings of W-149 Seminar, 1979.

Zeckhauser, R., and E. Keeler. "Another Type of Risk Aversion." *Econometrica* 38(1970): 661-65.

Appendix A.

Survey Questionnaires

This appendix contains the two questionnaires used in the study.
Survey A was sone with 240 farmers, and
Survey B was done with 30 farmers selected at random from the 240 farmers included in the first survey.

A. GENERAL INFORMATION:

1.1. Name of grower:______________________________
1.2. Mailing address:______________________________

1.3. Family information:

Relationship to head of household	sex/ age	Education	Employment	Experience (in years) on-farm	off-farm

1.4. Tenure systems:

System	acres under each system	crops grown

2. ENTERPRISES:

2.1. Crops:

2.1.1. Acreage and yield of annuals:

Crop	Acres	Mean average yield per year (specify unit)

2.1.2. Inputs used in a year:

Input	amount (specify unit)	cost (if available)

2.1.3. Acreage and yield of perennials:

Crop	Extent Acres	No. of trees

2.1.4. Inputs used in a year:

Crop	inputs (specify unit)	Average annual cost (if available)

2.2. ANIMALS:

Type	number	Average annual cost	Average annual output	Average annual return

3. Sales:

product	How sold	proportion sold

What is your annual income for a typical year?

4. LABOR:
4.1. Give the following information on the members of the household who work on farm. Try to get approximate number of days or hours worked in a year for the amount column. Please enter the unit of measurement.

Age	Sex	Amount	Activities

4.2: Hired labor.

Do you hire any labor for farming activities? Yes / No.

4.2.1. How do you usually pay the labor you hire? (cash / kind)

4.2.2. If cash, what is the rate per hour, day: ________ day/Hour

4.2.3 If paid in kind, give the cash equivalent at the time of payment:__________ day/hour

4.3. Off farm labor:

4.3.1. If you do not have a regular off-farm employment give the following information on the number of days worked in each month

Month	Number of days/hours worked
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	
Oct	
Nov	
Dec	

4.3.2. How are you paid? cash / kind

Give the rate per hour / day: ________ / day, hour.

If in kind, give the cash equivalent at the time of payment.

4.4. Does your off-farm activities affect your harvesting activities?
If yes, how?

4.5. Does your harvesting schedules affect off-farm activities?
If yes, how?

5. CREDIT/LOAN:

Do you borrow any money for use in production or consumption?
yes/no
If yes, then answer the following for each loan/credit obtained.

Source	
Amount	
Interest rate	
Purpose	

If the interest is paid in kind give the cash equivalent at the time of payment. _________

6. HARVESTING:

6.1. Do you practice premature harvesting? yes/no
If yes, why? (Give your reasons in order of importance)

Fear of theft _____
Immediate money needs _____
____________________ _____
____________________ _____
____________________ _____
____________________ _____

6.2. Do these reasons apply equally well to all the crops? yes/no
If not, what are the differences?

6.3. Do you practice premature harvesting with all the crops? yes/no
If not, why?

6.4. Which crops do you harvest at premature stages?

6.5. If you harvest your crop at premature stages and would like to improve on the harvesting practices, what kind of assistance would you like to receive from the government? Rank them in order of importance to you.

Protection from theft. (how?)
Consumption credit.
more stricter grading regulations.

Instructions to the enumerators.

Introduce yourself, at least your name and your affiliation. Explain to each respondent, grower, that the information will be used in a study at the University to estimate the loss in income due to premature harvesting. Assure them that the information will be held confidential and will nit be used by any government official.

A. General information:

1.1. Ask the grower's name and the name by which he is known in the village.

1.2. What is important here is the farmer's residential address which will be used for subsequent visits. If the direction to his home or farm is complicated, please write down the details behind page 1 of the questionnaire.

1.3. In this table record the information for each member of the family.

Education: Record the number of years of schooling or the highest examination passed by each individual member of the household.

Employment: Record the title and the nature of the job (teacher, clerk, etc.,) and the place of work. If self employed, record the nature of work and give a rough estimate of production and, if possible, the level of income.

Experience: Record in number of years the experience of each individual on farm in farming activities and off-farm activities.

1.4. This should contain the information on the nature of tenure systems (eg.lease, rent, "Kattimaru", Thattumaru". etc.). For each specific system record the area of land and the crops grown on them.

2.ENTERPRISES:

2.1.1. Self explanatory

2.1.2. Record the information on the various inputs used in a year. For labor ask for information on own, hired, and exchange labor.

2.1.3. Record the acreage and the number of trees of each MEC grown by the farmer.

2.1.4. Record the information on the various inputs used in a year. For labor ask for information on own, hired, and exchange labor. 2.2. Animals Type: the kind of animal- cattle, buffalo, chicken, etc.

Average annual cost: Obtain an estimate of the costs incurred in a year.

Average daily output: example: bottles of milk, number of eggs, etc. Number of days of draft.

3. Sales:

How sold: To whom the product is usually sold- village merchants, town merchants, wholesale buyers, etc. Proportion sold: This refers to the proportion of the total crop sold in each category.

4. Labor:

The information under this section will be used to determine the labor supply and use within the farm. As far as possible get the information on number of hours. If this is not possible, get the information as a fraction of a day (eg. 1/2 day, 1/4 day, etc.) The activity column should contain the nature of work performed.

5. Credit/Loan: Obtain information on all forms of credit and loans the farmer has obtained during the past year, from private as well as from government institutions and banks.

6. Explain the farmer what premature harvesting is - harvesting a crop before it is fully matured. If the grower harvests even one crop before it is matured record this information. If the farmer has any reasons other than those mentioned in the questionnaire, please ask them to be very specific.

6.5. Request the grower to be very specific. For example, if they say they need protection, ask what kind of protection do they need. If they say they need money to meet their immediate needs and expenses ask them how they expect to pay back. Please DO NOT LEAD the growers to any answers. Make them think about the possible solutions.

SURVEY B

A. GENERAL INFORMATION:

1.1. Name of grower:______________________________
1.2. Mailing address:_____________________________
____
____

2. INPUTS:
2.1.2. Inputs used in a year:

Input	amount (specify unit)	cost (if available)

2.2. Inputs used for the MEC in a year:

Crop	inputs (specify unit)	Average annual cost (if available)

3. Sales:

product	How sold or bartered	proportion sold	price per unit (specify unit

4. LABOR:

4.1. Give the following information on the members of the household who work on farm. Try to get approximate number of days or hours worked in a year for the amount column. Please enter the unit of measurement.

Age	Sex	Amount	Activities

4.2.1. How do you usually pay the labor you hire? (cash / kind)

4.2.2. If cash, what is the rate per hour, day: ________ day/Hour

4.2.3 If paid in kind, give the cash equivalent at the time of payment:_________ day/hour

4.3. Off farm labor:

4.3.1. If you do not have a regular off-farm employment give the following information on the number of days worked in each month

Month	Number of days/hours worked by each member 1	2	3	4	5	6	7	8	9	10
Jan										
Feb										
Mar										
Apr										
May										
Jun										
Jul										
Aug										
Sep										
Oct										
Nov										
Dec										

4.3.2. How are you paid? cash / kind

Give the rate per hour / day: ________ / day, hour.

If in kind, give the cash equivalent at the time of payment.

4.4. Do your off-farm activities affect your harvesting activities? If yes, how?

4.5. Do your harvesting schedules affect off-farm activities?
If yes, how?

B. ELICITATION OF UTILITY FUNCTIONS

1. ELCE Method

Instructions: Present the farmer with the following choice:

Choice a. A lottery: 50% chance of winning X1
50% chance of winning X2
(one or both of these outcomes can be negative)

Choice b. A sure payment of Y1

If the farmer chooses Y1, keep decreasing Y1 until the farmer feels indifferent between the lottery and the sure payment. Indifference could be detected by signs of discomfort on the part of the farmer. If the farmer chooses the lottery, keep increasing Y1 in short steps until the farmer is indifferent. The chart provided may help you interview the farmer.
Before you ask the questions explain to the grower that this is only a hypothetical situation but the farmer should answer them as if it were real.

Question 1: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you lose X1 and if you get tails you win X2. The sure income is Y1. You have to choose only one of the two choices. Which one will you choose. (determine Y1 from this)

Question 2: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you lose X1 and if you get tails you win Y1. The sure income is Y2. You have to choose only one of the two choices. Which one will you choose. (determine Y2 from this)

Question 3: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y1 and if you get tails you win X2. The sure income is Y3. You have to choose only one of the two choices. Which one will you choose. (determine Y3 from this)

Question 4: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you lose X1 and if you get tails you win Y2. The sure income is Y4. You have to choose only one of the two choices. Which one will you choose. (determine Y4 from this)

Question 5: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y2 and if you get tails you win Y1. The sure income is Y5. You have to choose only one of the two choices. Which one will you choose. (determine Y5 from this)

Question 6: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y1 and if you get tails you win Y3. The sure income is Y6. You have to choose only one of the two choices. Which one will you choose. (determine Y6 from this)

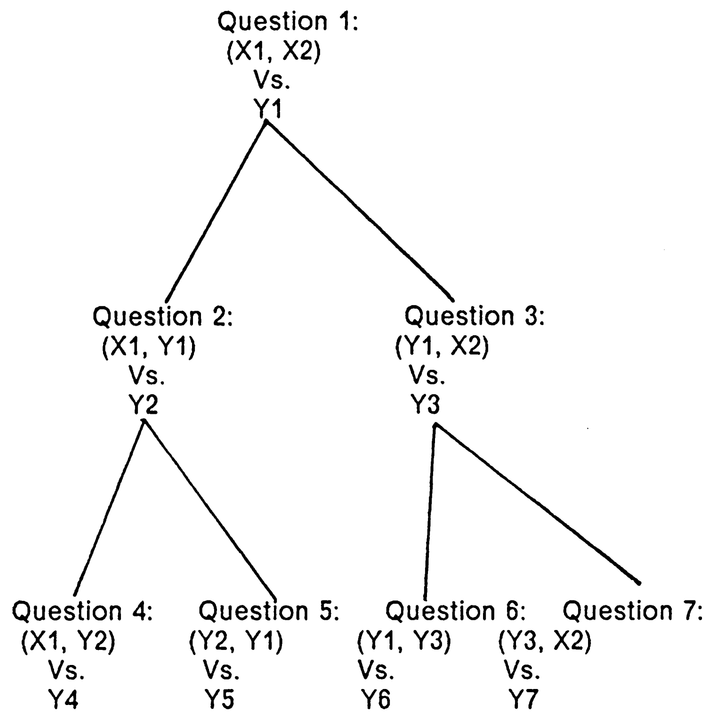
Question 7: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y3 and if you get tails you win X2. The sure income is Y7. You have to choose only one of the two choices. Which one will you chose. (determine Y7 from this)

Check questions:

Question 8: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y2 and if you get tails you win Y3. The sure income is Y1. You have to choose only one of the two choices. Which one will you choose. (The sure income to which the farmer is indifferent MUST be Y1. If not restart the procedure from question 1.)

