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Peasants and Risk

- A Study of Risk, Market Imperfections and Farm Household Behaviour in Northern Zambia -

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Abstract

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Abstracts follow for each article:

Individual Decision Making under Risk: Deficiencies of and Alternatives to Expected Utility Theory.

Expected Utility (EU) theory has been the dominating approach within economic theory during the last 50 years. During the last 20 years EU theory has slowly lost ground, due to growing evidence that individuals do not maximise expected utility. This paper gives an overview of the EU theory and presents and discusses six different non-expected utility approaches. Some of the empirical violations of EU theory are reviewed. More complex non-expected utility models have been developed to account for some of the violations of the EU model. Bounded rationality theories include the limitations of decision makers in getting and processing information. This paper also presents three bounded rationality models using safety-first rules of thumb, which fit better with observed behaviour in situations were potential crisis situations are involved.

Experimental Studies of Peasant's Attitudes toward Risk in Northern Zambia.

Attitudes toward risk were measured for 143 persons in Northern Zambia, using an experimental gambling approach with real payoffs which at maximum were equal to 30 percent of average total annual income per capita. The experimental measures indicate that on average more than 80 % of the farmers are moderately to extremely risk averse; that they exhibit decreasing absolute risk aversion and increasing partial risk aversion; and, that they are more risk averse in games with gains and losses than in games with gains only. Farmers in Northern Zambia showed both a wider spread in risk aversion and a more risk averse behaviour than farmers in similar studies in Asia.

Risk, Market Imperfections and Peasant Adaptation: Evidence from Northern Zambia

In the literature, considerations of risk and risk aversion have played central roles in understanding processes of technology adoption and choices of crop portfolios. Market imperfections are also frequently used to explain production decisions of farm households. This paper presents a theoretical framework for analysing how risk aversion and market imperfections may influence cropping decisions of farm households. Our econometric analysis using household data from northern Zambia indicates that both household specific variables, such as gender and education, market imperfections in commodity and credit markets, and, to a smaller degree individual risk aversion, influence cropping decisions of farm households.

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The turmoil caused by the war and change of government in Ethiopia in 1991, forced me to abandon data-collection, and eventually to change the topic for my dissertation. At this point, I was very lucky to get involved in on-going research in Zambia. My luck continued when Stein Holden, Associate Professor at the Department of Agricultural Economics and Social Sciences of the Agricultural University of Norway, agreed to serve as my advisor. I am extremely grateful to Stein for his guidance, invaluable assistance, and his encouragement. Without his unwavering belief in my ability to complete this study, and without his knowledge about Zambian conditions, this dissertation would never have been written. The dissertation was completed at the Department of Economics and Social Sciences, with financial support from the Norwegian Research Council. I would like to thank colleagues at the department, especially my colleagues in Skoggården, who have always provided a nice and encouraging working atmosphere. I would also like to thank the Misamfu Research Station in Kasama, Zambia, who gave access to research station facilities during the field-work period. A very special thanks to our assistants Leonard Simpamba and Elias Komba for translating and helping carry out interviews in the villages. Stein Holden, Tore Christiansen and Dag Olav Sæther were great company during the field work. I especially appreciate their generosity in offering full access to their data for my research.

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During my years as a Ph.D. student, I «produced» more than just exams and scientific papers. My sons, Martin and Thomas, were born during these years. It has not always been easy combining life as a Ph.D. student with motherhood. Nevertheless, their ability to get my mind off academics every day when I returned home, actually contributed to reducing stress, and certainly to giving my life a deeper meaning. Still, there were hard and lonely times on the road to my Ph.D. Often I wanted to quit. After my second son was born, I had almost made up my mind to do so. It was nearly impossible to find good day-care for both Martin and Thomas, and I did not see how I would be able to get all the work done. Thanks to a new rule at the University, priority for day-care was given to women who were close to finishing their Ph.D. When I got the message that both my children could enter Åkebakke kindergarten, the decision to continue was made easier. Thanks are due both to the University's Personnel Office for making it practically possible to finish this work, and to the staff at Åkebakke for providing excellent care for Martin and Thomas.

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Ås, August 1998.

Mette Wik

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Risk, Market Imperfections and Farm Household Behaviour in Northern Zambia: An Introduction.

1. Introduction.

In northern Zambia more than 80 per cent of the population belongs to the agricultural sector, which is dominated by small farm households. A large part of northern Zambia has traditionally been dominated by *chitemene* shifting cultivation. This system requires large amounts of woody biomass for crop production, and has a very low carrying capacity in terms of people per km^2. The carrying capacity has now been exceeded in large parts of the area, due to recent increases in population. Population concentration has been most pronounced near roads and lakes. This has led to accelerated deforestation (Chidumayo, 1987; Holden, 1991, 1997; Holden *et al.*, 1994; Strømgaard, 1984, 1989). In addition to reducing deforestation, the government of Zambia also wanted to improve national food security through increased production of maize in the north where rainfall was more stable than in the rest of the country. From the late 1970s to the late 1980s, the national strategy was, therefore, to replace shifting cultivation by more intensive agriculture through the use of modern inputs. Maize production was particularly stimulated through government sponsored research, extension, credit, marketing and price support programmes. Maize production expanded rapidly in northern Zambia as a result (Holden, 1993, 1997).

For decades, the Zambian economy has been heavily dependent on the export of a single commodity, copper. It contributed 38-48 % of total GDP and 91-96 % of export income in the 1960s (Holden, 1997). Due to decreases in copper prices and diminishing resources, the contribution of copper to GDP had declined to 12 % by 1989, though it still constituted 88 % of export incomes (*ibid*). Deterioration of the «copper economy» combined with sharp increases in oil-prices in the 1970s, and sharp increases in real interest rates on loans from the late 1970s, led Zambia into one of the most serious economic declines and crises in the history of modern Africa (Holden, 1997). The International Monetary Fund and the World Bank were involved in providing loans and sorting out the dept problems. This resulted in a number of attempts at changing the economic policies during the 1980s and 1990s, the so called Stabilisation and Structural Adjustment Programmes (SSAPs).

Since the late 1980s these Stabilisation and Structural Adjustment Programs (SSAPs) have resulted in significant changes in economic policies in Zambia. The most important changes for peasants in northern Zambia include:

1) removal of fixed pan-territorial prices, leading to regional and local price differentiation on inputs and outputs and to increased price variance;
2) removal of fertiliser subsidies and introduction of flexible exchange rates, leading to higher and possibly more variable fertiliser prices;
3) reduced government involvement in production and marketing, leading to contraction in credit supply to peasant farmers.

Many of the economic measures, including the introduction of a programme to eliminate maize subsidies, the removals of price controls (other than those on maize), an increase in interest rates and liberalisation of the exchange rates, were undertaken in 1989. In 1990 a reform of maize and fertiliser marketing was put into effect. However, in 1992, Zambia experienced the worst regional drought this century and economic reforms were partly derailed. Virtually all agricultural reforms were put on hold in early 1992. By mid 1993 the reforms were back on track and the government had implemented most major economic measures (Valdes, *et al.*, 1993; Economist Intelligence Unit, 1994). Holden *et al.* (1994) characterise the adjustments in agricultural policies in the late 1980s and the beginning of the 1990s as unsuccessful due to the ineffective mixture and sequencing of economic reform measures, and lack of consistency in the use of various measures. One illustrative example is the removal of agricultural input subsidies without lifting of controls on output price for maize. Another example is the prohibition of maize exports even in surplus years to force maize-prices down to very low levels. Furthermore, removal of pan-territorial prices and subsidies, and a contraction in the credit supply to farmers led to a more risky production environment for the farm households. These factors have all had an adverse effect on agricultural production.

Knowledge of how subsistence farmers make decisions is important in determining strategies for agricultural development. Poor farm households are generally known to be risk averse, and their production- and economic environment is characterised by a high degree of uncertainty. In addition to an already risky production environment, farm households in Zambia have been confronted with new sources of risk due to changes in economic policies,.

Many studies on risk have focused on production decisions and choice of technology. We will review some of this literature later in this paper. Other studies have analysed risk coping and risk management strategies, for example, risk sharing (Udry, 1990, 1994; Townsend, 1994), or use of assets or savings to cope with risk (Udry, 1995; Dercon, 1996). Bromley and Chavas (1989) and Carter (1997) conclude that traditional risk management strategies (such as risk-sharing at village level or crop diversification) can have serious negative implications for economic development.

In addition to making decisions in a highly risky environment, farm households in less developed countries also typically face pervasive market imperfections (Holden and Binswanger, 1998). In remote locations, markets may even be totally missing. Usually no land market exists in land abundant economies, and labour markets are also poorly developed. With equal access to technology, people prefer to work on their own land to secure the whole surplus of their efforts. Furthermore, incentive problems (moral hazard) and search costs may also make hiring of labour too costly and prevent labour markets from developing. Small farmers in land abundant economies are usually also rationed out of credit markets due to lack of collateral options (no land value, few or no suitable alternative assets) and moral hazard problems (Binswanger and McIntire, 1987). Imperfect markets for basic food commodities exist due to high transaction costs and imperfect information (Hoff *et al.*, 1993, deJanvry *et al.*, 1991).

In northern Zambia typical market imperfections include (Holden, 1997):

- Missing land market (usufruct rights to land only);

- Seasonal, rationed or missing labour market;
- Missing or very thin (and seasonal) commodity markets with limited competition;
- Missing or very limited insurance market;
- Rationed credit market interlinked with input supply (fertiliser and seeds);
- Missing or incomplete information.

The purpose of this Ph.D. study has been to investigate the importance of risk and risk aversion to farm households in northern Zambia. In particular I wanted to; 1) estimate farmers' risk preferences and identify how these were correlated with individual and socio-economic characteristics; and 2) assess the importance of risk for farm household production decisions in relation to other sources of constraints in farm households' production, such as market imperfections in labour, credit input and output markets.

In Section 2 of this introduction paper, I will briefly introduce some issues of risk and market imperfections in the economic literature relevant to the main research questions of this Ph.D. study. Section 3 presents the methods used for collection of the primary data. Section 4 discusses risk and market imperfections in northern Zambia and the main findings from this research.

2. Risk in economic literature.

2.1 The Expected Utility literature.

Utility based models originated with Bernoulli (1738). Axiomatic foundations for the theory were first provided by Ramsey (1926) and independently by von Neuman and Morgenstern (1944). A number of variants have been proposed; the unifying thread among these models is the notion that the decision maker chooses among alternative random prospects as though he evaluates the desirability of each prospect as a function of the subjective value (utility) of each of the possible outcomes, weighing these utilities by a function of the probability that each outcome will be realised.

The original utility-based model and the one most often used in the theoretical applications, is the expected utility (EU) model developed by von Neumann and Morgenstern (1944). This model assumes that the decision maker has a complete and continuous preference ordering over all prospects. The final axiom of expected utility is the *independence axiom.*[1]

Given the axioms, it can be proved (Baumol, 1972) that the decision maker maximises his expected utility of the prospect X (whose uncertain consequenses are $x_1, x_2,...x_n$ with respective probabilities $p_1, p_2,...p_n$) as defined by the expected utility rule:

$$U(X) = p_1u(x_1) + p_2u(x_2) + \dots\dots\dots + p_nu(x_n) \qquad (1)$$
$$= \sum_{i=1}^{n} p_iu(x_i)$$

The expected utility rule states that the decision-maker will make choices as if he maximises the utility in the different states weighted by the probabilities for each state to occur. The expected utility rule is applicable if and only if the utility function u(x) has been determined in a particular way such that utility (intensity of preference) is a cardinal rather than an ordinal variable. Von Neumann and Morgenstern (1944) did not specify the nature of these prospects or states, i.e., whether the outcomes should be interpreted as alternative wealth states or as gains and losses relative to the current wealth states. If the decision maker's preferences are defined over prospects in wealth states, the axioms of expected utility imply that the decision maker will exhibit *asset integration.* This means that the decision maker will behave as though he possesses a fixed cardinal utility function defined over wealth states, and evaluates the utility of each prospect on the basis of the expected value of the utility of the ultimate wealth states implied by the outcomes. In this case, the x's representing the outcomes in expression (1) may be replaced by wealth states w:

$$U(X) = p_1u(w_1) + p_2u(w_2) + \dots\dots\dots + p_nu(w_n) \qquad (2)$$
$$= \sum_{i=1}^{n} p_iu(w_i)$$

Even if the decision maker displays asset integration, risky prospects generally present themselves in terms of gains and losses relative to an initial position. It is therefore helpful to

[1] see *Article 1*, for a thorough presentation of the axioms of the EU theory

be able to reinterpret (2) in the following alternative way: If the initial certain wealth is given by w_0, and $z_i=w_i-w_0$ are gains and losses relative to w_0, then accepting a risky prospect in gains and losses $X_0(p_1,p_2,...p_n;z_1,z_2,...z_n)$ is the same as accepting a change to the uncertain wealth state $X(p_1,p_2,...p_n;w_1,w_2,...w_n)$. Equation (2) can then be rewritten in the equivalent form:

$$U(X_0+w_0) = p_1u(z_1+w_0) + p_2u(z_2+w_0) + \dots\dots\dots + p_nu(z_n+w_0) \qquad (3)$$
$$= \sum_{i=1}^{n} p_iu(z_i+w_0)$$

Asset integration makes it irrelevant whether we think in terms of the individual's risk preferences defined over gains and losses relative to his current position, or over the implied ultimate wealth states. Thus, *asset integration* has important empirical implications for patterns of behaviour under risk in general, and for distribution of risk preferences across wealth groups in particular.

In the expected utility model the decision maker's utility function summarises his preferences among risky prospects. The first derivative of the utility function is positive (more income is preferred to less). The second derivative of the utility function depends on the decision maker's preferences toward risk. A decision maker is said to be risk averse if he prefers the expected value of a prospect (the certain income) to the prospect itself. In this most common case, the utility function is concave and the second derivative is negative.

Von Neumann and Morgenstern (1944) originally proposed the expected utility model as a normative framework for decision making under risk. A number of psychologists and economists have devoted considerable effort to testing the performance of the model as a positive model of decision making under risk. In the course of this ongoing investigation, researchers have identified several situations in which the predictions of the expected utility model appear to be inconsistent with «typical» patterns of choice under risk, and have proposed various modifications of the model in order to improve its predictive power. In *Article 1*, I have reviewed some of the empirical violations of the EU theory, and presented more complex non-expected utility models developed to account for some of the violations of the EU model. I have also discussed three bounded rationality models in *Article 1*.

In my empirical work (*Articles 2* and *3*), I have chosen to use the EU model, in spite of the numerous examples of violation of this model. This decision was based on the following reasons:

1) Several studies (Rubinstein, 1988; Bar-Shira, 1992; Buschena and Zilberman, 1992; Bar-Shira *et al.,* 1997) have showed that the EU hypothesis will only be violated when either outcomes or probabilities are indistinguishable. In the experimental study used here, outcomes are distinguishable, and probabilities are constant.

2) The EU model is still the most widely used model of decisions under uncertainty in economics, and our data could be used to test for some of the usual assumptions made. In *Article 2*, we discuss and test for asset integration, as well as whether the utility function should exhibit increasing or constant partial risk aversion and/or decreasing absolute risk aversion.