Question 9: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y5 and if you get tails you win Y6. The sure income is Y1. You have to choose only one of the two choices. Which one will you choose. (The sure income to which the farmer is indifferent MUST be Y1. If not restart the procedure from question 1.)

Question 10: You are given a choice: Choose a lottery or a sure amount of income. The lottery is such that if you toss a coin and you get heads you win Y4 and if you get tails you win Y7. The sure income is Y1. You have to choose only one of the two choices. Which one will you choose. (The sure income to which the farmer is indifferent MUST be Y1. If not restart the procedure from question 1.)



Checks: Question 8: (Y2, Y3) = Y1
Question 9: (Y5, Y6) = Y1
Question 10: (Y4, Y7) = Y1

RESULTS: (record the results in the following table)

question number	lottery 50%	50%	sure income to which farmer is indifferent
1	X1=	X2=	Y1=
2	X1=	Y1=	Y2=
3	Y1=	X2=	Y3=
4	X1=	Y2=	Y4=
5	Y2=	Y1=	Y5=
6	Y1=	Y3=	Y6=
7	Y3=	X2=	Y7=
8	Y2=	Y3=	(?=Y1)
9	Y5=	Y6=	(?=Y1)
10	Y4=	Y7=	(?=Y1)

ELICITATION OF SUBJECTIVE PROBABILITY DISTRIBUTIONS

1. Price distributions: Mature harvest
Consider a typical year for the crop you grow. Give the price distribution during the peak season assuming you harvest the crop at the mature stage.

Crop	Best of 20 times	Most likely	Worst of 20 times
Cocoa			
Coffee			
Nutmeg			
Pepper			
Cardomom			

2. Output distributions: Mature harvest
Consider a typical year for the crop you grow. Give the output (total output for the crop from the farm) distribution during the peak season assuming you harvest the crop at the mature stage.

Crop	Best of 20 times	Most likely	Worst of 20 times
Cocoa			
Coffee			
Nutmeg			
Pepper			
Cardomom			

1. Price distributions: premature harvest
Consider a typical year for the crop you grow. Give the price distribution during the peak season assuming you harvest the crop at a premature stage.

Crop	Best of 20 times	Most likely	Worst of 20 times
Cocoa			
Coffee			
Nutmeg			
Pepper			
Cardomom			

2. Output distributions: Premature harvest

Consider a typical year for the crop you grow. Give the output (total output for the crop from the farm) distribution during the peak season assuming you harvest the crop at a premature stage.

Crop	Best of 20 times	Most likely	Worst of 20 times
Cocoa			
Coffee			
Nutmeg			
Pepper			
Cardomom			

ELICITATION OF SUBJECTIVE DISCOUNT RATES

Present the farmer with the following scenario: He faces a choice: Both are sure, no chances involved. He has to choose between two outcomes:

1. Receive X1 today or
2. Receive Y1 in a months time.

In this fix X1 and keep changing Y1 in very short steps until the farmer is indifferent, difficult to choose between, X1 and Y1. Now do the same process for a three month period, that is X1 now versus Y1 in three months period. Repeat the process for a twelve month period. Record the results in the following table:

Current payoff	future payoffs to which farmer is indifferent		
	1 month	3 months	1 year
X1=	Y1=	Y2=	Y3=

4. Information on Wealth
List the assets owned and mortgaged by you and their current market values:

Asset	Value

5. Decision Factors:

5.1. Who in your family makes decisions regarding production and harvesting of MEC's?

5.2. If more than one, who takes the leadership role in making decisions?

5.3. What factors are taken into consideration when making a production or harvesting decision?

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

5.4. What levels do you try to achieve in the above factors?

Factor	Level
1.	
2.	
3.	
4.	
5.	

5.5. How much money do you need to meet the expences of an average day?

Name of enumerator:
Date of interview:
Signature:

Appendix B

Summary Tables of Farm Family Characteristics

NOTE: The tables given in this appendix were computed by the author from primary survey data.

Table B.1: Family Characteristics

	Mean	S.D.	Min	Max
Number in family	5.19	1.96	1	10
Age of COH	54.20	8.27	32	71
Farming experience of COH	16.41	14.89	0	55
Off-farm experience of COH	8.38	11.65	0	60
Total family income	11,288.13	11,193.55	500	60,000.00
Total land	2.49	2.46	0.12	19.8
Highland	2.04	2.14	0.12	19
Lowland	1.24	2.98	0.125	8.0
Number of MEC	3.2	0.8	1	5

Sex of Chief of Household

	Frequency	Percentage
Male	215	89.6
Female	25	10.4

Education of Chief of Household

Level of education	Frequency	Percent of sample
No education	6	2.5
Less than grade 5	17	7.08
Grade 6-8	45	18.76
Grade 9-10	114	47.5
Grade 11-12	41	17.08
Grade 12 plus	12	5.0
College degree	5	2.08

Table B.2: Decision Making

Decision maker	Number reported	Percentage
Farming decisions:		
Farmer	218	90.8
Wife	16	6.7
Eldest son	6	2.5
Harvesting decisions:		
Farmer	216	90.0
Wife	17	7.1
Eldest son	7	2.9

This table gives the family member who makes decisions regarding farming activities and harvesting activities.

Table B.3: Animal hubandary:

	Frequency	Percentage	
Yes	30	12.5	
No	210	87.5	
	Cattle	Goat	Poultry
Cattle	20		
Goat	7	7	
Poultry	3	2	25

Table B.4: Labor hired for farming:

	Frequency	Percentage
Yes	87	36.25
No	153	63.75
Activities for which labor is hired		
Land preperation	59	24.5
Irrigation	6	2.5
Soil conservation	53	22.8
Fertilizer application	53	22.8
Planting	20	8.3
Weeding	46	19.17
Pruning	6	2.5

Table B.5: Harvesting of minor export crops

	Frequency	Percentage
Aware of mature stage of crops	236	98.3
Off-farm activities affect farming activities	41	17.08
Harvesting affects off-farm activities	36	15.0
Practice premature harvesting	56	23.33
Grading does not affect income	176	73.3

Table B.6: Method of disposal

	Number of responses				
Method	Cocoa	Coffee	Pepper	Cardomom	Nutmeg
On tree	2	5	8	0	1
Sell green	10	18	18	0	3
Sell dry	92	193	169	4	31
Sell graded	14	22	21	2	2
Sell ungraded	88	189	166	2	32

Appendix C

Certainty Equivalents Used to Estimate the Utility Functions

The data in this appendix were elicited from farmers by the method explained in chapter 3 of this dissertation.

Utility Index	Farmer number 19	24	26	34	35	36	38	39	40	42
0	-11600	-980	-150	-420	-710	-1700	-940	-4560	-410	-540
10	-7500	-775	150	-125	-30	-800	-100	1000	100	-100
20	450	-550	560	25	15	300	275	2500	500	50
30	1575	500	725	250	400	1000	325	4700	875	150
40	2500	1000	1200	725	725	2600	975	10000	1675	1350
50	4250	1050	1575	900	1050	3200	1350	12700	1700	1500
60	6000	1100	2050	1100	1425	4000	1800	14000	1820	1700
70	8500	1450	2500	1450	1950	4800	2100	15600	1950	2100
80	58000	4900	3000	2100	3550	8500	4700	22800	2100	2750

Utility Index	Farmer number 52	62	64	66	69	72	95	96	103	113
0	-3794	-12120	-970	-11920	-760	-1600	-240	-2000	-446	-2500
10	-1500	-8550	-200	-5500	100	2000	-100	-1000	-200	-2100
20	-1000	-5350	100	9000	1000	4250	50	100	-50	-1940
30	2500	350	150	10000	1120	4800	150	150	350	1000
40	3500	3575	300	20000	1375	5500	400	500	550	2400
50	4200	3700	875	20500	1420	7600	450	750	650	3100
60	5500	4000	1125	21000	1750	7900	600	1500	700	3800
70	7000	7500	1600	24000	2000	7950	800	2500	1000	5000
80	19000	60600	4850	59600	3800	8000	1200	10000	2200	9720

Utility Index	Farmer number 162	168	170	182	186	195	196	199	201	204
0	-50	-300	-584	-3000	-920	-200	-1120	-1790	-2500	-140
10	-10	-100	109	-1250	-100	-100	200	-1300	-500	-25
20	50	200	475	375	250	50	875	-500	350	95
30	65	700	720	1950	1000	75	1050	50	625	95
40	90	1150	950	4950	2500	150	1500	500	1500	85
50	105	1950	1600	5100	2800	300	1825	800	1975	100
60	130	2340	2250	6250	3150	425	2250	1000	2200	165
70	160	3350	2500	8270	3500	575	3000	2750	3750	225
80	325	9350	2900	15000	4600	1000	5600	9000	12800	700

[1] The values corresponding to a utility index of 80 represent farmers annual income and the those corresponding to a utility index of 0 represent a negative twenty percent of the annual income. The other values are the certainty equivalents elicited from the farmers as explained in chapters 2 and 3 of this dissertation.