2.2 Risk, market imperfections and choice of farm technology

A common finding is that third world farmers often use less fertiliser and other inputs than they would have done if they maximised expected profits. It is also common to find that farmers do not adopt - or only partially adopt - new technologies (including new crops) even when these technologies provide higher returns to land and labour than the old technologies (Goetz *et al.,* 1988; von Braun *et al.,* 1989). Theories of farmer behaviour under risk (Fafchamps, 1992; Feder, 1980; Finkelshtain and Chalfant, 1991; Just and Zilberman, 1983), and access to markets (de Janvry *et al.,* 1991; Fafchamps, 1992; Goetz, 1992; Strauss, 1986) have been advanced to explain land and other resource allocation decisions of farm households[2]. Because each of these theories focus on specific aspects of the decision-making process, often to the exclusion of other potentially important factors, they might lead to erroneous or only partially correct conclusions. For example, a risk model might lead to

[2] Theories of environmental constraints (Bellon and Taylor, 1993; Jansen *et al.,* 1990; Perrin and Winkelmann, 1976) have also been developed to explain farm households' diversification strategies. These theories are not presented here as they have not been used in the succeeding work. See Meng (1997) for a single model incorporating risk, market, and land quality variables to explain variety choices at the farm level.

prescriptions to provide households with insurance, while a missing-markets model would stress public investments in market infrastructure. Moreover, explanations from the two models are not likely to be independent of each other. Omitted variables (e.g. significant market variables left out of a risk model) result in inconsistent estimates, except in the unlikely case of zero correlation among the different sets of variables.

2.2.1 Risk models and technology adoption

The most widely used theory to explain partial adoption involves behaviour under some type of risk. In this literature the presence of production and/or price risk is incorporated into models of farm household behaviour. A brief review of this literature, primarily based on a more thorough review in Meng (1997), will be presented.

Sandmo (1971) models risk originating from a stochastic output price. Using the EU approach, he demonstrates that optimal output for a risk averse firm under price risk will be less than for a firm facing a known output price. In an attempt to reduce the exposure to risk, the producer reduces his output. Similar results hold in the case of yield risk (Feder *et al.* 1985). Sandmo's framework is, however, not suitable for examining allocation decisions between different technologies.

Feder (1980) and Just and Zilberman (1986) apply an EU approach to analyse land allocation to modern crop technologies in developing countries. In a farm household where crop production contributes a large percentage of household farm income, yield performances in different crop technologies are major factors to be considered in the land use decision. The household must incorporate the uncertain distribution of the yields from the different technologies into its decision. Risk is influenced both by the mean, variance and covariance of yields under various crop technology alternatives. Both of these studies demonstrate analytically that an optimal solution characterised by diversification between two crop technologies is quite possible. Other research characterising the choice between traditional and modern technologies as production portfolio selection problems include Herath *et al.* (1982), Lin (1991) and Smale *et al.* (1994).

Restricting the risk analysis to the production side, however, can result in false conclusions when the producing unit is a farm household that consumes a large part of its output. Finkelshtain and Chalfant (1991) expand Sandmo's results for a firm under price risk and recognise that a household consuming its own output may face additional constraints on its behaviour. As both producer and consumer of its own produce, the farm household must deal with multivariate risk from both prices and income. By defining a new measure of risk aversion that incorporates the covariance between consumption price and income, Finkelshtain and Chalfant demonstrate that Sandmo's findings can be reversed when consumption risk is taken into account. This means that a farm household's optimal response to price risk in some cases can be to increase its production of the risky crop in order to protect itself from price risk on the consumption side. Such an outcome will depend on the level of market participation for the crop and on the household's income elasticity of demand for the consumed output. This approach is, however, similar to that of Sandmo's in that it does not specifically address allocation decisions between different technologies.

Fafchamps (1992) uses a similar approach to model land allocation decisions of households facing consumption risk resulting from price and income risk. He finds optimal allocation between a food and cash crop to be a function of various parameters measuring market risk and market participation. When the household consumes a large share of the food crop, and when a large covariance exists between price and income, protection against the stochastic price of the food crop becomes increasingly more important. The existence of consumption risk can thus also explain the decision of a farm household to allocating land to more than one technology.

Since measures of people's risk attitudes are usually not available, socio-economic characteristics of the households have frequently been found central in the establishment of a linkage between risk attitudes and production choices. Feinerman and Finkelshtain (1996) propose that a change in socioeconomic characteristics can affect household production choices in one of two ways: 1) it can alter the household's indifference map, thereby changing its choices, or 2) it can affect the household's risk attitudes and thus its production decisions. Specifically, changes in household characteristics significant for overall household wealth, including off-farm employment opportunities and livestock holdings, could affect risk attitudes by increasing or decreasing the household's access to risk-reducing inputs and activities. In empirical studies the following household characteristics have been found to influence risk attitudes, and through them, land-use decisions: farm size (Feder, 1980; Feder and O'Mara, 1981; Moscardi and deJanvry, 1977; Perrin and Winkelmann, 1975), off-farm income (Dillon and Scandizzo, 1978; Feinerman and Finkelshtain, 1996), age and family size (Dillon and Scandizzo, 1978; Moscardi and deJanvry,1977).

Several studies have also attempted to estimate risk attitudes. Risk attitudes of households in traditional farming systems have been estimated using both indirect or econometric methods (Antle, 1987; Moscardi and deJanvry, 1977)[3] and direct or experimental methods (Binswanger, 1980; Dillon and Scandizzo, 1978; Sillers, 1980). These studies have largely confirmed that traditional farm households reveal risk averse attitudes. However, the econometric approaches generally ignore potentially important multivariate risks (Finkelshtain and Chalfant, 1991), and thus, might give biased estimates for risk attitudes. Furthermore, informal insurance systems such as extended family ties and buffer stocks/livestock may cause households to behave in a less risk averse manner than they would otherwise. It is usually very difficult to control for these types of informal insurance systems. Econometrically estimated risk attitudes in traditional agriculture should therefore be interpreted very carefully.

The strength of the theoretical argument, combined with a persuasive, though admittedly smaller body of empirical evidence, gives credence to the importance of risk attitudes. However, focusing only on risk-related issues to the exclusion of other potentially significant reasons for households to diversify technologies, might lead to erroneous or incomplete conclusions.

2.2.2 Market imperfection models and technology adoption

Although household response to risk dominates the economic literature on partial adoption, it does not provide a complete explanation. The presence of household specific transaction costs that impede market access can also influence technology choices (deJanvry *et al.*, 1991; Fafchamps, 1992; Goetz, 1992). The presence of transaction costs creates a wedge between purchase and sale price. This price band is determined by household specific characteristics; thus, two households with identical parcels of land, identical perceptions of risk, and identical ability to cope with risk may still choose to cultivate different crops or different crop combinations. Within the price band, the relevant output price is the household-specific endogenous «shadow» price of the non-traded good(s). The shadow price is dependent on production technology and household preferences and is implied by the intersection of household supply and demand curves. With the presence of endogenous prices, the separability or recursiveness of the household model breaks down, and the household's production and consumption behaviour can no longer be modelled sequentially.

For households with endogenous prices within the price band, i.e., households which do not participate in the market for that particular crop, constraints on its subsistence requirements may become binding. In other words, the amount of food the household itself is capable of supplying must equal or exceed the amount demanded by the household. In order to ensure the availability of a particular crop, the household must allocate the necessary resources to meet its own demand. Thus it is possible that consumption preferences shape crop technology choices. Cultivation of different crops will then occur if some or all crops are non-tradeables and the household demands diversity in consumption.

3.0 Methodology

This study uses data from five different sources:

1) A household survey done by Stein Holden, Helge Hvoslef and Prem Sankhayan in November and December 1992 (Q1 in the Appendix). In this survey twenty farm households were selected randomly in each of nine villages in northern Zambia. Demographic data, as well as consumption, income and production data were collected during a formal interview. All fields were measured for each household.

[3] There are many other studies using this approach for farmers in developed countries (*inter alia* Antle, 1983, 1989; Bardsley and Harris, 1987; Bar-Shira *et al.*, 1997; Chavas and Holt, 1996; Love and Buccola, 1991; Pope

2) In 1993, Stein Holden and Helge Hvoslef did a follow up household survey of the same households (Q2 in the Appendix). These two surveys collected complete production and income data for the 1992/93 season. These data have previously been used to study the impact of adjustment programmes on peasants and the environment in northern Zambia (Holden *et al.*, 1994).

3) In July and August of 1994, Tore Christiansen and Dag Olav Sæther conducted a new survey of 110 households in six of the villages (Q3 in the Appendix). This survey provided data on income and expenditures, and was used together with the first two surveys to develop a Social Accounting Matrix for three of the villages (Christiansen and Sæther, 1995).

4) During the same period, Stein Holden and I visited the same 110 households to do a survey of farmers' perceptions of profitability and risk for different crops (Q4 in the Appendix).

5) Finally, in 1994, Stein Holden and I also did a survey of the same farm households[4] to measure individuals' attitudes to risk using an experimental approach similar to Binswanger's (1980).

In our experiment, subjects were confronted with series of choices among sets of alternative prospects (gambles) involving real money payment.[5] Each gamble lists six alternative prospects or gambles, each with a 50% probability of winning (see Table 1). The subjects were asked to select one of the six alternatives. The alternatives represented increased expected gains, but at the cost of increased spread between the two outcomes. The six alternatives were classified from extreme risk aversion to neutral to preferring. The subject's choice among these alternative prospects was taken as an indication of the degree of the

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and Just, 1991; Saha *et al.*, 1994).

[4] Both household heads and their wives were invited to participate in the experiment. In total, 176 individuals participated, out of which 33 were excluded from the data-set because they had serious problems understanding the game.

[5] See *Article 2* for a detailed description of the experiment.

decision-maker's risk aversion. The individuals played eleven games, with different levels of possible gains, and three games at different levels, with both gains and losses.

Table 1.
The 100 Kw game for «gains-only» and «gains and losses» games.

	Gains only.			Gains and losses.	
Choice	***Bad luck payoff "Heads"***	***Good luck payoff "Tails"***	***Risk aversion class***	***Bad luck payoff "Heads"***	***Good luck payoff "Tails"***
0	100	100	Extreme	0	0
A	90	180	Severe	-10	80
B	80	240	Intermediate	-20	140
C	60	300	Moderate	-40	200
D	20	380	Slight to neutral	-80	280
E	0	400	Neutral to preferring	-100	300

The 1994 surveys could not replicate the 1992 and 1993 surveys precisely. Some of the households no longer existed. And in some cases, we were unable to meet any of the household members from the 1992 and 1993 surveys. Still, when combining data from all these surveys, we had complete sets of data for 92 households.

I have used the same functional definition of the household unit as the one used by Holden (1991). This definition is based on residence, working group, and consumption group. All who stayed, worked and ate in the same group were included. Dependent children were also included if they stayed outside the household because they usually came back for weekends and holidays and belonged to the same consumption unit. Also, absentees were included if they pooled their income with the rest of the household or assisted the household (by providing labour or other items of value) and received products from the farm.

4. Risk and market access in northern Zambia.

Farm households in northern Zambia combine two main production systems. They produce several crops (fingermillet, beans, groundnuts and cassava) in the *chitemene* traditional slash and burn system, and they produce monoculture maize in more «permanent» fields. In the *chitemene* system trees are cut in a large area and piled on a smaller area and burned. Crops are planted in the ash. Fingermillet is planted in the first year, groundnuts in the second year, and beans from the third to as much as the seventh year, depending upon the nutrient content of the soil (Vedeld and Øygard, 1982). The field is then left fallow for a period of 10-20 years. Cassava is usually interplanted with the fingermillet during the first year, and the roots are harvested during the third and fourth year after planting. Each household usually has several *chitemene* plots of different age. To have a mixed consumption basket of food crops, the usual structure is to have one first year plot with fingermillet, one second year plot with groundnuts, one third year plot with cassava (planted in the first year) and one fourth year plot with beans. On average, the households in the sample cultivate 1.37 ha of land, of which 0.52 ha is used for maize production and 0.74 ha for *chitemene* crops. While the *chitemene* crops are mainly grown for consumption, maize is primarily a cash crop using hybrid seeds and fertiliser. These inputs have only been available through government-sponsored credit programs and their quantities have been limited.

As background information for the succeeding formal studies, we wanted to investigate the farmer's own perceptions of relative risk and profitability between the different crops. When asked to rank the most important reasons for variation in profitability in maize production (Table 2), 70 percent of the farmers in the sample ranked lack of or late supply of fertiliser as the most important source of risk. Eighty-eight percent had lack of/ late supply of fertiliser as one of the three most important reasons for variation in profitability. Approximately 11 percent stated that lack of credit was one of the three most important reasons. The formal credit market in this area was rationed and commodity specific (fertiliser and maize seeds). Poor, cash-constrained peasants were not able to purchase fertiliser without access to credit. The reported lack of fertiliser as the main source of variation in profitability in maize, could be just another way of expressing that the farmers did not have access to enough credits to buy fertiliser.

Only 10 percent considered price variation as one of the three most important risk factors in maize production. One likely reason why price-variation was not ranked higher is that price controls had been efficient for maize and fertilisers until 1993/94 (Holden 1997). As a result, peasants had not been experiencing big variations in the ratios between input and output prices.

Table 2.
Peasant responses to the question: «What is the most important reason for variation in profitability in maize, finger-millet, cassava, beans and groundnut production?» (shown as percentage of total responses for each crop).

	Maize	***Finger-millet***	***Cassava***	***Beans***	***Ground-nuts***
Weather-conditions	15	51	24	59	34
Agronomic conditions	2	16	50	33	51
Management-problems	2	14	24	8	14
Lack of/ late supply of fertiliser	70	15	0	0	0
Lack of credit	7	1	0	0	0
Other	4	4	2	0	1
Total	100	100	100	100	100

In the more extensive *chitemene* production system, weather and agronomic conditions seemed to be the most important reasons for variation in profitability (Table 2).

Table 3.
Peasants' ranking of the profitability of six different crops.

	Ground-nuts	***Beans***	***Maize***	***Finger-millet***	***Cassava***	***Bananas***	***Total***
1 Most profitable	36	27	28	7	2	0	100
2	30	32	13	19	5	1	100
3	17	22	18	32	9	2	100
4	10	11	29	33	14	3	100
5	5	4	6	7	68	10	100
6 Least profitable	0	3	3	1	9	84	100

While maize production was still considered the most profitable just a few years earlier (Holden *et al.*, 1994), we see from Table 3 that it was only ranked as the third most profitable crop in 1994. Furthermore, 42 percent said they thought profitability in maize production was decreasing (Table 4). Only eight to seventeen percent of the respondents found the trend to be decreasing in the other 5 crops. For groundnuts, beans and fingermillet the majority of the respondents considered the profitability to be increasing.

Table 4.
Trend in profitability (shown as percentage of total responses)

	Increasing profitability	***Constant profitability***	***Decreasing profitability***
Groundnuts	72	19	8
Beans	64	24	12
Fingermillet	61	26	12
Cassava	38	47	15
Banana	27	56	17
Maize	25	33	42

Table 5.
Peasants' ranking of the riskiness of six different crops

	Maize	***Beans***	***Ground-nuts***	***Finger-millet***	***Cassava***	***Bananas***	***Total***
1 Most risky	72	8	6	6	5	4	100
2	8	33	24	19	16	0	100
3	11	29	36	19	3	2	100
4	4	22	22	36	13	4	100
5	5	6	8	16	58	7	100
6 Least risky	2	1	5	2	11	78	100

Even though price risk was still not prominent in 1994, Table 5 shows that 72 percent of the farmers in the sample considered maize to be the most risky crop. In maize production peasants were heavily dependent on access to credit, seeds and fertiliser. Even when they had access to credit, they had often experienced insufficient supplies and late deliveries of seeds and fertilisers. Recently, credit had also become harder to obtain. The majority also found maize production to be increasingly risky, and the other five crops to have constant or decreasing risk (Table 6). Cassava and bananas were considered the least risky crops.

Table 6.
Trend in riskiness (shown as percentage of total responses)

	Increasing risk	***Constant risk***	***Decreasing risk***
Maize	70	18	12
Beans	27	37	35
Groundnuts	25	34	41
Fingermillet	19	41	40
Cassava	15	40	45
Banana	10	58	33

Peasant responses indicate that maize production in northern Zambia is becoming less profitable and more risky. The most important risks in maize production are market-related. In 1994 these risk factors were lack of, or late supply of fertiliser, and lack of credit. With the lifting of control of maize prices in 1994, risk is likely to have increased considerably.

Finkelshtain and Chalfant (1991) showed that under certain conditions a peasant farmer will produce more in a situation with price risk than he would have done under certainty. Sandmo's qualitative conclusion that peasants will produce less output under uncertainty does not necessarily hold. Using the multivariate risk approach, we can briefly discuss how increased price risk in maize production in northern Zambia might affect production.

Finkelshtain and Chalfant (1991) present the following relationship between optimal quantities produced under certainty x^c and uncertainty x^u:

$$x^u < x^c \Leftrightarrow \eta > r(1-\frac{x^u}{h}),$$

$$x^u = x^c \Leftrightarrow \eta = r(1-\frac{x^u}{h}), \text{ and} \qquad (4)$$

$$x^u > x^c \Leftrightarrow \eta < r(1-\frac{x^u}{h})$$

where η is the income elasticity of demand for home-consumption of the farm crop, r is the Arrow-Pratt measure of relative risk aversion and h is the home-consumption of the farm crop. Assuming a risk averse producer ($r>0$), we see that a sufficient condition for Sandmo's qualitative result to hold when the producer is a net seller, is that the good produced is a normal good. If the good is inferior and the producer is a net seller, we need to know the sizes of η, r and the ratio x^u/h to determine whether production under uncertainty is smaller or bigger than under certainty. For the net buyer, a necessary, but not a sufficient condition for reduced output under uncertainty, is that the good produced is a normal good. We will also need to know the sizes of r, η and the ratio x^u/h to determine whether output will be reduced. An inferior good is a sufficient condition for increased production under uncertainty for the net buyer.

Finkelshtain and Chalfant (1991) show that output is affected by increases in risk even for the risk neutral peasant. Even though the producer is indifferent to income risk, the consumption effect of increased risk in prices will have an effect on his output. From the condition above (4) we see that a risk neutral producer will produce less than under certainty if the farm-produced good is a normal good, and more than under certainty if it is inferior.

Assuming no other sources of risk affecting profits in maize production, we can use the above conditions to see how increased price-risk will influence maize production in northern Zambia. Income elasticities of demand for maize in the research area in northern Zambia were found to be 2.3 in 1992 and 0.89 in 1994 (Christiansen and Sæther, 1995). The big difference between the two years is explained by high relative maize prices and low maize production in 1992, making maize a luxury good for most peasants. In 1994, the yields were good and prices were low. In this situation maize was an affordable substitute for cassava and millet. The big differences in income elasticities between the two years is probably also overestimated because price elasticities were omitted from the model estimating income elasticities. Even though the size of the elasticity is uncertain, we can still conclude that maize is a normal good for the peasants. Peasants are generally found to be risk averse ($r>0$), and the producers in northern Zambia are net sellers of maize. These three conditions are sufficient to conclude that Sandmo's qualitative result will hold when price-risk in maize production increases.

4.1 Peasants' attitudes toward risk.

Considerable research has attempted to provide empirical evidence of individuals' risk attitudes. As we have seen above, these attempts can be classified into an experimental and an econometric approach, the latter being the most widely represented in the literature. *Article 2* in this dissertation contributes to the small number of articles which use the experimental approach for eliciting estimates of peasants' risk aversion.

Our experiment followed a method developed by Binswanger (1980, 1981). Binswanger measured attitudes toward risk in rural India. The same method was used later in the Philippines (Sillers, 1980), El Salvador (Walker, 1980) and Thailand (Grisley, 1980). As far as I know, no such studies have been done in sub-Saharan Africa. Using the same approach as in the previous studies, facilitates comparisons between the results from the different regions.

This approach uses experimental gambling with real payoffs which at maximum were equal to 30 percent of average total annual income per capita. Binswanger's experiments involved gambles with gains only. One elaboration of the experiment includes games with both gains and losses in the game sequence. Binswanger (1980) argued it was morally questionable to confront low income people with a gambling situation where they could actually loose money. Binswanger also argued that engaging individuals in games where the worst possible loss could exceed their current cash holding, would probably produce results reflecting the effects of budget constraints rather than risk preferences. To avoid these possible problems, we made sure the individuals had already won more money in previous game rounds, than they they could possibly loose in the gains-and-losses games.

We found that farmers in our sample revealed a wider spread in risk aversion as well as a more risk averse behaviour than farmers in similar studies in Asia. Our results were more in line with Walker's (1980) results from El Salvador, than the general pattern of moderate risk aversion found in studies in Asia. These results could indicate that the variation in risk preferences is different from area to area. However, we should not dismiss the possibility of the big spread in our data being a result of subjects choosing alternatives randomly, and that the individual risk estimates elicited in this study are not good estimates of the subjects' real risk aversion. These results could also indicate a difference in attitudes toward and/or experiences with gambling from culture to culture.

In the low levels of the games, individuals seemed to chose alternatives evenly spread from severe to slight-to-neutral risk aversion[6]. Only six to ten percent chose the «extreme» risk aversion category, and seven to eight percent the «neutral to preferring» risk aversion category. When the game level rose, the distribution shifted towards a more risk averse

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[6] The distribution of risk aversion in different types of games and at different game levels is shown in Table 5 in the second article of this dissertation.

attitude, and 80 percent of the subjects revealed moderate to extreme risk aversion in the highest level of the game.

In the experiment, subjects have, through choosing between six different alternatives, revealed which choice gives the highest utility. Assuming a utility function with constant partial risk aversion, each observed response would represent an interval of risk aversion into which the true, but unobservable, risk aversion coefficient falls. The implicit risk aversion interval was used as the dependent variable in a censored latent variable regression model. This model was used to test for correlation between different socio-economic variables and risk aversion. Furthermore, the model was used to investigate how game levels, previous luck and different types of games were correlated with risk aversion.

Our results indicate that the utility function should display increasing partial risk aversion. Wealth also seems to have an effect on risk aversion. We found evidence of decreasing absolute risk aversion (DARA) as wealth increases. This effect is, however, not necessarily directly related to a utility function in ultimate wealth.

We also found that people were more risk averse in games with gains and losses than in games with gains only. This indicates that people do not treat opportunity losses in the same way as real losses, and thus, that asset integration does not hold.

Several socio-economic variables seemed to be correlated significantly with risk aversion. Women chose more risk averse alternatives than men. This probably reflects traditional roles in this society, where men were warriors, and were expected to engage in dangerous and risky activities. Total farm land was positively correlated with risk aversion, supporting a hypothesis that when land is abundant, cultivating more land would be a risk-coping strategy. Family size was negatively correlated with risk aversion, indicating that a bigger family provides more labour and improved possibilities of insurance, diversification, and coping opportunities. A bigger family can tolerate and withstand more risk.

A variable for «luck» in previous games was also highly significant, suggesting the strong impact of prior luck on people's choices in these types of games. Subjects who had previously experienced «good luck» were more willing to take risk than subjects who had experienced «bad luck».

4.2 Risk, market imperfections and peasant adaptation

Risk and risk aversion have played central roles in explaining farm household technology choices in agriculture in developing countries. We have also seen that limited market access can also successfully explain the technology choices. Having access to individual risk aversion coefficients and extensive production and income data for a considerable number of households in northern Zambia, we wanted to test whether the risk aversion coefficient could contribute to explaining peasants' cropping decisions. Bearing in mind that market imperfections are also highly relevant for the peasants in this area, we did not want to exclude limited market access as a more significant or additional source of explanation. The third article in this dissertation examines the importance of both risk and market imperfections for farm households' land allocation decisions in northern Zambia.

Until recently, maize has been considered the most profitable, as well as the most risky crop. Maize production is dependent upon access to credit and to a supply of fertiliser. In a risk-free world with perfect markets and homogeneous land quality, the profit-maximising farmer would produce only maize. (- *and there would be no agricultural economists...*) If maize is a risky crop, and the farmer is risk-averse, he will, according to Sandmo, produce less maize than in the pure profit-maximising case. If labour, credit or commodity markets are imperfect, farm households might face resource constraints, and thus, endogenous shadow-prices which may also cause reduced maize production. Using farm household survey data, we tested the hypothesis that farm households' allocations of land to maize and *chitemene* are influenced by individual risk aversion as well as market imperfections in credit, labour and/or commodity markets.

Simple farm household models with the main focus on land allocation decisions were developed. Since the survey was done in an area where land is relatively abundant, one important assumption for the models was that the farm households can choose how much land to put into *chitemene* cultivation and maize production. The theoretical farm household models explore what happens when: a) labour markets are imperfect; b) credit markets are imperfect; c) commodity markets are imperfect; and d) there is risk in production of maize and *chitemene* crops and no insurance markets. These models helped in identifying relevant variables for the econometric estimations.

Censorship-corrected Three Stage Least Square (3SLS) regression systems models and Seemingly Unrelated Regressions (SUR) systems models were used to test for the effect of the different possible relevant variables on *chitemene* and maize areas.

The findings reported in the third article in this dissertation provide empirical evidence that both household specific socio-economic variables and different types of market imperfections influence farm households' cropping decisions in northern Zambia. We also found some weak evidence that households who revealed a high degree of risk aversion placed a smaller share of maize in their crop portfolio, other things being equal, than households who revealed a low degree of risk aversion. However, other constraints, rather than differences in risk preferences appeared to explain most of the variation in crop portfolios.

The findings provide evidence of imperfect credit and commodity markets. Access to credit seemed to be an important determinant of how much land farm households allocate to maize production. Distance to markets and size of the household appeared to be important factors in deciding how much subsistence crops to grow. Farm households living far away from town and farm households with big families to feed, put a relatively bigger area into *chitemene* cultivation, other things being equal, than did farm households living close to town and farm households with small families to feed.

Surprisingly, the empirical analysis provided no evidence that access to male labour had a significant impact on farm households' decisions about how much land to allocate to maize and *chitemene* cultivation. Other studies have documented highly imperfect labour markets in this area of Zambia. We therefore take these results as evidence of access to male labour not being a binding constraint in production.

The third article concludes that many circumstances seem to influence cropping decisions. Missing credit and commodity markets were found to be important determinants of how much (or how little) maize and *chitemene* crops the farm households decide to grow. Differences in risk preferences, however, seemed to have only a minor effect on cropping decisions. High degrees of risk aversion may influence farmers to have a smaller share of the mix devoted to maize. The results of structural adjustment policies during the last four to five years have been decreased profitability, increased risk, and reduced access to credit in maize production, which have probably further limited maize production in this area. Expansion of *chitemene* cultivation and more rapid deforestation are consequences of this. One important reason behind the government sponsored programs to stimulate maize production in northern Zambia from the late 1970s to the late 1980s, was to ease the population pressure and the successive deforestation through a shift from *chitemene* cultivation to maize production. If this development path is still desired, the results from this study indicate that policy options to increase maize production and reduce *chitemene* cultivation should recognise the importance of development of commodity markets and infrastructure, and improved access to credit.

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Individual Decision Making under Risk:
Deficiencies of and Alternatives to Expected Utility Theory[1].

Abstract:
Expected Utility (EU) theory has been the dominating approach within economic theory during the last 50 years. During the last 20 years EU theory has slowly lost ground, due to growing evidence that individuals do not maximise expected utility. This paper gives an overview of the EU theory and presents and discusses six different non-expected utility approaches. Some of the empirical violations of EU theory are reviewed. More complex non-expected utility models have been developed to account for some of the violations of the EU model. Bounded rationality theories include the limitations of decision makers in getting and processing information. This paper also presents three bounded rationality models using safety-first rules of thumb, which fit better with observed behaviour in situations were potential crisis situations are involved.

1.0 Introduction

The development of effective tools to address decision making under risk has been a major objective of economic research during the last 60 years. Economic theory of choice has changed from being one of the most settled branches of economics 15-20 years ago, to one of the most unsettled today (Machina, 1989). The main debate centres on the issue of continued supremacy of the classical «expected utility» (EU) model of individual choice under risk, in light of the growing evidence that individuals do not maximise expected utility.

This paper attempts to give an overview of major positions and developments in the debate on individual decision making under uncertainty or risk. The terms «risk» and «uncertainty» will be used synonymously throughout the paper (see page 43 for a further discussion of the distinction between these terms).

Chapter 2 gives a presentation of the EU theory and reviews some of the criticism of the EU approach. The EU theory is the «point of departure» because it has been the major paradigm in individual decision making under risk since World War II (Schoemaker, 1982). Twenty years ago it was still considered as one of the success stories of economic analysis with solid axiomatic foundations. Even today most of the alternatives to EU theory are modifications of the classical EU

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theory. These new theories are usually called generalised expected utility models. They all include the EU model as a special case. In chapter 3 we review a few of these generalised EU models.

Some of the criticism of the EU model has come from outside the discipline, particularly from psychologists who use the term «rationality» more broadly than economists (Hogarth and Reder, 1986). In chapter 4 we present «prospect theory», a model for decision making under risk developed by the two psychologists Tversky and Kahneman. Their theory has many similarities to the generalised EU-models.

Chapter 5 reviews results from testing between alternative models of choice under risk (the EU model, generalised expected utility models and prospect theory). The studies conclude that no model can account for all EU violations in a satisfactory manner.

Simon (1986) argues that theories on decision making under uncertainty should incorporate limitations of a decision maker to process all information on goals and means. In chapter 6 we present the arguments for «bounded rationality», and discuss some models using safety-first rules of thumb as indices of choice.

The paper concludes suggesting that EU maximisation is more the exception than the rule. Complex generalised EU models can, at the cost of simplicity, improve descriptive and predictive accuracy. Incorporating decision costs and bounded rationality into the EU models can also improve their predictive power. While the discipline will continue to have different theories coexisting, economists will have to choose which approach to use, depending upon the actual research problem.

2.0 The Expected Utility Theory

2.1 Background

During the development of modern probability theory in the 17th century, mathematicians such as Blaise Pascal and Pierre de Fermat (Machina, 1987) explained the attractiveness of a gamble offering the payoffs $(x_1,...x_n)$ with probabilities $(p_1,...p_n)$ by its expected value $EV=\sum x_i p_i$. The fact that individuals consider more than just expected value was clearly illustrated by an example posed by Nicholas Bernoulli in the early eighteenth century. The convincing example, now known as the «St. Petersburg paradox», was later investigated rigorously by Nicholas' cousin Daniel (Bernoulli, 1738/1954). In the St. Petersburg paradox the following game is proposed:

«You are offered to participate in a gamble, where a fair coin is flipped until a head appears. You will get $1 if a head appears on the first flip, $2 if it takes two flips to land a head, $4 if it takes three flips etc. Thus if a head first appears on the *n*th flip, the player is paid $$2^{n-1}$. What is the largest sure gain you would be willing to forgo in order to undertake a single play of this game?»

The expected value (EV) of the St. Petersburg paradox game is infinite:

$$EV = \sum_{i=1}^{\infty} p^i x^{i-1} = \sum_{i=1}^{\infty} (\tfrac{1}{2})^i 2^{i-1} = \tfrac{1}{2} + \tfrac{1}{2} + \tfrac{1}{2} + \ldots + \tfrac{1}{2} = \infty.$$

It is clear that few players will forgo more than a moderate amount to play this game. Bernoulli's solution to this paradox was to argue that individuals do not care directly about the dollar prizes of a game; a gain of $ 200 was not necessarily «worth» twice as much as a gain of $ 100; rather people respond to the utility these dollars provide. He hypothesised that the individuals possess what is now called a *von Neumann-Morgenstern utility function* u(.). Rather than using expected value EV= $\sum x_i p_i$, people evaluate gambles on the basis of expected utility U(X) = $\sum u(x_i) p_i$. Bernoulli did not, however, address the issue of how to measure utility, nor why his expectation principle would be rational. Thus his theory is mostly a descriptive model. It was not until John von Neumann and Oskar Morgenstern (1944) that expected utility maximisation was formally proved to be a rational decision criterion.