Appendix D

Data Used to Estimate the Logit Function

This Appendix is in two parts.
Part I: Summary statistics of the data used for the model.
Part II: The data.

The Variables:

FMN is the farmer number;
HFMAT is the harvesting behavior, 1 = Premature, 0 = Mature;
NUM is the family size in number of units;
AGE is the age of head of the family, in years;
EDU1 is the level of education of head of the family.
Where:
EDU1 = 0 for schooling less than 6 years, and
EDU1 = 1 for schooling 6 or more years of schooling.
EXFM is the experience in farming, in years;
RLND is the ratio of lowland to total land;
NCROP is the number of minor export crops grown by the farmer; and
TTI is the farm net income, in Rupees.

Part I: Summary Statistics

Variable	Mean	Standard deviation	Min value	Max value	Std. error of mean
HFMAT	0.233333	0.42384	0.00	1.0	0.0273585
NUM	5.195833	1.96603	1.00	10.0	0.1269064
AGE	54.208333	8.27447	32.00	71.0	0.5341148
EDU	2.929167	1.07811	0.00	6.0	0.0695918
EDU1	0.07833	0.2570	0	1	3.2809
EXOFM	8.383333	11.65845	0.00	60.0	0.7525495
HLND	2.042479	2.13966	0.12	19.0	0.1381143
LLND	0.450937	1.08444	0.00	8.0	0.0700005
TLND	2.493417	2.46634	0.12	19.8	0.1592016
RLND	0.118200	0.20839	0.0	0.95	1.7630
NCROP	2.770833	0.83940	1.00	5.0	0.0541828
TTI	11288.125000	11193.54989	500.00	60000.0	722.5405387

Part II: The Data

FMN	HFMAT	NUM	AGE	EDU	EXFM	EXOFM	HLND	LLND	NCROP	TTI
1	0	7	62	2	32	0	1.25	0.00	2	5500
2	0	5	70	2	0	20	2.50	0.00	3	9000
3	0	2	52	1	0	0	0.75	0.00	3	10500
4	1	5	59	4	0	2	0.25	0.00	1	1800
5	0	5	63	3	10	5	0.25	0.00	2	8000
6	1	6	45	4	0	20	0.75	0.00	2	3500
7	0	4	47	3	15	5	0.50	0.00	2	8500
8	0	5	51	2	4	3	0.25	0.00	2	9000
9	0	5	44	2	10	0	1.00	0.00	2	5000
10	0	2	56	2	25	0	1.00	0.00	3	1000
11	0	4	48	3	5	0	0.25	0.00	2	4500
12	0	7	56	3	5	20	0.25	0.00	2	3500
13	0	3	67	4	20	3	0.12	0.00	3	7500
14	0	4	39	3	5	0	0.50	0.25	4	9000
15	0	4	33	2	5	0	0.50	0.25	4	8000
16	0	2	62	3	25	0	2.00	0.00	3	10000
17	0	6	39	1	10	0	5.00	0.50	3	15000
18	0	4	55	2	25	0	4.00	1.00	3	34500
19	0	5	58	0	30	0	6.00	1.50	3	40000
20	0	4	42	6	0	20	1.25	0.75	2	7550
21	0	2	70	3	20	0	1.00	0.00	1	3000
22	0	7	52	3	10	5	0.50	0.00	2	3500
23	0	6	60	3	15	0	1.50	0.50	2	7000
24	0	6	54	3	40	0	2.50	0.00	2	4000
25	0	4	63	3	15	0	1.05	0.00	4	6100
26	1	4	48	3	0	0	4.00	0.00	3	3000
27	1	7	59	3	0	20	2.00	1.75	3	4500
28	1	8	60	3	35	0	6.00	2.00	4	2000
29	1	6	47	4	4	15	2.25	0.50	1	1500
30	0	6	56	2	30	0	1.00	0.00	1	3000
31	0	5	67	3	0	20	1.25	0.00	2	4500
32	0	4	45	5	0	25	1.00	0.00	2	4000
33	0	5	39	2	10	15	3.00	0.00	4	10000
34	0	6	54	2	8	2	0.50	0.00	4	4500
35	0	5	56	6	0	21	0.75	0.00	4	6000
36	0	10	57	2	40	0	2.75	1.00	3	12500
37	0	7	49	3	10	23	1.50	0.25	3	7000
38	0	10	57	3	30	0	2.50	0.00	3	7500
39	0	4	43	4	10	0	7.75	0.50	4	24500
40	1	7	46	3	25	0	2.50	0.25	4	4000
41	0	2	50	4	20	0	1.00	0.00	4	6000
42	0	4	57	3	20	0	1.00	0.00	4	7500
43	1	6	54	3	40	0	1.00	0.00	2	4000
44	0	7	63	4	3	0	4.50	1.00	4	37000
45	0	5	67	5	50	0	7.75	1.00	4	43500

FMN	HFMAT	NUM	AGE	EDU	EXFM	EXOFM	HLND	LLND	NCROP	TTI
46	0	3	70	3	50	0	0.25	0.00	3	3500
47	0	8	66	3	35	0	0.75	0.00	4	5500
48	0	6	57	3	0	0	2.75	0.50	3	10500
49	0	6	46	3	20	0	1.50	0.00	4	7000
50	0	4	43	3	30	0	0.75	0.25	3	5500
51	1	4	68	3	50	0	4.00	0.25	4	8000
52	0	6	45	4	20	0	0.25	0.00	2	12000
53	0	3	56	3	20	2	2.00	1.50	3	10000
54	1	5	59	0	10	0	0.75	0.25	3	3500
55	0	10	57	1	35	0	1.50	0.00	3	6000
56	0	6	54	2	0	30	2.00	3.50	4	52000
57	0	8	59	2	25	0	0.50	0.000	3	4000
58	0	6	45	3	15	0	0.50	0.000	4	5000
59	1	5	42	3	10	0	0.50	0.250	3	1200
60	0	5	56	3	15	0	1.25	0.000	3	5500
61	0	5	57	4	0	22	4.00	0.000	4	12200
62	0	7	60	4	0	26	7.00	0.000	3	30000
63	0	5	64	2	0	22	0.50	0.250	4	6500
64	0	8	53	3	25	0	1.00	0.500	3	10000
65	0	9	54	3	35	0	5.00	0.000	3	24000
66	0	8	56	3	25	0	4.50	1.500	4	55000
67	0	5	59	2	0	20	0.50	0.000	2	7000
68	0	4	48	3	0	8	1.00	0.000	3	8500
69	0	7	51	3	8	20	0.75	0.000	3	8000
70	0	3	34	2	9	3	5.75	0.000	4	25500
71	0	10	67	2	0	30	0.30	0.000	4	4000
72	0	2	56	2	20	0	1.50	0.500	2	9000
73	0	5	58	3	10	16	0.50	0.000	2	8000
74	0	5	59	4	40	0	3.50	0.125	3	20500
75	0	4	54	3	8	35	0.75	0.000	2	9500
76	0	8	47	3	0	30	2.75	0.500	4	21000
77	0	4	64	3	55	0	1.50	0.000	3	6000
78	0	3	49	3	15	3	3.75	0.000	3	10700
79	0	5	63	2	10	17	0.75	0.000	3	4500
80	0	5	49	3	5	7	1.50	0.000	1	4200
81	0	9	59	3	0	35	2.00	0.250	3	8500
82	0	3	55	3	15	30	0.25	0.000	2	3700
83	1	8	57	1	0	20	0.25	0.000	1	600
84	1	9	53	3	0	18	0.25	0.000	4	1500
85	0	8	54	3	25	15	1.00	0.000	3	8500
86	0	5	59	3	5	40	0.75	0.000	2	7000
87	0	5	50	1	0	0	0.25	0.000	4	4500
88	0	8	52	3	30	0	0.25	0.000	1	8500
89	1	7	56	2	0	40	0.25	0.000	2	2500
90	0	5	43	4	0	10	0.25	0.000	3	9000
91	0	7	45	4	10	0	1.25	0.000	3	7500
92	0	3	64	3	25	0	1.50	1.000	3	20000
93	0	3	49	3	0	10	0.25	0.000	3	9500
94	0	10	44	3	10	0	0.50	0.000	1	8000
95	0	7	69	5	15	4	3.50	2.500	2	6000