2.2 The von Neumann and Morgenstern expected utility model (EU)

In the following paragraphs we may think of a decision maker as choosing among probability distributions or prospects. The decision maker can choose an act **X** (prospect **X**), whose uncertain consequences are $x = (x_1, x_2, \ldots x_n)$ to be received with respective state-probabilities $p = (p_1, p_2, \ldots p_n)$ with $\Sigma p_i = 1$, $i=1,\ldots n$. The prospect **X** is then;

$$\mathbf{X} = (p_1, p_2, \ldots p_n; x_1, x_2, \ldots x_n) = (\mathbf{p}, \mathbf{x})$$

The entire consequence of an action is fully described by a prospect. The choice between different actions is thus equivalent to the choices between different prospects. Utility attaches directly to consequences, and only derivatively to actions. It is therefore important to bear in mind the crucial distinction between;

$u(x)$: a preference scaling function defined over consequences

$U(\mathbf{X})$: a utility function defined over actions (prospects)

(Hirshleifer and Riley, 1992)

The analytical problem is to show how, given his direct preferences over *consequences*, the individual can order the desirability of the *actions* available to him. By their «Expected-utility rule», von Neumann and Morgenstern (1944) have shown how to connect the u(x) function for consequences with the utility ordering U(X) of acts;

$$U(\mathbf{X}) = Eu = p_1u(x_1) + p_2u(x_2) + \ldots + p_nu(x_n) = \sum_{i=1}^{n} p_iu(x_i)$$

Von Neumann and Morgenstern proved that five basic axioms implied the existence of the «expected-utility rule». These axioms have been presented in slightly different ways in different papers and textbooks. Here I will present a set of axioms which is closely related to the original work of von Neumann and Morgenstern (1944). The set I present here is inspired by the works of Marschak (1950), Schoemaker (1982), Luce and Raiffa (1957), Angelsen (1993) and Hirshleifer and Riley (1992).

Axiom 1. Completeness and transitivity.

Preferences for prospects $\mathbf{X}_i$ are complete and transitive. Completeness means that the decision maker can always state whether $\mathbf{X}_1$ is preferred to $\mathbf{X}_2$ (denoted $\mathbf{X}_1 > \mathbf{X}_2$), $\mathbf{X}_2$ is preferred to $\mathbf{X}_1$ ($\mathbf{X}_1 < \mathbf{X}_2$), or whether both are equally attractive ($\mathbf{X}_1 \approx \mathbf{X}_2$). Transitivity means that if $\mathbf{X}_1 > \mathbf{X}_2$ and $\mathbf{X}_2 > \mathbf{X}_3$, then we should have $\mathbf{X}_1 > \mathbf{X}_3$.

Axiom 2. Continuity / Equivalent standard prospects.

Assume we have three different outcomes x_1, x_2 and x_3. If $x_1 > x_2 > x_3$, there exist some probability value p such that x_2 is equally preferred to an uncertain prospect $\mathbf{X}_0$ consisting of x_1 and x_3, where x_1 is realisable with probability p and x_3 with probability (1-p):

$$x_2 \approx \mathbf{X}_0 = px_1 + (1-p)x_3 = (p,x_1,x_3)$$

There exists one and only one value p that makes the decision maker indifferent between x_2 and the risky prospect $\mathbf{X}_0$. Such a prospect is called the equivalent standard prospect for x_2, and x_2 is called the certainty equivalent of the standard prospect $\mathbf{X}_0$.

Axiom 3. Preference increasing with probability.

Consider two alternative prospects, both with only two states with the same outcomes x_1 and x_2 ($x_1 > x_2$). The probabilities of x_1 is p in the first prospect and q in the second.

$$\mathbf{X}_1 = px_1 + (1\text{-}p)x_2 = (p,x_1,x_2)$$
$$\mathbf{X}_2 = qx_1 + (1\text{-}q)x_2 = (q,x_1,x_2)$$

The decision maker will prefer $\mathbf{X}_1$ to $\mathbf{X}_2$ if and only if $p > q$. This axiom states that the decision maker will always prefer a standard prospect with the highest chance of getting the higher-valued outcome.

Axiom 4. Rational equivalence.

A compound prospect is a prospect that for at least one of its outcomes has another prospect, rather than a certain outcome. Consider a compound prospect $\mathbf{X}_c$ with the probability p of winning the standard prospects $\mathbf{X}_1$ and the probability (1-p) of winning the standard prospect $\mathbf{X}_2$.

$$\begin{aligned}\mathbf{X}_c = (p,\mathbf{X}_1,\mathbf{X}_2) &= [p, (q_1,x_1,x_2), (q_2,x_1,x_2)] \\ &= p[q_1x_1 + (1\text{-}q_1)x_2] + (1\text{-}p)[q_2x_1 + (1\text{-}q_2)x_2] \\ &= [pq_1 + (1\text{-}p)q_2]x_1 + [p(1\text{-}q_1) + (1\text{-}p)(1\text{-}q_2)]x_2\end{aligned}$$

The axiom states that the compound prospect is equally attractive as the simple prospect that would result when multiplying probabilities through according to standard probability theory. Thus if we set:

$$p^* = pq_1 + (1\text{-}p)q_2$$

we can then define the *rational equivalent* prospect of X_c as:

$$\mathbf{X}_r = (p^*,x_1,x_2)$$

According to the axiom $X_c \approx X_r$. The axiom asserts that the decision maker rationally evaluates the probabilities of ultimately obtaining the two outcomes, and is not at all affected by the two (or more) stages of the gamble. There is no risk illusion present.

Axiom 5. Independence of irrelevant alternatives.

Consider three prospects X_1, X_2 and X_3. If $X_1 > X_2$, then the standard prospect X_{11} consisting of winning X_1 with probability p and X_3 with probability (1-p) will be preferred to the prospect X_{12} consisting of X_2 and X_3 with the same probabilities:

$$X_{11} = (p, X_1, X_3) > X_{12} = (p, X_2, X_3)$$

In the certainty case the independence axiom is a strong assertion, because there can be many types of substitutability or complementarity relationships between two goods. In the case of preferences for uncertain prospects, however, the individual will never get X_1 and X_3 together or X_2 and X_3 together. It is therefore unlikely that the presence of X_3 will affect the preferences for X_1 and X_2.

Given the above axioms it can be proved (see Baumol, 1972) that the decision maker maximises his expected utility as defined by the expected utility rule:

$$U(X) = Eu = p_1u(x_1) + p_2u(x_2) + \ldots\ldots\ldots + p_nu(x_n)$$
$$= \sum_{i=1}^{n} p_iu(x_i)$$

The expected utility rule states that the decision-maker will make choices as if he maximises the utility in the different states weighted by the probabilities for each state to occur. The expected utility rule is applicable if and only if the utility function u(x) has been determined in a particular way such that utility (intensity of preference) is a cardinal rather than an ordinal variable. A cardinal utility function will give the same ranking of probability distribution after any positive linear transformation ($v(x) = \alpha + \beta u(x)$, α and β constants, $\beta > 0$). This is a stronger restriction than for the standard, ordinal utility function we use when dealing with certainty choices. For an ordinal utility function (I prefer basket A to basket B) any positive monotonic transformation is valid. The only requirement is that the first derivative of the utility function is positive. In EU theory (with cardinal utility function) the sign of the second derivative of the utility function is also important, and can not change during a valid transformation. An intuitive explanation of this is that when someone can rank consequences in terms of preferences in the certainty case we don't need more information for the purpose of making a decision. He will choose the action giving him the preferred consequence. In the uncertainty case, however, it is not evident how a ranking of consequences leads to an ordering of actions, since each action implies different probabilities for the different consequences. It now becomes important also to know «how much more» utility the decision maker gets from basket A than from basket B.

The expected utility function has dropped the linearity in outcome compared to the expected value form ($\Sigma p_i x_i$), but still retains linearities in probabilities. We will discuss this property further in paragraphs 2.2.3 and 2.3.

The entire u(x) curve is determined by finding the certainty equivalents of standard lotteries. The decision maker is faced with a standard lottery yielding the best possible outcome x_3 with probability p, and the worst possible outcome x_1 with probability (1-p). The question is: what is the decision maker's certainty equivalent c such that he is indifferent between c and the standard lottery:

$$u(c) = U(p, 1-p; x_3, x_1)$$

After proceeding assigning cardinal preference values to income in the same way for numerous standard lotteries, we can generate the u(c) function over the range from x_1 to x_3.

2.2.1 Risk Preferences

We assume that the utility function is twice differentiable. The first derivative of u(x) is positive (more income is preferred to less). The second derivative of u(x) depends on the decision maker's preferences toward risk.

A decision maker is faced with a gamble and given the choice whether he will accept the gamble or receive for certain the expected outcome of the gamble. A risk averse individual will prefer the certain income, a risk neutral individual will be indifferent between the two and a risk lover will prefer the gamble.

In Figure 1 we see three preference scaling functions u_1, u_2 and u_3 representing respectively a risk averse, risk neutral and risk loving decision maker. For the prospect (p, x_1, x_3) with expected outcome $Ex = x_2$, Jensen's inequality will give three different results for the three different u-functions. We see that;

when $u''(x) < 0$ then $u(px_1 + (1-p)x_3) > pu(x_1) + (1-p)u(x_3)$

when $u''(x) = 0$ then $u(px_1 + (1-p)x_3) = pu(x_1) + (1-p)u(x_3)$

when $u''(x) > 0$ then $u(px_1 + (1-p)x_3) < pu(x_1) + (1-p)u(x_3)$

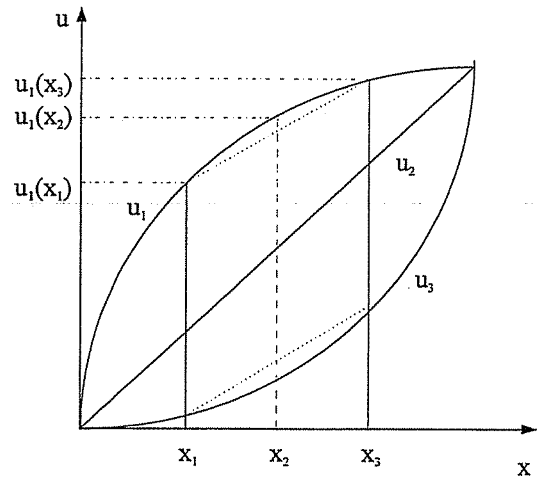

Figure 1. Attitudes toward risk.

Risk aversion, implying concave utility curves like u_1 and diminishing marginal utility ($u''(x)<0$), is considered to be the normal case. The intuitive way of understanding risk aversion is that a possible loss of a given size is more important than a gain of the same size.

In the study of economic choices in risky situations, it is often convenient to have a quantitative measure of how averse to risk a person is. The most commonly used measure of risk aversion was originally developed by Pratt (1964), but is now often called the Arrow-Pratt measure of *absolute risk aversion*:

$$R_a = - u''(x) / u'(x)$$

Arrow (1970) also provided another measure of risk-aversion which he called *relative risk aversion*:

$$R_r = - xu''(x) / u'(x)$$

The two measures are both positive for a risk averse individual (u''(x)<0). Arrow assumed that a person will be more willing to accept risk as his income increases, i.e. a decreasing absolute risk aversion (DARA) with increasing wealth. This seems to be supported by intuition. But as we will see below, whether the R_a and R_r is decreasing or increasing depends on the precise shape of the utility function. Arrow also assumed increasing relative risk aversion (IRRA) with increased wealth. This is not as intuitively obvious as a decreasing absolute risk aversion. Arrow (1970) explains the increasing relative risk aversion as «the assertion that if both wealth and the size of the bet are increased in the same proportion, the willingness to accept the bet (....) should decrease». He continues to defend the increasing R_r hypothesis by showing its consistency with general theoretical principles and by its success in explaining economic behaviour.

Table 1. Functional forms for utility functions.

Utility function	**U''(x)**	**R_a**	**R_r**	**Risk preference structure**
Quadratic $U=a+bx+cx^2$	2c	$-\frac{2c}{b+2cx}$	$-\frac{2cx}{b+2cx}$	-requires U'(x)=b+2cx>0 -risk preferring if c>0, risk aversion if c<0 -IARA, IRRA
Exponential $U=K-\theta e^{-\lambda x}$	$-\lambda^2\theta e^{-\lambda x}$	λ	λx	-CARA, IRRA
Cubic $U=a+bx+cx^2+dx^3$	2c+3dx	$-\frac{2c+6dx}{6+2cx+3dx^2}$	$-\frac{(2c+6dx)x}{6+2cx+3dx^2}$	- R_a and R_r can be positive or negative depending upon parameters c, d and the level of income x.
Semilog U=a+b logx	$-\frac{b}{x^2}$	$\frac{1}{x}$	1	-imposes risk aversion. DARA, CRRA -all individuals have same R_a-value for any value of x
Modified power $U=a+bx^c$	$(c-1)cb^{x-2}$	$\frac{1-c}{x}$	1-c	-requires b>0 and c≥0 -risk averse if c<1 (DARA, CRRA), risk neutral if c=1, risk seeking if c>1.
Expo-power $U=\theta- e^{-\beta x^\alpha}$	$\alpha\beta e^{-\beta x^\alpha} x^{\alpha-2}$ $[\alpha-1-\alpha\beta x^\alpha]$	$\frac{1-\alpha+\alpha\beta x^\alpha}{x}$	$1-\alpha+\alpha\beta x^\alpha$	-parameter restrictions: θ>1, α≠0, β≠0, αβ>0 -DARA if α<1, CARA if α=1, IARA if α>1, DRRA if β<0, IRRA if β>0

In the empirical risk literature, a variety of different functional forms for a decision maker's utility has been used. Most of these forms require certain restrictive a priori assumptions on the decision maker's risk preference structure[2]. In Table 1 above, 6 different functional forms for utility functions are presented. Columns 3 and 4 show the different absolute and relative risk aversion coefficients, while column 5 summarises the restrictions on the risk preference structure.

A well known method of analysing decision making under uncertainty is the mean-variance analysis. This analysis is consistent with the expected utility theorem under the assumptions that: a) The possible returns associated with each alternative facing the decision maker are normally distributed, or; b) The decision maker's preferences can be represented by a quadratic utility function. (Roumasset, 1976; Hazell and Norton, 1986). As we see in Table 1 above, the quadratic utility function is characterised by increasing absolute risk aversion (IARA), and has therefore been rejected as faulty by many theorists (e.g. Pratt, 1964). For a discussion on mean-variance analysis see Hazell and Norton (1986).

A few studies have compared results from using different functional forms for the utility function. Zuhair *et al.* (1992) compared the quadratic, exponential and cubic utility function on data on harvesting behaviour in Sri Lanka. They found that in contrast to the exponential utility function which imposes risk aversion on all farmers, the quadratic utility function classified 90 percent of the farmers as risk-averse, while the cubic utility function classified half of the farmers as risk-averse and half as risk-preferring. In their study they also found that the exponential utility function performed the best in predicting overall farmer behaviour.

Musser *et al.* (1984) used elicited data from graduate students and compared quadratic, semilog and modified power functional forms. The semilog function imposes risk aversion, and thus found all individuals to be risk averse. The quadratic form found 3 decision makers to be risk averse, while the 10 others to be risk neutral. The modified power function found all 13 individuals to be risk neutral.