FMN	HFMAT	NUM	AGE	EDU	EXFM	EXOFM	HLND	LLND	NCROP	TTI
96	1	4	62	3	15	0	1.00	0.500	1	5000
97	0	5	66	3	20	0	0.50	0.000	2	3500
98	0	6	59	3	15	0	1.00	0.000	4	8000
99	1	3	70	1	30	0	3.00	0.000	3	4000
100	0	2	55	1	30	0	5.00	0.000	2	22000
101	0	4	63	4	30	0	2.00	2.500	3	38000
102	0	5	44	4	0	1	2.50	0.000	2	11000
103	0	6	46	3	25	0	1.00	0.000	2	7000
104	0	6	52	4	0	20	7.50	1.250	2	22500
105	0	3	54	4	0	24	2.50	0.000	4	10000
106	0	2	34	4	0	12	5.00	0.000	2	12000
107	0	3	45	4	10	0	1.25	0.000	2	8500
108	0	8	49	2	15	0	2.00	2.000	4	16000
109	0	9	54	3	15	0	5.00	0.000	1	11000
110	0	6	50	3	15	0	2.50	0.000	2	8000
111	0	3	64	3	30	0	1.00	0.000	2	4000
112	0	3	45	4	0	4	1.00	0.000	2	4500
113	0	6	55	3	20	0	2.000	5.00	3	9000
114	0	5	49	3	30	0	2.500	0.00	3	8000
115	0	5	54	4	0	20	3.000	0.00	4	40000
116	0	3	47	3	15	0	1.500	0.00	4	7000
117	0	2	68	2	40	0	3.500	0.00	3	10000
118	0	3	43	3	10	0	3.000	1.00	3	35000
119	0	10	67	3	55	0	3.000	5.00	3	60000
120	1	4	63	3	20	17	2.000	0.00	2	4000
121	0	3	49	5	0	28	1.500	0.00	4	8000
122	0	7	44	3	10	12	2.000	0.00	1	7500
123	0	6	58	4	10	0	4.500	0.00	2	12000
124	1	4	46	1	8	12	0.500	0.00	3	4000
125	0	3	67	3	40	0	3.000	0.00	3	18000
126	0	6	56	2	15	0	3.000	0.00	3	15000
127	0	3	52	4	4	8	2.000	0.00	3	9000
128	0	8	60	4	0	30	1.500	0.50	3	10000
129	0	5	45	5	0	25	3.000	0.00	3	12500
130	0	5	56	4	0	26	3.000	0.00	3	15000
131	1	5	53	4	1	35	3.500	0.00	3	4500
132	0	6	52	3	25	0	1.500	1.50	3	22000
133	0	4	57	0	40	0	2.750	0.25	3	9500
134	0	4	65	2	50	0	3.000	0.00	2	8000
135	0	3	58	3	15	15	0.800	0.00	3	7500
136	0	6	55	2	0	35	0.250	0.00	2	9000
137	1	6	52	3	0	0	0.250	0.75	2	3500
138	0	4	51	2	4	4	0.600	0.00	2	8500
139	0	4	58	2	20	20	0.750	0.25	3	16000
140	0	6	59	3	1	20	1.000	0.00	3	7000
141	0	3	63	1	40	0	0.500	0.25	3	9000
142	0	10	45	5	1	30	1.250	0.50	4	12500
143	0	4	34	4	15	15	5.000	0.50	3	25000
144	0	8	48	2	15	15	2.000	1.00	3	32000
145	0	8	56	2	10	25	0.250	0.00	3	7500

FMN	HFMAT	NUM	AGE	EDU	EXFM	EXOFM	HLND	LLND	NCROP	TTI
146	0	4	51	0	10	20	7.500	0.00	2	18500
147	0	3	54	1	20	10	2.500	0.00	2	9000
148	1	6	58	1	15	10	1.000	0.25	3	12000
149	0	9	59	2	40	0	0.500	1.00	3	18000
150	0	7	60	3	15	15	0.125	0.00	3	9000
151	0	6	61	3	20	0	0.750	0.50	3	15000
152	0	5	43	2	15	0	2.000	0.00	2	12000
153	0	5	49	4	0	8	0.750	0.00	2	9000
154	0	6	58	3	10	0	0.500	0.00	2	8000
155	0	5	48	5	0	10	0.500	0.00	3	7500
156	0	4	50	4	6	0	0.250	0.00	2	6500
157	0	6	60	3	15	0	0.750	0.00	2	10500
158	0	6	49	5	0	15	0.500	1.50	3	20000
159	0	6	68	2	20	0	0.750	0.00	2	8500
160	0	4	56	3	10	0	0.500	0.00	2	9000
161	0	3	47	4	15	0	2.000	0.00	2	9000
162	0	3	64	2	35	0	0.500	0.00	2	6500
163	0	3	69	3	20	0	1.000	0.00	3	5000
164	1	4	56	4	0	12	2.000	5.00	3	4500
165	0	5	59	3	20	0	1.500	0.00	3	9000
166	0	5	53	3	15	0	2.500	0.00	3	15000
167	0	5	56	4	0	24	1.000	0.00	3	15000
168	0	2	53	3	30	0	4.000	0.00	3	11000
169	0	1	67	2	30	0	0.75	0.00	3	9500
170	0	7	63	2	30	0	5.00	0.00	3	10000
171	0	5	49	4	0	16	2.00	5.00	2	26000
172	0	5	70	3	40	0	1.00	5.00	1	24000
173	0	5	45	3	15	31	0.75	0.00	3	16000
174	0	8	49	3	0	17	2.00	5.00	2	30000
175	0	3	64	3	20	0	0.75	0.00	3	6000
176	1	4	59	3	20	0	2.50	0.25	3	5000
177	0	7	57	3	3	4	0.50	0.00	2	18000
178	0	7	57	3	5	25	2.75	0.75	2	22000
179	0	4	62	2	35	0	1.50	1.00	3	10000
180	1	6	54	3	15	19	5.00	0.30	4	500
181	0	9	71	3	10	30	1.50	0.50	3	18000
182	1	6	63	4	10	30	0.50	2.00	3	12000
183	1	4	56	1	10	0	2.00	0.00	3	5000
184	1	4	52	3	35	0	2.50	0.00	3	4000
185	1	8	54	2	10	4	1.75	0.00	3	2500
186	1	6	53	2	20	5	3.00	0.25	3	7500
187	0	5	57	4	8	34	11.00	0.00	3	45000
188	1	4	59	3	15	7	1.00	0.00	2	4000
189	1	4	51	2	8	4	4.00	0.00	3	1500
190	1	3	64	3	10	25	8.00	0.00	3	6000
191	0	4	46	3	0	3	2.25	0.50	2	10000
192	0	2	61	1	30	0	1.25	1.00	2	9000
193	0	6	53	4	0	20	2.00	0.00	3	12000
194	0	6	54	3	7	27	1.00	1.00	3	9000
195	0	5	57	3	4	30	2.50	1.50	3	9000

FMN	HFMAT	NUM	AGE	EDU	EXFM	EXOFM	HLND	LLND	NCROP	TTI
196	0	5	45	3	10	0	5.00	0.00	2	10000
197	0	3	43	3	40	0	3.00	1.50	4	16000
198	0	2	56	4	50	0	3.00	0.75	3	24000
199	0	5	67	4	26	53	8.00	0.00	2	12000
200	1	8	52	2	20	28	4.75	0.75	3	6000
201	1	7	47	1	15	0	0.50	0.00	3	12000
202	0	8	54	3	40	0	2.00	3.00	5	60000
203	0	4	63	2	40	0	3.50	0.00	3	20000
204	1	7	64	3	50	0	5.00	0.00	3	3000
205	0	3	47	3	30	0	4.75	0.50	4	25000
206	0	5	61	3	30	0	1.50	0.50	2	9000
207	0	7	49	3	30	0	1.00	0.25	3	10000
208	0	4	34	4	0	15	1.50	0.25	2	6000
209	1	3	38	6	0	12	2.00	8.00	5	2500
210	0	5	54	4	0	10	0.75	0.00	2	9000
211	1	5	42	6	0	30	1.00	1.00	2	6000
212	1	6	57	3	0	18	0.25	0.00	3	3000
213	1	4	43	3	30	0	0.25	5.00	2	2500
214	1	2	65	2	50	0	2.75	1.50	3	4500
215	0	3	68	2	20	0	2.00	0.00	2	15000
216	1	6	54	3	30	10	0.20	0.00	2	2000
217	0	4	32	3	15	1	1.25	0.00	1	9000
218	0	2	46	3	10	0	0.25	0.00	1	7500
219	0	3	37	3	0	10	0.50	1.00	3	12000
220	0	5	63	3	50	0	19.00	0.80	3	45000
221	1	4	46	2	20	5	3.00	0.25	1	2000
222	0	8	51	2	15	12	1.00	0.00	3	9000
223	0	6	47	4	14	1	1.00	0.25	3	18000
224	1	10	58	2	35	0	5.00	0.25	3	4000
225	1	8	59	4	40	0	0.25	0.25	3	4500
226	0	5	56	3	0	20	1.00	0.00	3	7500
227	0	4	45	1	25	0	5.00	0.25	3	35000
228	1	8	63	3	0	5	2.50	0.00	3	6000
229	1	8	67	2	40	0	1.50	0.00	4	4500
230	0	4	48	3	30	0	0.50	0.00	3	12000
231	1	4	54	2	0	20	5.00	0.00	4	4000
232	1	4	43	1	15	8	5.50	0.50	4	6000
233	1	3	57	5	10	0	0.25	0.00	4	4500
234	1	4	47	1	30	0	1.00	0.00	4	3000
235	1	7	53	6	23	6	1.00	0.00	4	4000
236	1	3	59	5	0	25	0.25	0.00	2	2000
237	1	6	42	3	30	0	0.25	0.00	2	2500
238	1	3	63	3	45	0	0.50	0.00	2	3000
239	1	5	47	3	10	8	0.50	0.00	2	1500
240	1	4	54	3	15	10	0.25	0.00	3	2400

Appendix E

Farm Budgets and Elicited Price and Output Distributions

This Appendix first presents the summary of costs, incomes, wealth and minimum income required to meet the expenses of a typical month followed by their summary statistics. In the second section, the various components of the budget are given for each farmer.