These studies demonstrate that caution must be observed in analysing utility functions derived from a specified functional form. Depending upon the functional form chosen by the researcher, decision makers may be classified as risk averse, risk neutral or even risk preferring.

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[2] See Saha (1994), p. 174 for a list of papers focusing on risk preference structure, and their principal findings.

A substantial body of research has found evidence of risk aversion (for example Antle, 1987; Binswanger, 1980, 1983; Just, 1974; Szpiro, 1986). There is, however, not enough empirical evidence to support Arrow's argument that utility functions should exhibit decreasing absolute risk aversion (DARA). Both Pope (1982) and Wolf and Pohlman (1983) have shown that it is ambiguous whether absolute risk aversion decreases (DARA), stays constant (CARA) or increases (IARA). Empirical findings are also ambiguous when it comes to justifying whether relative risk aversion is increasing (IRRA), constant (CRRA) or decreasing (DRRA) (Cohn *et al*, 1975; Szpiro, 1986; Wolf and Pohlman, 1983; Saha *et al.* 1994).

Saha (1993) argues that «given the ambiguity of empirical evidence regarding the observed nature of absolute and relative risk aversion, a priori reasons to assume a particular risk preference structure usually are weak.» He continues arguing that a flexible utility function, free from risk preference restrictions, may prove useful in providing the underpinning for risk programming and simulation models. This utility function should allow the data to «reveal» not only the degree of risk aversion, but the structure of risk preferences (whether it is DARA, CARA or IARA) as well. He proposed a new utility function, expo power (Table 1, row 6), that exhibits decreasing, constant or increasing absolute risk aversion and decreasing or increasing relative risk aversion, depending on parameter values.

2.2.2 Marschak-Machina triangle.

We can get additional insight into the expected utility model by presenting it graphically in a Marschak-Machina triangle (from Marschak, 1950 and Machina, 1982). The graphical presentation below will give an illustration of the property of linearity in the probabilities (independence axiom). The same graphical presentation will be useful in some of the following discussions on violation of the expected utility theory. The presentation below follows the work of Machina (1987).

Consider the prospect X with the outcome levels $x_1<x_2<x_3$ and corresponding probabilities p_1, p_2 and p_3, $\sum p_i=1$. Since $p_2=1-p_1-p_3$, it is possible to express the utility of the prospect depending only on p_1 and p_3:

$$U(X) = p_1u(x_1) + (1-p_1-p_3)u(x_2) + p_3u(x_3) = c, \quad c = \text{constant}$$

The individuals' indifference curves are given by the above equation. We have:

$$p_1(u_1-u_2) + p_3(u_3-u_2) = c - u_2, \quad u_1=u(x_1),\ u_2=u(x_2), \text{ etc.}$$

The indifference curves will consist of parallel straight lines with the slope given by:

$$dp_3/dp_1|_{U=c} = (\delta U_1/\delta x_1) / (\delta U_3/\delta x_3) = (u_1-u_2) / (u_3-u_2)$$

The indifference curves are shown in Figure 2. A movement toward Northwest in the triangle will lead to increased preference, as the probability of the highest income (x_3) increases as we move north, and a leftward movement reduces the probability of x_1 to the benefit of the probability of x_2. All Northwest movements lead to stochastically dominating lotteries, and will therefore, as stated in axiom 3, be preferred.

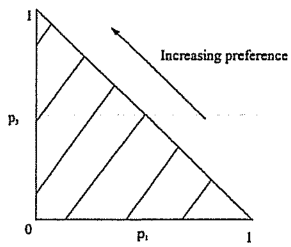

Figure 2. *Expected utility indifference curves in a p_1p_3 diagram.*

This diagram can also be used to illustrate attitudes towards risk. By drawing the iso-expected value lines (dashed lines in Figure 3) given by:

$$E(x) = p_1x_1 + (1-p_1-p_3)x_2 + p_3x_3 = k, \quad k = \text{constant}$$

We find the slope of the iso-expected value lines in the same way as for the indifference curves:

$$dp_3/dp_1|_{U=k} = (x_1-x_2) / (x_3-x_2)$$

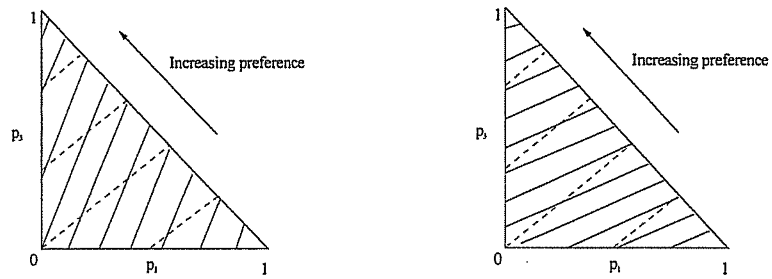

Figure 3. Indifference curves (solid lines) and expected value lines (dashed lines). The left triangle shows the steeper indifference curves for a risk averter. The triangle to the right illustrates the flatter indifference curves for a risk lover. (from Machina 87)

These curves will also be parallel straight lines. Moving Northeast on these lines increases the probabilities of the tail outcomes x_1 and x_3 at the expense of the middle outcome x_2. Thus risk increases while expected outcome remains constant. For a risk averter (concave u-function) the indifference curve is steeper than the iso-expected value curve, i.e. as we move to the Northeast (higher risk) on a iso-expected value curve we get lower indifference curves. For a risk lover (convex u-function) the opposite is the case, the iso-expected value curves are steeper than the indifference curves and increasing risk will lead to higher indifference curves. This can also be shown in the following way:

Whenever $x_1<x_2<x_3$ and u(x) is concave, we have by definition:

$$(u_2-u_1)/(x_2-x_1) > (u_3-u_2)/(x_3-x_2) \quad \Leftrightarrow$$

$$(u_2-u_1)/(u_3-u_2) > (x_2-x_1)/(x_3-x_2)$$

This expression shows that the indifference curves are steeper than the iso-expected value curves when the utility function is concave (risk-aversion). In the same way we can show that the opposite holds when the utility function is convex (risk-lover). In the case of risk neutrality, the curves would, of course, be parallel.

2.3 Subjective probabilities

So far we have treated probabilities as if they are measurable and *objective*. Objective probability can be defined as «...the relative frequency or properties of occurrences of A if conditions C are realised a large number of times...) (Roberts, 1979, in Zuhair, 1986), or as «...the limit of relative frequency...» (Roumasset, 1976). 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 realised on a large number of tosses.

Roumasset (1976) argues that while objective probability may be a useful hypothetical construct for some decision-making situations, it has little value in real world decision making. Bessler (1984) states that «...subjective probability is well accepted in the theory of individual choice. Almost nobody today argues for its non-existence or its inappropriateness for describing rational choice under uncertainty. Among theorists of individual decision making, the heated debates about types of probability are essential reading only for historical purposes...».

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). Savage formalised a theory of consistent preferences under uncertainty wherein an individual's ordering among acts implicitly defines his subjective probabilities over the relevant states-of-the world. The basic idea is that if an individual is indifferent between x_1 with certainty and a lottery with outcomes x_2 and x_3, then his subjective probability of the occurrence of x_2 is given by p in the relationship (Roumasset, 1976):

$$u(x_1) = pu(x_2) + (1-p)u(x_3)$$

where $u(x_i)$ is the individual's utility function of the certain consequence i.

The only normative criterion applied to these subjective probabilities is that they meet a condition of coherence (Bessler, 1984). The coherence principle can be explained 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, 1984, in Zuhair, 1986). This principle implies that a set of probabilities for a particular system of bets should not guarantee *a priori* a winner or loser (Bessler, 1984). The condition of coherence can be used to derive the entire calculus of probability. Thus the usual restrictions applying to disjunction (addition), conjunction (multiplication) and equivalence can be used (Bessler, 1984).

Assuming subjective instead of objective probabilities is an important step towards a more realistic choice-model. But even models using subjective probabilities assume stable probabilities. This assumption may be too strong. Empirical studies using coin-flips (i.e. Binswanger, 1980, 1981) have shown that people's choices get influenced by luck in prior games. If the decision-maker has had luck in one or two prior games, he tends to choose a more risky prospect than he would otherwise have done. This indicates that subjective probabilities may not be stable, but may be influenced by the decision-maker's state of mind, prior luck, superstition etc. The human brain does not necessarily accept that all games are independent and with the same distribution of probabilities.

Knight (1921) defined risk as a situation where the alternative outcomes exist with known probabilities, whereas uncertainty refers to a situation where the probabilities are unknown. Knight emphasised the measurability of probabilities in making the distinction, rather than the extent to which they are known to the decision maker. «Since in Savage's system of personal probability, it is not necessary that probabilities be either known or measurable, modern analysis no longer views the two classes (risk and uncertainty) as different in kind.» (Roumasset, 1976).

The question how to estimate underlying probabilities seems to depend on whether the purpose of the study is normative or positive. In both cases the subjective definition of probabilities apply. If the study is normative, the best-guess of the analyst should be used. If the study is descriptive we need to estimate the subjective probabilities of the decision-maker. (Roumasset, 1976).

2.4 Critique of the EU model

The EU-model is being challenged on several grounds, both from within and outside economics. In the next paragraphs I will present some of the main critique of the model. But before starting the discussion on the acceptability of the model, it is important to have a clear idea about its purposes. A model should be evaluated according to its stated objectives. Schoemaker (1982) distinguishes four different purposes the EU model can serve:

(1) The model can be used *descriptively* to describe the decision processes under risk and uncertainty. Validity of underlying axioms and evidence on the manner in which information is being processed are important when the model is used explanatory.

(2) Often the model is viewed as *predictive* or *positivistic*. The importance is whether the model is more accurate in predicting actual behaviour than competing models, and not how realistic the assumptions behind the model are.

(3) Those who view the EU-model as a *postdictive* model, believe that all observed human behaviour is optimal. If it seems to be suboptimal, it is just because it is not modelled in the appropriate manner (new considerations like costs, constraints etc. should be introduced).

(4) When the model is used *prescriptively* or *normatively*, the implicit assumption is that human behaviour is not necessarily optimal. The model is then used to improve decisions in complex decision situations based on the individual's basic tastes and preferences.

The criticism of the EU model is mainly towards its abilities as a descriptive and predictive model. As the evidence against the model arises, there is a growing tension between those who view economic analysis as the description and prediction of what they consider to be rational behaviour and those who view it as the description and prediction of observed behaviour (Machina, 1987).

The large «dissident» literature on decision making under uncertainty shows that decision makers do not always behave according to the Expected utility rule. A large part of this literature has been supported by experimental evidence. Below a few examples of violations of the EU-theory follow.[3]

2.4.1 Framing effects

The EU theory is insensitive to differences in contexts. Several authors (e.g. Slovic, 1969; Hersey and Schoemaker, 1979; Tversky and Kahneman, 1981) have shown that alternative ways of representing or «framing» similar choice problems will lead to systematic differences in actual choices.

Hersey and Schoemaker (1979) gave subjects the following two choices:

Gamble formulation:

1a. A sure loss of $ 10.

1b. A one percent chance of loosing $ 1,000.

Insurance formulation:

2a. Pay an insurance premium of $ 10.

[3] For excellent and more complete surveys of the empirical testing of the EU-theory, see Schoemaker (1982) or Machina (1987).

2b. Remain exposed to a hazard of losing $1,000 with a one percent chance.

According to EU theory the two choices are identical. But people do not treat them as identical. Hershey and Schoemaker found that 56 percent preferred the sure loss in the gamble formulation, while 81 percent preferred to pay the insurance premium in the insurance formulation.

Another good example of how framing influences choices is given by Tversky and Kahneman (1981). Two groups were given the following cover story: Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the programs are as follows:

Group 1:

- If program A is adopted, 200 people will be saved. (72 percent chose A)
- If program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved. (28 percent chose B)

Group 2:

- If program C is adopted 400 people will die. (22 percent chose C)
- If program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die. (78 percent chose D)

Again the two choice-sets are identical according to EU-theory. The only difference is that group 1 got the outcomes described as lives saved, and group 2 as lives lost. We see that this change in wording leads to a considerable shift from risk aversion to risk taking.

2.4.2 Preference reversal phenomenon.

«Preference reversal occurs when individuals are presented with two gambles, one featuring a high probability of winning a modest sum of money (the P bet), the other featuring a low probability of winning a large amount of money (the $ bet). The typical finding is that people often choose the P bet, but assign a larger monetary value to the $ bet.» (Slovic and Lichtenstein, 1983).

The expected utility theory implies that the bet which is actually chosen also will be the one which will be assigned the largest selling or buying price. But the psychologists Slovic and Lichtenstein (1983) had observed in a study in 1968 (Slovic and Lichtenstein, 1968) that «choices among pairs of gambles appeared to be influenced primarily by probabilities of winning and loosing, whereas buying and selling prices were primarily determined by the dollar amounts that could be won or lost». Following this observation they argued that, «if the information in a gamble is processed differently when making choices and setting prices, it should be possible to construct pairs of gambles such that people would choose one member of the pair, but set a higher price on the other.» In their 1971 (Lichtenstein and Slovic, 1971) article they presented a study using a small set of pairs of gambles that clearly demonstrated the predicted effect. A typical set of pair would be:

P-bet: 99 percent chance of winning $ 4
1 percent chance of losing $ 1
expected outcome: $ 3.95

$-bet: 33 percent chance of winning $ 16
67 percent chance of loosing $ 2
expected outcome: $ 3.94

The participants were confronted with several sets of pairs of gambles similar to this. Expected outcome of the two gambles were always almost the same. Some of the gambles had a slightly higher outcome for the P-bet, others for the $-bet. First the participants were asked to choose which game they would prefer to play. Later they were told that they had the ticket to play the bet and was asked to name a minimum selling price for the ticket, such that they would be indifferent to playing the bet or receiving the selling price. Lichtenstein and Slovic (1971) found that 73 percent of the participants consistently gave a higher price to the $-bet even though they had chosen the P-bet. The opposite reversal, choosing the $-bet, but giving a higher price to the P-bet, was almost never found.

The economists Grether and Plott (1979) designed a pair of experiments which controlled for such economic explanations as income effects, real vs. hypothetical payoffs, hidden incentives, strategic misrepresentation, etc. They nonetheless found preference reversal phenomena in their experiments.

2.4.3 The common consequence effect.

The best known example of violation of the independence axiom (linearity of probabilities) is Allais paradox (Allais, 1953): Individuals are presented with the following two pairs of gambles:

1. A1: 100 percent chance of $ 1,000,000

A2: 10 percent chance of \$ 5,000,000
89 percent chance of \$ 1,000,000
1 percent chance of \$ 0

2 A3: 10 percent chance of \$ 5,000,000
90 percent chance of \$ 0

A4: 11 percent chance of \$ 1,000,000
89 percent chance of \$ 0

It has been found that most people prefer A1 to A2, and A3 to A4. This seems to be quite reasonable, but is as we will see below, inconsistent with the expected utility theory:

A1 > A2 implies:

$1\ u(1{,}000{,}000) > 0.1\ u(5{,}000{,}000) + 0.89\ u(1{,}000{,}000) + 0.01\ u(0)$, or

$0.11\ u(1{,}000{,}000) > 0.1\ u(5{,}000{,}000) + 0.01\ u(0)$, or

$0.11\ u(1{,}000{,}000) + 0.89\ u(0) > o.1\ u(5{,}000{,}000) + 0.9\ u(0)$

The last inequality is equal to A4 > A3, which is the opposite of what most people actually choose.

The Allais paradox is now known as a special case of a general empirical pattern called the common consequence effect. The name comes from the «common consequence» 1,000,000 in gamble 1 and 0 in gamble 2. According to the independence axiom, an individual's preferences in one event should not depend on the outcome in another event. The common consequence effect shows that it may well depend upon what would otherwise happen. (Winning a car as the top price in a lottery might make you happier than winning a car in a lottery where the top price is \$ 5,000,000 (see Bell, 1982) The common consequence effect states that the better off the individual would be in the event of a tail (in the coin-flip scenario), the more risk averse they become in the event of a head.