The net income reported by the farmers in the first survey were different from that reported in the second survey. Specifically, farmers with a lower income levels reported a higher income on the first survey and a lower income in the detailed second survey. Farmers with high income levels reported a lower net income in the first survey and a higher income in the second survey. Both income levels are presented in the respective budgets.

Key to Variables:

FMNO is the farmer number;
TC is the total cost;
INMEC is the total income from minor export crops;
OTHER is the income from other sources;
TI is the farm total income;
NI(1) is the farm net income, as reported in the first survey;
NI(2) is the farm net income, as reported in the second survey;
MREQ is the amount of money required to meet the monthly expences; and
WELTH is the wealth owned by the farmer, in thousand Rupees.

Key to other abbreviations:

Rs. = Sri Lankan Rupees, the local currency;
kg. = Kilograms;
Bu. = Bushels;
MEC = Minor export crop;
MH = Mature Harvest; and
PH = Premature Harvest.

Budget summary

FMNO	TC	INMEC	OTHER	TI	NI(1)	NI(2)	MREQ	WELTH
19	3725	35100	27375	62475	40000	58750	1500	2000
24	1690	1250	5362	6612	4000	4922	1200	400
26	4415	3030	4375	7405	3000	2990	900	110
34	1800	1350	2540	3890	4500	2090	400	60
35	350	1400	2500	3900	6000	3550	600	50
36	1620	6720	3400	10120	12500	8500	1500	350
38	2600	600	6700	7300	7500	4700	1000	120
39	7700	6500	23975	30475	25000	22775	2250	200
40	1590	1200	2490	0	4000	3690	2100	800
42	920	1960	1700	3660	7500	2740	750	45
52	0	985	18000	18985	15000	18985	1500	50
62	15900	56500	20000	76500	50000	60600	1500	500
64	4600	1450	8000	9450	10000	4850	1000	250
66	71420	17000	114000	131000	55000	59580	3000	1520
69	0	200	3600	3800	8000	3800	1200	75
72	0	5190	2800	7990	9000	7990	1500	105
95	0	1250	0	1250	6000	1250	900	130
96	2575	11920	670	12590	5000	10015	1400	255
103	0	1900	300	2200	7000	2200	450	75
113	4900	720	13900	14620	9000	9720	1000	500
162	0	140	185	325	6500	325	450	200
168	2800	950	11200	12150	11000	9350	900	600
170	480	3400	0	3400	10000	2920	900	150
182	2555	3800	13750	17550	12000	14995	1200	400
186	3500	5050	3050	8100	7500	4600	1000	100
195	1170	1520	650	2170	9000	1000	750	675
196	0	2100	3500	5600	10000	5600	900	100
199	3010	1200	10750	11950	12000	8940	900	420
201	350	9500	3640	13140	12000	12790	1000	400
204	0	712	0	712	3000	712	600	45

Summary statistics

Variable	Mean	Standard deviation	Minimum value	Maximum value	Std. error of mean	C.V.[1]
TC	4655.66	13004.25	0.00	71420.00	2374.24	279.32
INMEC	6153.23	11765.13	140.00	56500.00	2148.01	191.20
OTHER	10280.40	20962.69	0.00	114000.00	3827.24	203.90
TI	16310.63	27514.00	0.00	131000.00	5023.34	168.68
NI(1)	13778.47	18933.57	712.00	60600.00	3456.78	137.41
NI(2)	12700.00	12971.85	3000.00	55000.00	2368.53	102.16
MREQ	1180.00	858.38	250.00	4500.00	156.72	72.74
WELTH	356.17	438.16	45.00	2000.00	79.99	23.02

[1] Coefficient of variation

Farmer number: 19

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			2,200.00		
Chemicals			1,250.00		
Labor			275.00		
Total cost:					3,725.00
INCOME:					
Cocoa (kg)	250	85.00	21,250.00		
Coffee (kg)	20	80.00	1,600.00		
Pepper (kg)	350	35.00	12,250.00		
Rice (Bu)	300	85.00	25,500.00		
Coconut	300	1.25	375.00		
Arecanut	15000	0.10	1,500.00		
Total income from MEC:				*35,100.00*	
Total income from other sources:				*27,375.00*	
Total income:					62,475.00
FARM NET INCOME:					***58,750.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	100.00	40.00	30.00	260	200	120
	Coffee	100.00	60.00	20.00	20	14	10
	Pepper	60.00	40.00	25.00	360	200	90
PH	Cocoa	60.00	20.00	10.00	200	150	50
	Coffee	50.00	30.00	20.00	15	10	5
	Pepper	40.00	20.00	5.00	300	150	60

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs. 40,000.00
Total wealth: Rs.2,000,000.00
Monthly minimum requirement for subsistence: Rs.1,500.00

Farmer number: 24

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			230.00		
Chemicals			100.00		
Labor			1,360.00		
Total cost:					1,690.00
INCOME:					
Coffee (kg)	25	50.00	1,250.00		
Rice (Bu)	70	70.00	4,900.00		
Coconut	600	0.75	450.00		
Arecanut	300	0.04	12.00		
Total income from MEC:				*1,250.00*	
Total income from other sources:				*5,362.00*	
Total income:					6,612.00
FARM NET INCOME:					***4,922.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)*			***Output** (kg)*		
		Best of 20 times	Most likely	Worst of 20 times	Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	56.00	42.00	32.00	30	22	20
PH	Coffee	40.00	30.00	20.00	20	10	5

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.4,000.00
Total wealth: Rs.400,000.00
Monthly minimum requirement for subsistence: Rs.1,200.00

Farmer number: 26

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,350.00		
Chemicals			65.00		
Labor			2000.00		
Organic manure			1000.00		
Total cost:					4,415.00
INCOME:					
Cocoa (kg)	35	50.00	1,750.00		
Coffee (kg)	5	60.00	300.00		
Pepper (kg)	14	70.00	980.00		
Rice (Bu)	60	70.00	4,200.00		
Other			175.00		
Total income from MEC:				*3,030.00*	
Total income from other sources:				*4,375.00*	
Total income:					7,405.00
FARM NET INCOME:					***2,990.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	70.00	35.00	20.00	60	25	5
	Coffee	100.00	60.00	30.00	10	6	2
	Pepper	100.00	60.00	20.00	20	10	5
PH	Cocoa	60.00	30.00	10.00	50	30	15
	Coffee	80.00	50.00	30.00	20	15	10
	Pepper	80.00	60.00	20.00	16	10	5

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.3,000.00
Total wealth: Rs.110,000.00
Monthly minimum requirement for subsistence: Rs.900.00

Farmer number: 34

	Quantity	Unit price	Total		
COSTS:					
Labor			1,800.00		
Total cost:					1,800.00
INCOME:					
Coffee (kg)	60	7.50	450.00		
Pepper (kg)	90	10.00	900.00		
Off-farm			1,540.00		
Other			1,000.00		
Total income from MEC:				*1,350.00*	
Total income from other sources:				*2,540.00*	
Total income:					3,890.00
FARM NET INCOME:					***2,090.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	15.00	10.00	3.50	70	50	20
	Pepper	20.00	12.00	5.50	80	50	30
PH	Coffee	10.00	5.00	2.00	70	45	25
	Pepper	15.00	10.00	7.00	70	40	25

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.4,500.00
Total wealth: Rs.60,000.00
Monthly minimum requirement for subsistence: Rs.600.00

Farmer number: 35

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			200.00		
Chemicals			150.00		
Total cost:					350.00
INCOME:					
Coffee (kg)	12	50.00	600.00		
Pepper (kg)	(leased out)		800.00		
Off-farm			1,500.00		
Other			1,000.00		
Total income from MEC:				*1,400.00*	
Total income from other sources:				*2,500.00*	
Total income:					3,900.00
FARM NET INCOME:					***3,550.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	60.00	30.00	12.00	15	7	3
PH	Coffee	40.00	25.00	10.00	10	6	2

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.6,000.00
Total wealth: Rs.50,000.00
Monthly minimum requirement for subsistence: Rs.600.00

Farmer number: 36

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			130.00		
Chemicals			200.00		
Labor			1200.00		
Organic manure			90.00		
Total cost:					1,620.00
INCOME:					
Coffee (kg)	120	6.00	720.00		
Pepper (kg) (leased out)			6,000.00		
Rice (Bu)	50	60.00	3,000.00		
Other			400.00		
Total income from MEC:				*6,720.00*	
Total income from other sources:				*3,400.00*	
Total income:					10,120.00
FARM NET INCOME:					***8,500.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	140.00	100.00	60.00	10	5	2
PH	Coffee	100.00	60.00	45.00	8	4	1

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.12,500.00
Total wealth: Rs.350,000.00
Monthly minimum requirement for subsistence: Rs.1,200.00

Farmer number: 38

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,000.00		
Chemicals			600.00		
Labor			1,000.00		
Total cost:					2,600.00
INCOME:					
Coffee (kg)	15	40.00	600.00		
Rice (Bu)	50	70.00	3,500.00		
Cloves (kg)	20	160.00	3,200.00		
Total income from MEC:				*600.00*	
Total income from other sources:				*6,700.00*	
Total income:					7,300.00
FARM NET INCOME:					***4,700.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	40.00	20.00	7.00	20	15	5
PH	Coffee	30.00	15.00	5.00	15	10	2

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.7,500.00
Total wealth: Rs.120,000.00
Monthly minimum requirement for subsistence: Rs.1000.00