The common consequence effect can also be illustrated in a p1-p3 diagram as used earlier. Using the figures from Allais Paradox as example we define (x_1, x_2, x_3) = (\$ 0; \$ 1,000,000; \$ 5,000,000). Then we have the corresponding probability vectors p_1=(0,1,0), p_2=(0.01,0.89,0.1), p_3=(0.9,0,0.1) and p_4=(0.89,0,0.11). These four gambles form a parallelogram in the p1-p3 triangle, as in figure 4

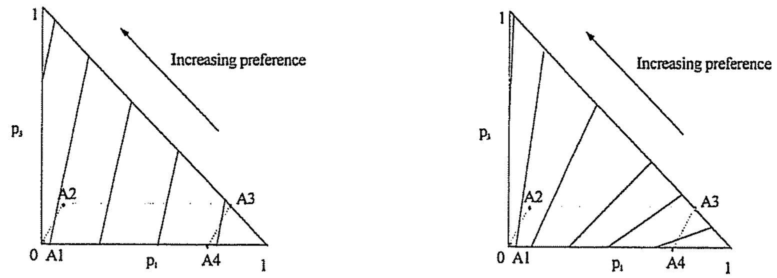

Figure 4. Expected utility indifference curves (left) and indifference curves which fan out (right) and the Allais paradox. (Machina, 1987)

We see that under the expected utility hypothesis (linearity in probabilities), a choice of A1 to A2 is only consistent with a choice of A4 to A3. In the alternative case when the indifference curves had been relatively flat a choice of A2 in the first set would be consistent with the choice of A4 in the second. To be consistent with observed behaviour (the common consequence effect) the indifference curves have to fan out (be less steep as you go to the Southeast) and not be parallel as assumed by the expected utility theory.

2.4.4 The common ratio effect.

Another closely related violation of the independence axiom is what is often called the common ratio effect or certainty effect (Kahnemann and Tversky, 1979). Individuals are asked to make choices in the following two gambles:

1. A1: 100 percent chance of $ 3,000
   A2: 80 percent chance of $ 4,000
   20 percent chance of $ 0

2 A3: 25 percent chance of $ 3,000
   75 percent chance of $ 0
   A4: 20 percent chance of $ 4,000
   80 percent chance of $ 0

The majority (80 %) chose A1 in the first gamble, while 65 % chose A4 in the second gamble. In the same way as for the common consequence effect it can be shown that these choices are not consistent with expected utility theory. The choice of A1 in the first gamble implies u(3,000)/u(4,000)>4/5 (u(0)=0), while the choice of A4 in the second gamble implies the reverse inequality. Note that the ratio of the probabilities of winning are the same in the two gambles (1/0.8 = 0.25/0.2), from this comes the name the common ratio effect.

In Figure 5 we see the above example, explained in a p1-p3 triangle with indifference curves which fan out. If the indifference curves had been parallel (as in EU theory), we would have seen that the choices A1 and A4 was not consistent with EU theory.

In their paper Kahneman and Tversky (1979) present several examples of this effect. As for the common consequence effect we see that people are attracted to a certain gain (A1) rather than a gamble with a slightly higher expected value (A2). But when it comes to games where the chance of winning anything at all is relatively small, people seem attracted to the gamble with the largest price (A4) (Sugden, 1987).

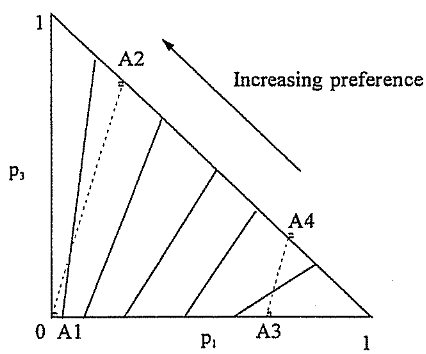

Figure 5. Indifference curves which fan out and the common ratio effect (Machina,1987)

Interestingly, Kahneman and Tversky (1979) did not find this rule to hold for gambles involving losses. Conducting the same experiment as above, but with possible losses of $ 3,000 and $ 4,000, they found that 92 % chose A2 and 58 % chose A3. These choices also violate the independence axiom. Following the expected utility theory we would expect individuals to choose either A1 and A3 or A2 and A4. Moreover people choose the gamble with the lowest expected value and the highest variance in the first game. It seems like the small possibility of not loosing anything is more important than a small increase in expected loss. When it comes to the second game people choose the gamble where the worse outcome is less bad.

As a response to these violations of the independence axiom, new theories of decision making under uncertainty have emerged. Several authors have made modifications to the Expected Utility model to avoid independence. Some of these new models are included in the group called *generalised utility models* (see chapter 3). Kahneman and Tversky (1979) have developed a different theory called *prospect theory* (see chapter 4). Both generalised utility models and prospect theory models are usually classified as *non expected utility models.*

2.4.5 Ellsberg's paradox - ambiguity aversion.

Another paradox that has puzzled economists and psychologists since its presentation is the Ellsberg Paradox (Ellsberg, 1961). One of his famous examples goes as follows: One ball is to be drawn at random from an urn containing 90 balls, 30 of which are red (R) and 60 of which are black (B) or yellow (Y) in unknown proportion. Consider the following two pairs of lotteries.

1. A1: Receive $ 1,000 if R, otherwise nothing.
   A2: Receive $ 1,000 if B, otherwise nothing.

2. B1: Receive $ 1,000 if R or Y, otherwise nothing.
   B2: Receive $ 1,000 if B or Y, otherwise nothing.

Ellsberg claimed, and later experiments have verified (Fishburn, 1988), that most people prefer A1 to A2 and B2 to B1. This paradox thus contradicts Savage's substitution principle (additive subjective probabilities). Since A1 is preferred to A2, we find the subjective probability of drawing a red ball p(R) to be bigger than the subjective probability of drawing a black ball p(B): $p(R)>p(B)$. Preferring B2 to B1 in the second game gives $p(R\cup Y)<p(B\cup Y)$, and hence $p(B)>p(R)$. This is inconsistent with additive subjective probabilities. Not only expected utility theory, but most other theories of rational behaviour under uncertainty assume that probabilities are additive. The Ellsberg paradox thus challenges all these theories.

Some models try to explain the Ellsberg paradox by using nonadditive probabilities (e.g. Fishburn, 1983a; Einhorn and Hogart, 1985), while Segal (1987) tries to explain the paradox using a model in which probabilities are additive, but not multiplicative (i.e. does not satisfy the rational equivalence axiom).

2.5 How to avoid the violations?

We have now seen several examples of empirical violations of the EU theory. The vast literature on decision making under uncertainty suggests many different solutions to the problem that decision-makers do not consistently follow the expected utility rule. Many economists have suggested adjustments to the EU model in such a way that the vast body of theoretical results and intuition we have developed within the expected utility framework can still be used. Much of this literature centres around the violation of the independence axiom (linearity in probabilities) (Chew and MacCrimmon, 1973; Machina, 1982; Fishburn, 1983; Chew, 1983; Quiggin, 1982; Quiggin, 1993; Dekel, 1986). Models addressing the common consequence effect and the common ratio effect (independence axiom) seek to generalise EU theory by introducing some form of a decision weight as a function of the probabilities (Buschena and Zilberman, 1994). The *fanning out hypothesis* (chapter 3.1) and *weighed utility theory* (chapter 3.2) are examples of theories addressing violation of the independence axiom. The *regret/rejoice theory* (Bell, 1982; Loomes and Sugden, 1982) (chapter 3.4) and the *skew-symmetric bilinear theory* (Fishburn, 1982, 1983, 1984) (chapter 3.3) can account for the intransitivities experienced in the preference reversal paradox in addition to the behaviour under the common consequence and common ratio effects. The *implicit expected utility theory* (chapter 3.5) should be able to account for both violations of the independence axiom and the Ellsberg Paradox. All these models are called *generalised utility models* because they include the EU model as a special case.

Another theory which also avoids the independence axiom is *prospect theory* (Kahneman and Tversky, 1979). This model is similar to the generalised EU models in the use of a decision weight as a function of the probabilities. But since it does not include EU as a special case, it is not comprehended as a generalised utility model. This theory is outlined in chapter 4.

There exist no unified model capable of simultaneously handling all of the EU violations. Many phenomena are especially difficult to explain. These include framing effects, reversals of preferences, and aversion to ambiguity. See Machina (1987) and Buschena and Zilberman (1994) for a discussion on how these violations will impact the way we view and model economic behaviour under uncertainty.

A different school of thought believes that the decision maker has limitations in his ability to process information on goals and means. Theories which include these limitations are called *theories of bounded rationality* (Simon, 1955, 1986; Roumasset, 1976). Some theories using bounded rationality «rules of thumb» are outlined in chapter 5.

3.0 Generalised utility models

In this chapter I will give a short introduction to models which clearly build on the expected utility theory, but try to avoid some of the violations of this theory.

3.1 The fanning out hypothesis.

In some of the above examples we have seen violations of the assumption of linearity in probabilities (produced by the independence axiom). In this chapter we will look at models which abandon the independence axiom, but retain the other axioms. The fanning out hypothesis was first put forward by Machina (1982). This presentation is based on the more easily accessible presentation in Sugden (1987) (See also Machina, 1987 for a readable presentation).

In chapter 2.2.4 D and E we saw graphically in a p1-p3 diagram how indifference curves which fan out would be consistent with the common consequence and common ratio effects. In this paragraph we will discuss the properties of the utility functions that yield indifference curves which fan out.

In expected utility theory we have seen that the local utility function is the same for every prospect, that is U(x;p) = U(x;q) for all p,q. If we drop the independence axiom, different prospects may have different local utility functions. The fanning out hypothesis is then described in terms of properties of these local utility functions (Sugden, 1987). Machina (1982) discusses the properties of these utility functions. The two most important such properties are (from Sugden, 1987):

1) Each local utility function U(x,F), where F is a probability distribution, should be increasing in x. This ensures that stochastically dominating distributions are always preferred. In the p1-p3 diagram it means that the indifference curves slope upwards.

2) Let R(x;F) be the Arrow-Pratt measure of absolute risk aversion at x on the local utility function U(x;F):

$$R(x;F) = -[\delta^2 U(x;F)/\delta x^2] / [\delta U(x;F)/\delta x]$$

For any two distributions F_1 and F_2, where F_1 stochastically dominates F_2 we have: $R(x;F_1) \geq R(x,F_2)$. In other words, when we move towards stochastically dominating distributions, the degree of local risk aversion associated with any given level of wealth increases (or at least, does not decrease). In the triangle diagram this means that as we move north or west, indifference curves get steeper, i.e. greater risk aversion. In this way the indifference curves will tend to fan out.

Several non-linear functional forms for the individual preference function have been suggested in the literature (see Machina, 1987). In the following paragraphs we will look briefly at some of these models.

3.2 Weighted utility theory

A simple functional form, which has proved to be very useful both theoretically and empirically (Machina, 1987), was first suggested by Chew and MacCrimmon (1979) (See also Fishburn, 1983b and Chew, 1983). Chew and MacCrimmon wanted to weaken the independence axiom to explain the Allais paradox. Weak independence assumes that for each probability q, there is a probability r for which X~Y (X indifferent to Y) implies qX+(1-q)Z ~ rY+(1-r)Z for any Z. (EU independence, also called strong independence, requires q=r) (Camerer, 1989). The weighted utility functional form is:

$$U(p_1,\dots p_n) = [\Sigma_i\, u(x_i)p_i] \,/\, [\Sigma_i\, w(x_i)p_i]$$

u(·) and w(·) are two *different* functions of the same kind as in ordinary EU theory. The utility of the prospect as a whole is the ratio between two expected utility measures. We see that if $w(x_i)=1$ for all i, we will get back to standard EU theory.

For the special case, where there are just three pure consequences ($p_1<p_2<p_3$), indifference curves in the p1-p3 diagram are defined by $V(p_1.p_2,p_3)=v^*$. Using the Chew-MacCrimmon functional form we get:

$$[u_1p_1 + u_2(1-p_1-p_3) + u_3p_3] \,/\, [w_1p_1 + w_2(1-p_1-p_3) + w_3p_3] = v^*$$

By rearranging this expression, we get:

$$p_1\,[v^*(w_1-w_2) - (u_1-u_2)] + p_3[v^*(w_3-w_2) - (u_3-u_2)] = u_2 - v^*w_2$$

The slope of the indifference curve is:

$$dp_3/dp_1|_{U=v^*} = -\,[v^*(w_1-w_2) - (u_1-u_2)] \,/\, [v^*(w_3-w_2) - (u_3-u_2)]$$

Since all variables determining the slope are being held constant, the indifference curves are linear. It can also be shown that only two such equations, i.e. $V(p_1,p_2,p_3)=v^*$ and $V(p_1,p_2.p_3)=v^{**}$ can be linearly independent (Sugden, 1987). Hence, the equation for the indifference curves defines a set of linear indifference curves which all intersect at the same point. This point must, to be meaningful (when $1 \geq p_1+p_3 \geq 0$), lay outside the triangle of meaningful prospects. This is illustrated in Figure 6.

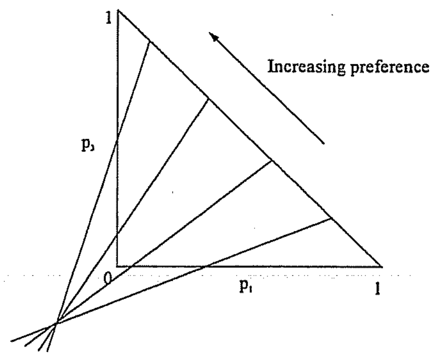

Fig. 6. Chew-MacCrimmon fanning out indifference curves in a p_3p_1 diagram

This Figure shows that the Chew-MacCrimmon model satisfies both of Machina's requirements as long as the indifference curves intersect at a point south-west of the origin. The intersection point depends on the nature of the functions u(·) and w(·)

3.3 Skew symmetric bilinear utility

Skew symmetric bilinear (SSB) utility functions were suggested by Fishburn (1982, 1983, 1984). The theory does not use the transitivity and the independence axioms. This presentation is based on the more accessible presentation in Camerer (1989).

In SSB utility, preferences are defined over pairs of gambles (X,Y) and is represented by a function $\phi(X,Y)$. If $\phi(X,Y)=U(X)-U(Y)$, then SSB reduces to EU. The function is bilinear if it is linear in each argument (i.e. $\phi(\alpha X,Y+(1-\alpha)Z,Y) = \alpha\phi(X,Y)+(1-\alpha)\phi(Z,Y)$), and skew-symmetric if $\phi(X,Y)=-\phi(Y,X)$.

Fishburn (1982, 1983) showed that SSB functions represent preference if they satisfy the following 3 axioms:

1. Continuity: If X>Y and Y>Z then $Y\sim\gamma X+(1-\gamma)Z$ for at least one $0<\gamma<1$

2. Dominance: If X>Y and X≥Z then $X>\lambda Y+(1-\lambda)Z$; if Y>X and Z≥X then $\lambda Y+(1-\lambda)Z>X$; if X~Y and X~Z then $X\sim\lambda Y+(1-\lambda)Z$

3. Symmetry: If X>Y>Z, X>Z and Y~0.5X+0.5Z, then αX+(1-α)Z ~ 0.5X+0.5Y, if and only if αZ+(1-α)X ~ 0.5Z+0.5Y

When Y=0.5X+0.5Y indifference curves must be symmetric around the 45-degree line in a triangle diagram. The indifference curves will be straight lines due to a dominance axiom that ensures bilinearity. If transitivity is not assumed, the indifference curves can meet at a point inside the triangle (Figure 7).