Farmer number: 39

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			800.00		
Chemicals			6,900.00		
Total cost:					7,700.00
INCOME:					
Coffee (kg)	50	40.00	2,000.00		
Pepper (kg)	45	100.00	4,500.00		
Cloves (kg)	60	150.00	9,000.00		
Rice (Bu)	50	70.00	3,500.00		
Tea (Kg)	3000	3.80	11,400.00		
Arecanut (nuts)	1500	0.05	75.00		
Total income from MEC:				*6,500.00*	
Total income from other sources:				*23,975.00*	
Total income:					30,475.00
FARM NET INCOME:					***22,775.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	60.00	40.00	25.00	60	45	15
	Pepper	100.00	65.00	40.00	50	30	20
PH	Coffee	45.00	25.00	10.00	50	30	15
	Pepper	70.00	40.00	20.00	35	20	15

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.25,000.00
Total wealth: Rs.200,000.00
Monthly minimum requirement for subsistence: Rs.2,250.00

Farmer number: 40

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			640.00		
Chemicals			100.00		
Labor			850.00		
Total cost:					1,590.00
INCOME:					
Cocoa (kg)	20	30.00	600.00		
Coffee (kg)	10	60.00	600.00		
Rice (Bu)	15	65.00	975.00		
Tea (kg)	120	2.50	300.00		
Arecanut (nuts)	5000	0.04	200.00		
Banana			800.00		
Other			215.00		
Total income from MEC:				*1,200.00*	
Total income from other sources:				*2,490.00*	
Total income:					3,690.00
FARM NET INCOME:					***2,100.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	80.00	60.00	45.00	30	20	15
	Coffee	100.00	75.00	40.00	20	15	8
PH	Cocoa	40.00	32.00	30.00	25	15	10
	Coffee	80.00	60.00	35.00	12	8	6

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.4,000.00
Total wealth: Rs.200,000.00
Monthly minimum requirement for subsistence: Rs.2100.00

Farmer number: 42

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			60.00		
Labor			860.00		
Total cost:					920.00
INCOME:					
Coffee (kg)	8	20.00	160.00		
Pepper (kg)	60	30.00	1,800.00		
Off-farm			1,700.00		
Total income from MEC:				*1,960.00*	
Total income from other sources:				*1,700.00*	
Total income:					3,660.00
FARM NET INCOME:					***2,740.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	30.00	20.00	8.00	15	10	4
	Pepper	50.00	30.00	8.00	75	40	20
PH	Coffee	20.00	10.00	5.00	10	8	4
	Pepper	40.00	25.00	5.00	60	30	10

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.7,500.00
Total wealth: Rs.45,000.00
Monthly minimum requirement for subsistence: Rs.750.00

Farmer number: 52

	Quantity	Unit price	Total		
COSTS:					
(Did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	7	55.00	385.00		
Pepper (kg)	10	60.00	600.00		
Off-farm (pension)			12,000.00		
Off-farm (allowance from son)			6,000.00		
Total income from MEC:				*985.00*	
Total income from other sources:				*18,000.00*	
Total income:					18,985.00
FARM NET INCOME:					***18,985.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	55.00	30.00	20.00	7	3	1
	Pepper	60.00	55.00	50.00	10	6	2
PH	Coffee	35.00	20.00	10.00	5	2	1
	Pepper	40.00	35.00	25.00	8	6	2

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.15,000.00
Total wealth: Rs.50,000.00
Monthly minimum requirement for subsistence: Rs.1,500.00

Farmer number: 62

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			4,000.00		
Labor			7,500.00		
Organic manure			4,400.00		
Total cost:					15,900.00
INCOME:					
Cocoa (kg)	60	50.00	3,000.00		
Coffee (kg)	50	70.00	3,500.00		
Pepper (kg)	500	100.00	50,000.00		
Off-farm (business)			20,000.00		
Total income from MEC:				*56,500.00*	
Total income from other sources:				*20,000.00*	
Total income:					76,500.00
FARM NET INCOME:					***60,600.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	60.00	40.00	30.00	75	50	20
	Coffee	75.00	60.00	30.00	50	40	10
	Pepper	100.00	90.00	40.00	600	400	200
PH	Cocoa	50.00	35.00	25.00	60	40	20
	Coffee	60.00	40.00	25.00	30	20	15
	Pepper	75.00	50.00	30.00	450	300	200

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.50,000.00
Total wealth: Rs.500,000.00
Monthly minimum requirement for subsistence: Rs.4,500.00

Farmer number: 64

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			800.00		
Chemicals			400.00		
Labor			1000.00		
Equipment rental			2,400.00		
Total cost:					4,600.00
INCOME:					
Coffee (kg)	10	75.00	750.00		
Pepper (kg)	10	70.00	700.00		
Vegetables			8,000.00		
Total income from MEC:				*1,450.00*	
Total income from other sources:				*8,000.00*	
Total income:					9,450.00
FARM NET INCOME:					***4,850.00***

Price and Output Distributions:

	Crop	***Price*** *(Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output*** *(kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	90.00	75.00	15.00	12	8	4
	Pepper	80.00	60.00	20.00	15	10	5
PH	Coffee	60.00	45.00	10.00	8	4	2
	Pepper	50.00	30.00	15.00	12	10	5

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.10,000.00
Total wealth: Rs.250,000.00
Monthly minimum requirement for subsistence: Rs.1,000.00

Farmer number: 66

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			35,020.00		
Chemicals			8,000.00		
Labor			22,400.00		
Equipment rental			4,000.00		
Other			3,000.00		
Total cost:					71,420.00
INCOME:					
Coffee (kg)	200	65.00	13,000.00		
Pepper (kg)	50	80.00	4,000.00		
Tobbacco (kg)	3300	30.00	99,000.00		
Vegetables			12,000.00		
Other			3,500.00		
Total income from MEC:				*17,000.00*	
Total income from other sources:				*114,000.00*	
Total income:					131,000.00
FARM NET INCOME:					***59,580.00***

Price and Output Distributions:

	Crop	***Price*** *(Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output*** *(kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	80.00	60.00	20.00	200	100	10
	Pepper	90.00	60.00	40.00	60	40	10
PH	Coffee	60.00	45.00	20.00	150	80	10
	Pepper	75.00	50.00	30.00	50	30	10

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.55,000.00
Total wealth: Rs.1,520,000.00
Monthly minimum requirement for subsistence: Rs.3000.00

Farmer number: 69

	Quantity	Unit price	Total		
COSTS:					
(did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	1	40.00	40.00		
Pepper (kg)	4	40.00	160.00		
Off-farm			3,600.00		
Total income from MEC:				*200.00*	
Total income from other sources:				*3,600.00*	
Total income:					3,800.00
FARM NET INCOME:					***3,800.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	50.00	30.00	10.00	1	0.5	0
	Pepper	60.00	30.00	20.00	6	4	2
PH	Coffee	30.00	20.00	10.00	1	0.5	0
	Pepper	45.00	25.00	15.00	5	3	2

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.8,000.00
Total wealth: Rs.75,000.00
Monthly minimum requirement for subsistence: Rs.1200.00

Farmer number: 72

	Quantity	Unit price	Total		
COSTS:					
(did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	25	150.00	3750.00		
Pepper (kg)	32	45.00	1,440.00		
Rice (Bu)	40	70.00	2,800.00		
Total income from MEC:				*5,190.00*	
Total income from other sources:				*2,800.00*	
Total income:					7,990.00
FARM NET INCOME:					***7,990.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	180.00	120.00	50.00	30	15	5
	Pepper	60.00	45.00	30.00	40	25	10
PH	Coffee	100.00	75.00	50.00	25	10	5
	Pepper	50.00	30.00	10.00	30	20	10

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.9,000.00
Total wealth: Rs.105,000.00
Monthly minimum requirement for subsistence: Rs.1500.00

Farmer number: 95

	Quantity	Unit price	Total		
COSTS:					
(Did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	15	75.00	1,050.00		
Pepper (kg)	5	40.00	200.00		
Total income from MEC:				*1,250.00*	
Total income from other sources:				*00.00*	
Total income:					1,250.00
FARM NET INCOME:					***1,250.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	80.00	55.00	40.00	19	10	3
	Pepper	50.00	35.00	20.00	8	4	1
PH	Coffee	60.00	45.00	30.00	15	8	3
	Pepper	40.00	30.00	10.00	6	4	1

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.6,000.00
Total wealth: Rs.130,000.00
Monthly minimum requirement for subsistence: Rs.600.00

Farmer number: 96

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,575.00		
Labor			1,000.00		
Total cost:					2,575.00
INCOME:					
Coffee (kg)	8	90.00	720.00		
Pepper (kg)	100	112.00	11,200.00		
Rice (Bu)	10	67.00	670.00		
Total income from MEC:				*11,920.00*	
Total income from other sources:				*670.00*	
Total income:					12,590.00
FARM NET INCOME:					***10,015.00***

Price and Output Distributions:

	Crop	***Price (Rs.)*** Best of 20 times	Most likely	Worst of 20 times	***Output (kg)*** Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	120.00	75.00	10.00	5	3	2
	Pepper	130.00	70.00	40.00	100	60	30
PH	Coffee	90.00	40.00	20.00	10	5	4
	Pepper	115.00	45.00	20.00	125	70	40

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.5,000.00
Total wealth: Rs.255,000.00
Monthly minimum requirement for subsistence: Rs.1400.00

Farmer number: 103

	Quantity	Unit price	Total		
COSTS:					
(did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	10	50.00	500.00		
Pepper (kg)	20	70.00	1,400.00		
Other			300.00		
Total income from MEC:				*1,900.00*	
Total income from other sources:				*300.00*	
Total income:					2,200.00
FARM NET INCOME:					***2,200.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	60.00	40.00	10.00	15	5	1
	Pepper	80.00	50.00	30.00	25	20	15
PH	Coffee	45.00	43.00	10.00	10	5	1
	Pepper	60.00	45.00	20.00	20	15	10

Observed behavior: Mature harvest
Net income reported in the first survey: Rs.7,000.00
Total wealth: Rs.75,000.00
Monthly minimum requirement for subsistence: Rs.450.00