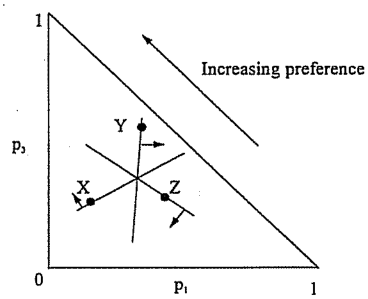

Fig. 7. Indifference curves in the triangle diagram for the SSB model when transitivity is not assumed.

When transitivity is assumed, then indifference curves meet outside the triangle, and SSB utility is equivalent to weighted utility (Camerer, 1989; Fishburn, 1983).

3.4 Regret theory

Given the fact that the independence axiom is frequently and systematically violated, we could conclude either that people are not rational, or that the independence axiom is not a necessary property of rational choice (Sugden, 1987). In consumer theory we have complementarity for physical mixtures of commodity bundles because the goods are consumed simultaneously. It has been assumed that since prospects in a probability mixture are mutually exclusive, there is no reason to think that an individual's preference between two prospects should be influenced by the nature of a third prospect in which they are combined (Samuelson, 1952). The fact that the independence axiom is frequently and systematically violated, suggests that there exist some kind of complementarity effect also in the case of mutually exclusive prospects. This is the basis of regret theory.

In regret theory «the utility you derive from a particular consequence of one action may be influenced by a consequence of a different action» (Sugden, 1987). The significance of regret and the regret model was developed independently by Bell (1982) and Loomes and Sugden (1982). This presentation is based on Sugden (1987):

A decision maker has a choice between two actions, he chooses one action and as a result he receives the consequence x_i. He knows that if he had chosen the other action he would have received the consequence x_j. There is a composite experience: having x_i and missing out on x_j. This experience may involve regret if x_i is worse than x_j, or rejoicing if x_i is better than x_j. A cardinal utility function $M(x_i,x_j)$ is defined to take account of regret or rejoicing. The two prospects $p=(p_1.....p_n)$ and $q=(q_1....q_n)$ are both defined in terms of the consequences $x=(x_1....x_n)$. The prospects are assumed to be statistically independent. If the decision-maker chooses p, the probability of receiving x_i is p_i. Had he chosen q, the probability that he would have received x_j would have been q_j. Thus the probability of receiving x_i and miss out on x_j is p_iq_j. The expected utility of choosing p rather than q is then:

$$\Sigma_i\Sigma_j\ p_iq_jM(x_i,x_j)$$

Then if p is preferred to q, we have:

$$\Sigma_i\Sigma_j\ p_iq_jM(x_i,x_j) > \Sigma_i\Sigma_j\ p_iq_jM(x_j,x_i)$$

We can define a new function $\Omega(.,.)$ by:

$$\Omega(x_i,x_j) = M(x_i,x_j)-M(x_j,x_i)$$

This formulation of regret theory is skew symmetric $[\Omega(x_i,x_j) = -\Omega(x_j,x_i)]$, and it corresponds exactly with Fishburn's SSB theory under intransitivity (Fishburn, 1982, 1984). Thus Figure 7 also gives a graphical presentation of regret theory. Sugden (1987) shows that there is also convergence between regret theory and weighted utility theory. The only real difference between these theories is the transitivity or nontransitivity of preferences. If the transitivity axiom is dropped in weighted utility theory, we will get regret theory (or SSB theory). The three theories diverge further if we do not assume statistically independent prospects.

The common ratio effect and it's reverse, the common consequences effect and some types of systematic non-transitivities (preference reversal) can be accounted for by regret theory (Loomes and Sugden, 1982). It can not, however, explain framing and context effects or violations of Savage's sure thing principle.

3.5 Implicit expected utility theory.

The implicit expected utility theory was developed by Chew (1985) and Dekel (1986). The presentation in this paragraph is based on Camerer (1989):

The theory is called implicit because it allows the utility function in EU to depend upon the expected utility:

$$U^* = U(X) = \Sigma_i p_i u(x_i, U^*)$$

Implicit expected utility describes a decision maker who uses a different utility function, perhaps reflecting different degrees of risk aversion, along each indifference curve. Therefore, curves do not necessarily fan out or fan in uniformly.

The only axiomatic difference from the EU theory is that the independence axiom is changed to the substantially weaker betweenness axiom (Dekel, 1986). This axiom states that if $X > Y$, then $X > qX+(1-q)Y > Y$ for any probability q, i.e. any gamble which is a probabilistic mixture of X and Y should be between them in preference. From this axiom and continuity we have that if a person is indifferent to X and Y then he will also be indifferent to any probability mixture of X and Y (if ($X \sim Y$, then $X \sim qX+(1-q)Y \sim Y$ for all q). Since the decision maker is indifferent between X, Y and any probability mixture of the two, and the probability mixture is located at the line segment between the two, the indifference curve must be a straight line. In Figure 8 we see the implicit expected utility theory graphically in a p_l-p_h diagram.

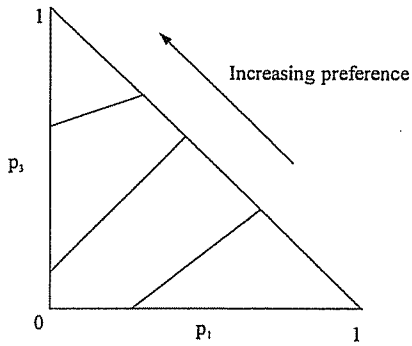

Fig. 8. Indifference curves for the implicit expected utility model.

This theory should be able to account for violations of the independence axiom and the Ellsberg Paradox (Dekel, 1986)

4.0 Prospect theory

The prospect theory of Kahneman and Tversky (1979) is included in the group of decision models called non expected utility models. But it does not include EU as a special case, and is therefore not a generalised expected utility model.

The prospect theory model was presented as a descriptive model to account for the common ratio effect, the common consequences effect and their reverses and some types of framing effects. Kahneman and Tversky (1979) distinguished two phases in the choice process. In the initial phase, prospects are edited to make them simpler to evaluate. In this phase outcomes are coded as gains or losses, prospects are simplified by combining probabilities associated with identical outcomes, risky components are segregated from riskless components, components that are shared by the offered prospects are cancelled, etc. The edited prospects are then evaluated according to one of the expectation-like rules that combine a value v(X) and a decision weight Π(p):

Consider a regular prospect (x,p;y,q) and either $p+q<1$ or $x\geq 0\geq y$ or $y\geq 0\geq x$, then the overall value of the prospect is:

$$V(x,p;y,q) = \Pi(p)v(x) + \Pi(q)v(y)$$

When the prospects are strictly positive or strictly negative, the evaluation follows a slightly different rule. In the editing phase the prospects are segregated into a riskless component (the minimum gain or loss which is certain to be gained or paid) and a risky component (the additional gain or loss which is actually at stake). I.e. if $p+q=1$ and either $x<y<0$ or $x>y>0$, then:

$$V(x,p;y,q) = v(y) + \Pi(p)[v(x)-v(y)]$$

In prospect theory, all outcomes are framed as changes (gains or losses) from a neutral reference point. The value function v(.) gives a measure of the value of changes of wealth, rather than final asset positions that include current wealth (as in EU theory). Kahnemann and Tversky propose that the value function is commonly S-shaped. It is normally concave above the reference point, and often concave below the reference point as in Figure 9. This means that the marginal value of both gains and losses generally decreases with their magnitude. Another property of the value function is that the response to losses is more extreme than the response to gains, i.e. the function is steeper below the reference point than above. The displeasure you get from losing a sum of money is generally greater than the pleasure of winning the same amount of money. This is also reflected in people's reluctance to accept fair bets on a toss of a coin (Tversky and Kahneman, 1981).

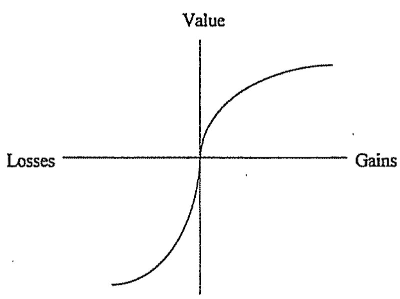

Figure 9.A hypothetical value function.

Another major departure of prospect theory from the EU model is the treatment of probabilities. While in EU models the uncertain outcome is weighted by its probability, the uncertain outcome in prospect theory is multiplied by the decision weight $\Pi(p)$. The decision weight $\Pi(p)$ is a monotonic function of p, but is not a probability and should not be interpreted as a measure of degree of belief. The weighting function Π has the following properties:

(1) Π is an increasing function of p, with Π(0)=0 and Π(1)=1. This means that impossible events are discarded, and the scale is normalised so that Π(p) is the ratio of the weight associated with the probability p to the weight associated with the certain event.

(2) Low probabilities are overweighted, that is Π(p)>p. At the same time, prospect theory suggest that for all 0<p<1, Π(p)+ Π(1-p)<1. This property is labelled *subcertainty*. It implies that as low probabilities are overweighted, moderate and high probabilities are underweighted. The underweighting of medium and high probabilities is more pronounced than the overweighting of low probabilities.

(3) The property of *subproportionality* means that for a fixed ratio of probabilities, the ratio of the corresponding decision weights is closer to unity when the probabilities are low than when they are high. This is: Π(pq)/Π(p) < Π(pqr)/Π(pr) for 1≥p,q,r>0.

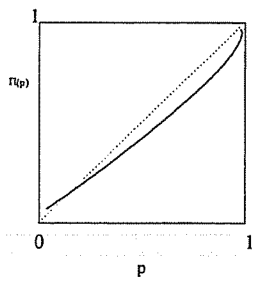

Figure 10. A hypothetical weighting function.

A hypothetical weighting function which satisfies these properties is shown in Figure 10. «People are limited in their ability to comprehend and evaluate extreme probabilities. Highly unlikely events are either ignored or overweighted, and the difference between high probability and certainty is either neglected or exaggerated» (Kahneman and Tversky, 1979). The discontinuities of Π at the endpoints are consistent with this notion.

According to prospect theory, attitudes toward risk are determined jointly by v and Π and not only by the utility function as in EU theory. Consider the choice between the gamble (x,p) and its expected value (xp). If x is a gain, risk seeking follows whenever $\Pi(p)v(x)>v(xp)$, or $\Pi(p)>v(xp)/v(x)$. The right hand side of the last inequality is greater than p by definition when the value function for gains is concave. Thus, overweighting ($\Pi(p)>p$) is necessary for risk seeking when $x>0$. Exactly the same condition is also necessary for risk aversion in the domain of losses. This analysis restricts risk seeking for gains and risk aversion for losses to small probabilities, where overweighting is expected to hold. We know these are the typical conditions under which lottery tickets and insurance policies are sold. Kahneman and Tversky (1979) warned that even though prospect theory predicts both insurance and gambling, these complex phenomena are not adequately accounted for by this analysis.

Tversky and Kahneman (1981) emphasised that «prospect theory should be viewed as an approximate, incomplete and simplified description of the evaluation of risky prospects. Although the properties of v and Π summarise a common pattern of choice, they are not universal: the preferences of some individuals are not well described by a S-shaped value function and a consistent set of decision weights. The simultaneous measurement of values and decision weights involves serious experimental and statistical difficulties.»

5.0 Testing between alternative models

Several papers present results from testing between alternative models of choice under risk.

Camerer (1989) reported results from empirical testing of five different generalised EU theories (weighted utility, implicit expected utility, fanning out hypothesis, lottery-dependent utility and rank-dependent utility) and prospect theory. He concludes that each theory can account for some of the EU violations, but not all.

Battalio, Kagel and Jiranyakul (1990) came to the same conclusion while testing between rank dependent expected utility theory, regret theory, fanning out hypothesis and prospect theory.

Harless and Camerer (1994) rejected all tested theories (expected utility, fanning out, fanning in, mixed fanning, rank dependent utility, prospect theory, implicit expected utility and weighted utility). They find that «for every theory there is systematic variation in excluded patterns which could, in principle, be explained by a more refined theory.» They argue that the choice of theory must depend upon the purpose of the research.

Hey and Orme (1994) tested the EU model and nine different generalised utility models (disappointment aversion theory, prospective reference theory, quadratic utility, regret theory (with and without independence), rank dependent utility (with two different weighting functions), weighted utility and Yaari's dual model). They concluded that «...EU appears to fit no worse than any of the other models...» and «behaviour can be reasonably well modelled ... as 'EU plus noise'» Instead of spending more time on thinking about developing even more alternatives to EU, Hey and Orme argue that more time should be allocated to thinking about the noise (nonconsistency in choices).

6.0 Bounded rationality

Rationality can be defined as taking action consistent with goals, means and constraints. (Zuhair 86). Simon (1957) distinguished between theories incorporating all the means and all the constraints, in a global sense (traditional neoclassical models), and theories incorporating limitations of a decision maker to process this global information on goals and means. Simon (1986) compared rational aspects of behaviour as defined by economists and psychologists. He concluded that economics sometimes use the term «irrationality» rather broadly, and the term «rationality» correspondingly narrowly, so as to exclude from the domain of the rational many phenomena that psychology would include in it. (Simon, 1986). The rational person of traditional neo-classical economics always reaches the optimal decision according to his utility function. The rational person of cognitive psychology is making his decisions in a way that is procedurally reasonable in the light of the available knowledge and means of computation. Simon argued that if we accept the proposition that both the knowledge, and the computational power of the decision maker are severely limited, then we must distinguish between the real world and the actor's perception of it and reasoning about it. Human rationality can then at best be an extremely crude and simplified approximation to the kind of global rationality that is implied in traditional neo-classical economics. (Simon, 1955). Theories which include the limitations of a decision maker in processing information are here called *theories of bounded rationality*.

Simon argues that a decision maker acts in a satisficing manner rather than an optimising manner as a result of the following characteristics (Zuhair, 1986):

a. Cognitive process: The human mind has an inherent limitation on its power to assimilate information.

b. 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.

c. Man's computational efficiency: Not only is man's cognitive power limited, but also his thinking ability. Simon (1982) claims that man's thinking process is serial (one thing leading to another), and declares that the human mind cannot solve a problem to find an optimal solution. Rather the limitations result in a satisficing sub-optimal solution.

Satisficing behaviour 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.

Expected utility maximisation, like ordinary utility maximisation, can be described as a «full optimality model». One of the criticisms of the optimality models in general is the exclusion of decision costs. (Radner, 1972). The full optimality models do not take account of the limited capacities of individual decision makers for imagination and computation. Roumasset (1976) stated that when costs of obtaining and processing information are substantial, it is not necessarily rational for an individual to act consistently with his underlying preferences (i.e. following the EU-rule). He continued (Roumasset, 1976): «A complete preordering only guarantees that an individual can make binary comparisons. But going from the binary comparisons to the most preferred alternative is not a trivial step. In fact, Kramer (1967) has shown that given a preordering over a set of possible acts it is impossible for a finite information processing devise to generate choices consistent with the preordering. The implication of all this is that full optimality models are, in many cases, not likely to be useful in describing human behaviour.» The case for building models according to behavioural models instead of full optimality models is summarised in Day's (1971) quote: «In other words, rational men do not behave according to models which smart men can't solve.»

These comments are directed at full optimality decision making in general. It is obvious that they are even more relevant to the theory of choice under uncertainty, since consideration of numerous possible outcomes greatly compounds the complexity of the decision problem (Roumasset, 1976).

Georgescu-Roegen (1958) argues that bounded rationality may be particularly useful for decision making in agriculture because the farmer has imperfect knowledge of future events, and his ability to use the available information in computations is limited. Roumasset (1976) reasons that «this is all the more applicable to peasant farmers in developing countries. Not only is the ability to process available information limited by education, but the benefits of so doing are undoubtedly smaller for smaller farms».