Farmer number: 113

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,500.00		
Chemicals			1,150.00		
Labor			2,250.00		
Total cost:					4,900.00
INCOME:					
Cocoa (kg)	8	40.00	320.00		
Coffee (kg)	50	80.00	400.00		
Rice (Bu)	70	70.00	4,900.00		
Coconut (nuts)	3500		3,000.00		
Off-farm (pension)			6,000.00		
Total income from MEC:				*720.00*	
Total income from other sources:				*13,900.00*	
Total income:					14,620.00
FARM NET INCOME:					***9,720.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	50.00	25.00	15.00	8	3	1
	Coffee	80.00	25.00	15.00	50	30	20
PH	Cocoa	40.00	20.00	10.00	6	3	1
	Coffee	60.00	40.00	10.00	40	20	10

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.9,000.00
Total wealth: Rs.500,000.00
Monthly minimum requirement for subsistence: Rs.1000.00

Farmer number: 162

	Quantity	Unit price	Total		
COSTS:					
(did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	5	28.00	140.00		
Coconut (nuts)	90	2.00	180.00		
Arecanut (nuts)	500	0.01	5.00		
Total income from MEC:				*140.00*	
Total income from other sources:				*185.00*	
Total income:					325.00
FARM NET INCOME:					***325.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	30.00	25.00	16.00	6	4	2
PH	Coffee	20.00	15.00	10.00	4	3	1

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.6,500.00
Total wealth: Rs.200,000.00
Monthly minimum requirement for subsistence: Rs.600.00

Farmer number: 168

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,000.00		
Labor			1,800.00		
Total cost:					2,800.00
INCOME:					
Cocoa (kg)	15	30.00	450.00		
Coffee (kg)	14	35.00	500.00		
Rice (Bu)	120	50.00	6,000.00		
Coconut (nuts)	5000	1.00	5,000.00		
Arecanut (nuts)	20000	0.01	200.00		
Total income from MEC:				*950.00*	
Total income from other sources:				*11,200.00*	
Total income:					12,150.00
FARM NET INCOME:					***9,350.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	40.00	25.00	20.00	16	15	8
	Coffee	45.00	35.00	20.00	18	10	7
PH	Cocoa	30.00	20.00	15.00	10	8	6
	Coffee	30.00	25.00	20.00	15	8	6

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.11,000.00
Total wealth: Rs.600,000.00
Monthly minimum requirement for subsistence: Rs.900.00

Farmer number: 170

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			425.00		
Chemicals			55.00		
Total cost:					480.00
INCOME:					
Cocoa (kg)	40	35.00	1,400.00		
Coffee (kg)	20	65.00	1,300.00		
Pepper (kg)	10	70.00	700.00		
Total income from MEC:				*3,400.00*	
Total income from other sources:				*00.00*	
Total income:					3,400.00
FARM NET INCOME:					***2,920.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	50.00	30.00	25.00	50	40	20
	Coffee	86.00	65.00	37.00	30	10	2
	Pepper	94.00	85.00	45.00	15	10	2
PH	Cocoa	30.00	20.00	15.00	30	20	15
	Coffee	60.00	45.00	30.00	20	10	2
	Pepper	80.00	65.00	40.00	10	8	2

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs. 10,000.00
Total wealth: Rs.150,000.00
Monthly minimum requirement for subsistence: Rs.900.00

Farmer number: 182

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			155.00		
Chemicals			60.00		
Labor			2,340.00		
Total cost:					2,555.00
INCOME:					
Cocoa (kg)	10	30.00	300.00		
Coffee (kg)	20	70.00	1,400.00		
Pepper (kg)	60	35.00	2,100.00		
Rice (Bu)	25	70.00	1,750.00		
Off-farm (pension)			12,000.00		
Total income from MEC:				*3,800.00*	
Total income from other sources:				*13,750.00*	
Total income:					17,550.00
FARM NET INCOME:					***14,995.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	60.00	40.00	15.00	15	8	2
	Coffee	100.00	60.00	40.00	45	30	20
	Pepper	60.00	40.00	25.00	100	60	35
PH	Cocoa	40.00	30.00	25.00	10	6	2
	Coffee	80.00	35.00	30.00	25	15	10
	Pepper	40.00	35.00	27.00	80	50	35

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.12,000.00
Total wealth: Rs.400,000.00
Monthly minimum requirement for subsistence: Rs.1,200.00

Farmer number: 186

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,400.00		
Chemicals			40.00		
Labor			2,000.00		
Other			60.00		
Total cost:					3,500.00
INCOME:					
Cocoa (kg)	200	20.00	4,000.00		
Coffee (kg)	30	35.00	1,050.00		
Rice (Bu)	15	70.00	1,050.00		
Off-farm (labor)			2,000.00		
Total income from MEC:				*5,050.00*	
Total income from other sources:				*3,050.00*	
Total income:					8,100.00
FARM NET INCOME:					***4,600.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	60.00	40.00	15.00	250	150	70
	Coffee	80.00	40.00	30.00	60	30	10
PH	Cocoa	40.00	25.00	15.00	200	120	70
	Coffee	55.00	35.00	20.00	50	30	5

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.7,500.00
Total wealth: Rs.100,000.00
Monthly minimum requirement for subsistence: Rs.1000.00

Farmer number: 195

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			150.00		
Chemicals			120.00		
Labor			900.00		
Total cost:					1,170.00
INCOME:					
Coffee (kg)	7	60.00	420.00		
Pepper (kg)	10	11.00	1,100.00		
Off-farm (labor)			650.00		
Total income from MEC:				*1,520.00*	
Total income from other sources:				*650.00*	
Total income:					2,170.00
FARM NET INCOME:					***1,000.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	70.00	50.00	30.00	8	6	4
	Pepper	120.00	80.00	50.00	15	8	4
PH	Coffee	50.00	35.00	20.00	6	4	2
	Pepper	80.00	60.00	45.00	12	5	4

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.9,000.00
Total wealth: Rs.675,000.00
Monthly minimum requirement for subsistence: Rs.750.00

Farmer number: 196

	Quantity	Unit price	Total		
COSTS:					
(did not report any costs)					
Total cost:					0.00
INCOME:					
Cocoa (kg)	20	30.00	600.00		
Coffee (kg)	4	150.00	600.00		
Pepper (kg)	15	60.00	900.00		
Off-farm (business)			3,500.00		
Total income from MEC:				*2,100.00*	
Total income from other sources:				*3,500.00*	
Total income:					5,600.00
FARM NET INCOME:					***5,600.00***

Price and Output Distributions:

	Crop	***Price** (Rs.)* Best of 20 times	Most likely	Worst of 20 times	***Output** (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Cocoa	40.00	35.00	20.00	25	20	5
	Coffee	180.00	65.00	40.00	6	4	2
	Pepper	80.00	60.00	50.00	20	14	5
PH	Cocoa	30.00	20.00	15.00	20	15	5
	Coffee	150.00	50.00	30.00	5	3	2
	Pepper	60.00	50.00	40.00	15	10	5

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.10,000.00
Total wealth: Rs.100,000.00
Monthly minimum requirement for subsistence: Rs.900.00

Farmer number: 199

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			1,175.00		
Chemicals			435.00		
Labor			1,400.00		
Total cost:			-		3,010.00
INCOME:					
Pepper (kg)	10	120.00	1,200.00		
Rice (Bu)	40	70.00	2,800.00		
Cloves (kg)	40	150.00	6,000.00		
Tea (kg)	600	3.25	1,950.00		
Total income from MEC:				*1,200.00*	
Total income from other sources:				*10,750.00*	
Total income:					11,950.00
FARM NET INCOME:					***8,940.00***

Price and Output Distributions:

	Crop	*Price (Rs.)* Best of 20 times	Most likely	Worst of 20 times	*Output (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Pepper	120.00	60.00	30.00	15	10	5
PH	Pepper	100.00	50.00	20.00	10	8	5

Observed behavior: Mature harvest
Net Income reported in the first survey: Rs.12,000.00
Total wealth: Rs.420,000.00
Monthly minimum requirement for subsistence: Rs.900.00

Farmer number: 201

	Quantity	Unit price	Total		
COSTS:					
Fertilizer			350.00		
Total cost:					350.00
INCOME:					
Coffee (kg)	70	110.00	7,700.00		
Pepper (kg)	60	30.00	1,800.00		
Rice (Bu)	52	70.00	3,640.00		
Total income from MEC:				*9,500.00*	
Total income from other sources:				*3,640.00*	
Total income:					13,140.00
FARM NET INCOME:					***12,790.00***

Price and Output Distributions:

	Crop	*Price (Rs.)* Best of 20 times	Most likely	Worst of 20 times	*Output (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	200.00	150.00	100.00	90	70	20
	Pepper	60.00	45.00	30.00	100	60	40
PH	Coffee	150.00	100.00	70.00	80	60	20
	Pepper	45.00	20.00	10.00	90	70	40

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.12,000.00
Total wealth: Rs.400,000.00
Monthly minimum requirement for subsistence: Rs.1,000.00

Farmer number: 204

	Quantity	Unit price	Total		
COSTS:					
(did not report any costs)					
Total cost:					0.00
INCOME:					
Coffee (kg)	37	16.00	600.00		
Pepper (kg)	7	16.00	112.00		
Total income from MEC:				*712.00*	
Total income from other sources:				*0.00*	
Total income:					712.00
FARM NET INCOME:					***712.00***

Price and Output Distributions:

	Crop	*Price (Rs.)* Best of 20 times	Most likely	Worst of 20 times	*Output (kg)* Best of 20 times	Most likely	Worst of 20 times
MH	Coffee	30.00	20.00	15.00	50	45	30
	Pepper	40.00	25.00	15.00	10	7	5
PH	Coffee	16.00	15.00	12.00	40	35	30
	Pepper	20.00	17.00	10.00	7	5	4

Observed behavior: Premature harvest
Net Income reported in the first survey: Rs.3,000.00
Total wealth: Rs.45,000.00
Monthly minimum requirement for subsistence: Rs.600.00

Appendix F

FORTRAN *Source Code Used to Compute Expected Income, Probability of a Regret, and the Indices of Expected Utility*

```
      DOUBLE PRECISION R(2000), R1(2000), R2(2000), P(3), SP(3), Q(3),
     +       SQ(3), DP(1000), DQ(1000), PD(1000), QD(1000), TR(3),
     +       PMIN(3), QMIN(3), RT(1,2000), RTOT(1000), TINDX(1000),
     +       TNIN(1000), TGY(30), EXY(30), PLOS(30),
     +       UNEX(30), UNQD(30), UNCB(30), RATED(30)
      DIMENSION INUM(30)
      ND=1000
      NN=0
      DN=FLOAT(ND)
C
C Call subroutine GGNML from the IMSL library, generate ND normal
C   deviates returned in the vector R(ND).
C   DSEED is the supplied seed for the generator.
C   R1(ND) is for the price distribution, and
C   R2(ND) is for the output distribution.
C
      DSEED=501.D0
      CALL GGNML (DSEED, 2000, R)
         DO 1 J=1, ND
    1    R1(J)= R(J)
C
      DSEED=335.D0
      CALL GGNML (DSEED, 2000, R)
         DO 2 J=1, ND
    2    R2(J)= R(J)
C
C  Read data: IFNO = Farmer number
C            NCROP = Number of crops
C
    5 READ (5, 800) IFNO, NCROP
         IF(IFNO.EQ.0) GO TO 999
C
C  Read data: P = Mean of price
C            SP = Std. dev of price
C          PMIN = Lower value of price distribution
C             Q = Mean of output
C            SQ = Std. dev of output
C          QMIN = Lower value of output distribution
C
      DO 10 I=1, NCROP
   10    READ (5, 801) P(I), SP(I), PMIN(I), Q(I), SQ(I), QMIN(I)
C
C  Read data:
C          YOTHER = Income from sources other than mec
C            YINC = Reported net income
C            RATE = Discount rate
C
      READ (5, 802) YOTHER, YINC, RATE
```

```
C   Read data: Parameters of the utility functions
C      803: Exponential: K, theta, lambda
C      804: Quadratic: constant, linear, quadratic
C      805: Cubic: constant, linear, quadratic, cubic
C
      READ (5, 803) EXK, EXTH, EXL
      READ (5, 804) QCON, QLIN, QQAD
      READ (5, 805) CBCON, CBLIN, CBQD, CBCUB
C
C Compute price and output distributions
C
      DO 20 I = 1, NCROP
         DO 30 J=1, ND
            PD(J)=P(I) + R1(J)*SP(I)
            IF(PD(J).GT.PMIN(I)) GO TO 40
            DP(J)=PMIN(I)
            GOTO 41
   40       DP(J)=PD(J)
C
   41       QD(J)=Q(I) + R2(J)*SQ(I)
            IF(QD(J).GT.QMIN(I)) GO TO 50
            DQ(J)=QMIN(I)
            GOTO 51
   50       DQ(J)=QD(J)
C
   51       RT(I,J)=DP(J)*DQ(J)
   30    CONTINUE
   20 CONTINUE
C
C   Here we have ND deviates for income from each MEC in the two
C   dimensional array RT(I,J), where I is the number of MEC and
C   J is the number of deviates
C
C   Deviates of total income from MEC, [RTOT(J)]
C
      DO 60 J=1, ND
         SUM=0.0
         DO 70 I=1, NCROP
   70       SUM=SUM+RT(I,J)
            DSUM=SUM*RATE
         RTOT(J)=DSUM
   60 CONTINUE
C
C   Compute farm net income, [TNIN(J)]
C
      DO 80 J=1, ND
         TNIN(J)=YOTHER + RTOT(J)
   80 CONTINUE
```

```
C   Compute mean income, [AVINC]
C
       AVINC=0.0
       DO 90 J=1, ND
   90     AVINC = AVINC + TNIN(J)/DN
C
C   Compute the probability of a disaster, [PRLOS]
C
       SPROB = 0.0
       DO 95 J=1, ND
          IF(TNIN(J).GE.AVINC) GO TO 95
          SPROB = SPROB+1.0
   95 CONTINUE
       PRLOS = SPROB/DN
C
C   Compute utility indices
C
C 1. Exponential, [EXUNDX]
C 2. Quadratic, [QDUNDX]
C 3. Cubic, [CBUNDX]
C
       EXUNDX = 0.0
       QDUNDX = 0.0
       CBUNDX = 0.0
       DO 100 J=1, ND
C   Exponential:
            VXP = -EXL*TNIN(J)
            VEXP = EXP(VXP)
            EXTNDX = EXK - EXTH*VEXP
            EXUNDX = EXUNDX + EXTNDX/DN
C   Quadratic:
            QDTNDX = QCON + QLIN*TNIN(J)+QQAD*TNIN(J)*TNIN(J)
            QDUNDX = QDUNDX + QDTNDX/DN
C   Cubic:
            CBTNDX = CBCON + CBLIN*TNIN(J) + CBQD*TNIN(J)*TNIN(J)
     +               + CBCUB*TNIN(J)*TNIN(J)*TNIN(J)
            CBUNDX = CBUNDX + CBTNDX/DN
  100 CONTINUE
C
C
       NN=NN+1
       INUM(NN)=IFNO
       TGY(NN)=YINC
       EXY(NN)=AVINC
       PLOS(NN)=PRLOS
```

```
      UNEX(NN)=EXUNDX
      UNQD(NN)=QDUNDX
      UNCB(NN)=CBUNDX
      RATED(NN)=RATE
C
C   Print data
C
      PRINT 900, IFNO
      PRINT 901
      PRINT 902, NCROP
      PRINT 903
      DO 110 I=1, NCROP
  110    PRINT 904, I, P(I), SP(I), PMIN(I), Q(I), SQ(I), QMIN(I)
      PRINT 908, YOTHER, YINC, RATE
      PRINT 905, EXK, EXTH, EXL
      PRINT 906, QCON, QLIN, QQAD
      PRINT 907, CBCON, CBLIN, CBQD, CBCUB
C
C   Print results
C
      PRINT 951, AVINC, PRLOS
      PRINT 952, EXUNDX, QDUNDX, CBUNDX
  888    GO TO 5
  999 PRINT 954
      DO 120  I=1, NN
  120    PRINT 955, INUM(I), TGY(I), EXY(I), PLOS(I), RATED(I)
      PRINT 959
      DO 130 I=1, NN
  130    PRINT 960, INUM(I), UNEX(I), UNQD(I), UNCB(I), RATED(I)
 9999 STOP99999
  800 FORMAT (I3,I2)
  801 FORMAT (6F10.4)
  802 FORMAT (4F10.2)
  803 FORMAT (F10.5, 3X, D15.10, D15.12)
  804 FORMAT (F10.5, 3X, D15.10, D15.12)
  805 FORMAT (F10.5, 3X, D15.10, D15.12, D15.12)
C
  900 FORMAT ('1',20X,'FARMER NUMBER:  ',I3,4X,
     +        '(MATURE HARVEST - DISCOUNTED)',//)
  901 FORMAT (1X,'************* THE DATA USED:')
  902 FORMAT (/1X,'NUMBER OF CROPS:  ',I2)
  903 FORMAT (//1X,'PRICE AND OUTPUT DISTRIBUTIONS:'/)
  904 FORMAT (5X,'CROP ',I1,':',1X, 6(F10.5)/)
```

```
  905 FORMAT (/1X,'PARAMETERS OF THE UTILITY FUNCTIONS:'/,
     +         5X,'EXPONENTIAL:', F10.5,3X,D20.10,3X,D20.12)
  906 FORMAT (5X,'QUADRATIC:  ', F10.5,3X,D20.10,3X,D20.12)
  907 FORMAT (5X,'CUBIC:      ', F10.5,3X,D20.10,3X,D20.12, 3X,D20.12)
  908 FORMAT (/1X,'COST AND INCOME:', 5X, 2F10.2,4X,
     +         'DISCOUNT RATE= ', F5.3)
C
  951 FORMAT (///,1X,'************  RESULTS:'//,
     +         5X,'MEAN INCOME =    ',D12.7,//,
     +         5X,'PROBABILITY OF A DISASTER =  ',F7.5///)
  952 FORMAT (5X,'UTILITY INDICES:'//,
     +         15X,'UTILITY INDEX OF EUF: ',D20.12,/,
     +         15X,'UTILITY INDEX OF QUF: ',D20.12,/,
     +         15X,'UTILITY INDEX OF CUF: ',D20.12)
  954 FORMAT ('1','EXPECTED INCOME AND PROBABILITY OF LOSS:'//,15X,
     +         'FMNO',3X,'TARGET (Y)',2X,'EXPECTED(Y)',3X,'PR(LOSS)',
     +         3X,'DISCOUNT RATE'/)
  955 FORMAT (15X,I4,3X,2(F10.3,2X),2(3X,F6.3))
  959 FORMAT ('1','UTILITY INDICES:'//,15X,'FMNO',5X,'EXPONEN',4X,
     +         'QUADRATIC', 5X, 'CUBIC',8X,'DISC RATE'/,)
  960 FORMAT (15X,I4,2X,3(F10.3,2X),6X,F6.3)
      END
```

The vita has been removed from the scanned document