Traditional neo-classical economists are likely to reply to these arguments that we need only incorporate decision costs into descriptive models in order to make full optimality a relevant principle. Roumasset (1976) shows the decision maker's problem then is to decide on a decision-procedure that he will use to make his ultimate decision. But this problem can only be solved using the full-optimality approach in which the decision costs of choosing a decision process are assumed in turn to be zero. Without that assumption the procedure may involve an infinite regress. In this respect Roumasset (1976) quotes Winter (1969):

> «I take it for granted that the regress must be stopped, that «the set of all procedures for choosing a procedure from the set of all procedures from the set of all procedures...(ad inf.)» is not sufficiently well-defined to be the foundation for a theory of rational choice.»

Another difficulty with selecting among decision procedures where the costs of those procedures are assumed to be known, is that real world decision-makers typically do not know the costs of making decisions until they have made them.

During the last decade, a new paradigm has partially replaced the traditional neoclassical model (Hoff, Bravermann and Stiglitz, 1993). The new paradigm is sometimes called the *Economics of Information* or the *Economics of Imperfect Information* (see also Phlips, 1988). This new school has partly emerged from, and is specially relevant for, development economics, since an environment of pervasive risks, incomplete markets, information asymmetry, and moral hazard is particularly acute in developing countries (Bardhan, 1989). Instead of assuming perfect information and complete markets as in traditional neoclassical economics, it assumes that economic institutions (including markets and property rights) reflect «rational» responses to economic problems. The institutions have to be understood in order to come up with efficient policy recommendations. This new theory «is neoclassical under the broad definition of neoclassical theory as the systematic exploration of the implications of rational, individualistic behaviour subject to constraints» (Hoff *et al.*, 1993). To my knowledge, this new school has not come up with alternative theories of choice. But since it is mainly concerned with imperfect information and transaction costs, it should be open to the arguments that the full optimality approach might be a weak basis for modelling decision making under uncertainty, especially for small farms in developing countries. Instead we might agree that under certain circumstances rules of thumb and partial optimisation might be more in accordance with rational behaviour than using EU maximisation.

6.1 Safety first models

In order to avoid some of the problems with expected utility maximisation, researchers have explored the potential usefulness of rules-of-thumb as alternate indices of choice. In this process we first need to define risk as the probability that the stochastic variable (often net income) will take on a value less than some critical minimum or disaster level. (Roumasset, 1976). Several writers (see below) have concluded that security varies inversely with risk and that concern with both income and security can therefore be modelled by rules-of-thumb which incorporate the probability of disaster. Most of these rules fall under the general heading of «safety first». Pyle and Turnovsky (1970) identified three such rules of thumb which fall into the broad category of safety-first decision models. Roumasset claimed that all other rules can be treated as special cases of these. The three safety-first models are (the presentation is based on Roumasset (1976), Zuhair (1986) and Anderson (1979)):

1. Safety principle (Cramer, 1930; Marschak, 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 minimisation of the probability that some objective function, usually profits, falls below a specified disaster level. This can be expressed as:

$$\min \alpha \equiv P(\pi < \bar{d})$$

where, α is 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.

2. **Strict safety first principle** comprises maximising an objective function, usually expected profits, subject to a constraint on disaster expressed in terms of an exogenously specified crucial probability. This can be expressed as:

$$\max E(\pi) \quad \text{subject to} \quad \bar{\alpha} \geq P(\pi<\bar{d})$$

where expected profit $E(\pi)$ is the objective function, $\bar{d}$ is the exogenously determined disaster level and $\bar{\alpha}$ is the exogenously specified probability limit.

3. **Safety-fixed principle** maximises the minimum return which can be attained with a fixed confidence level. That is:

$$\max d \quad \text{subject to} \quad \bar{\alpha} \geq P(\pi<d)$$

where d is the minimum return and $\bar{\alpha}$ is the exogenously determined probability of income being below the minimum return.

Roumasset (1976) discussed which of these three rules is the best. He argued that it depends on the particular research problem at hand, but also stated that there are some *a priori* characteristics of the rules which may also help to choose among them.

Both the safety principle (1) and the safety-fixed principle (3) ignore the expected value of income. The safety principle (1) in particular seems especially inappropriate for discriminating between choices of low risk. A very small difference in the probability of disaster will be treated as an important criterion in choice, even if the less favoured prospect has an expected value many times higher than that of the favoured one. The safety-fixed principle (3) is contrary to the idea of a disaster level determined by the situation of the decision maker. The strict safety first principle (2) is concerned with both the probability of disaster and with the expected value of income, but has another weakness. Roumasset (1976) argued that since it takes both $\bar{\alpha}$ and $\bar{d}$ exogenously, there is no guarantee that the constraint can be satisfied for all the available alternatives, in which case the strict safety first principle does not yield a complete preference ordering. If the constraint is violated by all alternatives this principle will not give a solution.

6.2 Lexicographic safety first rules.

Chipman (1960), Encarnation (1964) and Kunreuther and Wright (1979) have indicated that a lexicographic ordering may be a more appropriate way of structuring a class of decisions than by using a cardinal utility framework. Roumasset (1976) suggested to eliminate the weaknesses of the safety principle by ordering the two rules lexicographically as follows:

$V(\pi) \equiv 1 - \max[\alpha', F_\pi(d')]$ (probability of disaster)

$W(\pi) \equiv [V(\pi), E(\pi)]$ (decision rule)

where, π is a vector of choice variables, F_π is the cumulative distribution of π, $E(\pi)$ is the expected value of π, d' is the exogenously determined disaster level and α' is the exogenously specified probability level.

Roumasset (1976) summarised this decision rule as: «maximise expected value whenever the chance constraint is met, and minimise the probability of disaster when it isn't».

Roumasset also developed another lexicographic safety first model. This model chooses prospects by «maximising expected value whenever the strict safety first constraint (2) is met, and follows the safety fixed rule (3) when it is not». (Anderson, 1979).

These lexicographic safety first models hold some of the advantages of both the full optimality and bounded rationality approaches. The models are consistent with full optimality models in the sense that a complete lexicographic ordering fulfils the usual axioms for consistent choice. At the same time the model facilitates a formal description of satisficing (through for instance $V(\pi) = 1 - \max[\alpha', F_\pi(d')]$).

6.3. Status model

Buschena and Zilberman (1994) have developed a model that combines the treatment of discrete problems by safety rules with the axiomized treatment of decisions under risk by the EU and generalised EU models.

The status model incorporates an indicator variable D, having the value 1 if an adverse event (such as bankruptcy or starvation) occurs and 0 if the event does not occur. The probability of the adverse situation occurring depends on income x, i.e. $P(D=1)=f(x)$. The von Neumann-Morgenstern utility representation, $u_i(x) = u(x, D=i)$, depends on the value of D (i=0,1) in addition to income. For instance $u_1(x)$ may represent the utility of a farmer who retains ownership of his land, while $u_0(x)$ represents the utility of a farmer who had to give up his ownership of land and must rent the land. The function f(x) denotes the probability that the farmer will need to sell the land when his income equals x.

Then the decision maker's maximisation problem is:

$$EU(D,x) = \int_x u_1(x)[f(x)]g(x)\,dx + \int_x u_0(x)[1 - f(x)]g(x)\,dx$$

$$= \int_x u_1(x)f_1(x)\,dx + \int_x u_0(x)f_0(x)\,dx$$

where g(x) is the density function for x, $f_1(x)= [f(x)]g(x)$, and $f_0(x)= [1 - f(x)]g(x)$. The independence axiom could hold for a constant level of D, but, if both levels of D could occur, the independence axiom in general would not hold.

The status model has both safety rule models and the EU model as special cases. The safety-rule model is a special case when $u_0(x)$ is extremely negative, and $f(x)=1$ if $t \geq x$ for some level of income t. The EU model is special case when $u_1(x) = u_0(x)$ and g(x) are objective probabilities.

The disadvantage of this model is that it requires considerable knowledge of the the decision maker's situation and the nature of the decision problem.

7.0 Concluding remarks

Economic research over the last 60 years has identified and established the important role that risk management often has in the economy. Different tools to address decision-making under risk have been developed. Even though these issues have been given much effort and have been the foci of a considerable amount of research, researchers are still confused and unsure about modelling risk.

The expected utility theory has been the major paradigm in individual decision making under uncertainty the last 50 years (Schoemaker, 1982). The success of this model is due to its simple and general form, and the bold and testable predictions produced by the model (Angelsen, 1993). A large body of experimental evidence has cast doubt upon the validity of the EU theory as a descriptive and normative theory of choice under risk. Schoemaker (1982) concluded that «at the individual level EU maximisation is more the exception than the rule». He concluded that as a descriptive model EU theory fails on at least three counts. First, people do not structure problems in a holistic and comprehensive way. Second, people do not process information, particularly probabilities, according to the EU theory. Third, EU theory is a poor predictor of actual choice in laboratory situations. EU theory should therefore probably not be used as a general descriptive model.

All the EU violations, might, at first glance, seem to strengthen the case for a formal decision analysis «as a way of circumventing and supplementing the suboptimal nature of intuitive, unaided decision making» (Schoemaker, 1982). Schoemaker argued that before we decide that the EU theory provides a good normative model, we should consider the following two implications: First, some of the violations described (specially regarding the axioms) may be so basic that they render the normative theory inoperational (i.e. construction of utility functions compatible with the EU axioms). Second, persistent of the EU model violations (even after the decision maker is made aware of his inconsistencies) may raise questions as to its normative validity.

New models have been developed to account for violations of the EU model. Most of these are modifications of the EU theory which increases the complexity (generalised EU models). We then have a classic trade-off problem between simplicity and descriptive and predictive accuracy. Moreover, empirical testing of the new theories have shown that no single theory so far developed appears to be able to account for all of the violations of the EU theory.

Incorporating costs of decisions and bounded rationality into the EU model may improve the predictive power of the model. Buschena and Zilberman (1994) argued that expected utility is constrained in explaining actual behaviour because behaviour under risk is affected by anxieties and decision costs that are not incorporated into the model. They argued that quantification of these elements is not easy and might require assistance and methodologies from other disciplines.

It seems like the discipline will, for still a long time to go, have several different and competing theories coexisting. Which approach to use will have to depend upon the actual research problem. While EU theory may work well for portfolio analysis where there is no crisis outcome under complete optimisation, safety rules may be more advantageous for modelling when potential crisis situations are involved. It may be relevant to choose a combination of approaches and test relative performance.

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Experimental Studies of Peasant's Attitudes toward Risk in Northern Zambia[1]

Abstract

Attitudes toward risk were measured for 143 persons in Northern Zambia, using an experimental gambling approach with real payoffs which at maximum were equal to 30 percent of average total annual income per capita. The experimental measures indicate that on average more than 80 % of the farmers are moderately to extremely risk averse; that they exhibit decreasing absolute risk aversion and increasing partial risk aversion; and, that they are more risk averse in games with gains and losses than in games with gains only. Farmers in Northern Zambia showed both a wider spread in risk aversion and a more risk averse behaviour than farmers in similar studies in Asia.

1. Introduction

Knowledge of how subsistence farmers make decisions is important in determining strategies for agricultural development. There is evidence that poor peasant farmers are risk averse (Moscardi and de Janvry, 1977; Dillon and Scandizzo, 1978; Binswanger; 1980, 1981, 1982 and Binswanger and Sillers, 1983), and that their production and economic environment is characterised by a high degree of uncertainty (Roumasset, 1976). These general conclusions and observations have stimulated considerable research into the effects of risk on peasants' adaptation. Some studies have focused on production decisions and choice of technology (Wolgin, 1975; Adesina *et al.*, 1987; Antle and Crissmann, 1990; Nanseki and Morooka, 1991). Other studies have analysed risk coping and risk management strategies, for example, risk sharing (Udry, 1990, 1994; Townsend, 1994), or use of assets or savings to cope with risk (Udry, 1995; Dercon, 1996). Bromley and Chavas (1989) and Carter (1997) conclude that

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traditional risk management strategies (such as risk-sharing at village level or crop diversification) can have serious negative implications for economic development.

In Zambia, Structural Adjustment Programs (SSAPs) have resulted in significant changes in economic policies since the early 1990s. Removal of pan-territorial prices and subsidies has lead to increased price variation for outputs as well as inputs. Reduced government involvement in production and marketing is followed by contraction in credit supply to peasant farmers. In addition to a risky production-environment, peasants are confronted with new forms of market risk.

Considerable research has attempted to provide empirical evidence of individuals' risk attitudes. These attempts can be classified into an experimental and an econometric approach. The experimental approach is based on hypothetical questions regarding risky alternatives or risky games with or without real payments. Dillon and Scandizzo (1978) used hypothetical questions to elicit risk attitudes of subsistence farmers in northeast Brazil. Binswanger (1980, 1981), Binswanger and Sillers (1983) and Quizon *et al.*(1984) used risky games with real payments to measure peasants' risk preferences in a large scale experiment in rural India. Others who have applied the same general experimental method are Sillers (1980) in the Philippines, Grisley (1980) in Thailand, and Walker (1980) in El Salvador. To our knowledge, no earlier published studies on risk attitudes of peasants in sub-Saharan Africa exist.

The econometric approach is based on individuals' actual behaviour. The pioneering work by Moscardi and de Janvry (1977) used a safety-first rule approach. Later, individual risk attitudes have been elicited assuming expected utility maximisation. One of the best-known methods is that of Antle (1983, 1987, 1989), but Bardsley and Harris (1987), Love and Buccola (1991), Pope and Just (1991), Saha *et al.* (1994), Chavas and Holt (1996) and Bar-Shira *et al.* (1997) are all examples of econometric approaches assuming expected utility maximisation.

The econometric approach is criticised for confounding risk behaviour with other factors such as resource constraints faced by decision makers (Eswaran and Kotwal, 1990). Thus, it may appear as if individuals are more risk averse than they truly are (Binswanger, 1982, Wik and

Holden, 1996). This is particularly important in developing countries where market imperfections are prominent and production and consumption decisions, therefore, are non-separable (Singh *et al.*, 1986; de Janvry *et al.*, 1991; Sadoulet and de Janvry, 1995). Zambian peasants are faced with market imperfections such as: rationed credit markets interlinked with input supplies; seasonal, rationed or missing labour markets; missing land markets; missing insurance markets; and missing or very thin (and seasonal) commodity markets (Holden, 1997). For our purpose in Zambia, therefore, we found an experimental approach for eliciting estimates of peasants' risk aversion to be the most appropriate.

The purpose of this study is to measure peasants' risk attitudes, to compare these to estimates found in other studies and other regions, and to identify how these estimates are correlated with individual and socio-economic characteristics such as sex, age, wealth etc. Using the results of our research we discuss whether the assumption of asset integration holds. In Section 2, we briefly discuss expected utility (EU) theory and some of its controversies, and we define some measures for risk aversion. Section 3 presents the methodological approach for the experiment and the empirical estimation, and detailed hypothesis are discussed. In section 4, we present the results of the experiment, compare these results to findings from similar research in other countries, and give the results from the empirical estimation. Conclusions are offered in Section 5.

2. Theory.

The von Neumann-Morgenstern expected utility theory has been the dominant approach within economic theory of decision-making for the last 50 years. Growing experimental evidence that individuals do not maximise expected utility (Allais, 1953; Ellsberg, 1961; Slovic and Lichtenstein, 1968; Kahneman and Tversky, 1979)[2] has lead to developments of new, more complex non-expected utility models over the last 15-20 years (Machina, 1987; Battalio *et al.*, 1990).

One commonly stated fault of the EU model is that individuals are not making choices among different sets of prospects according to objective probabilities. Experimental evidence has shown that they tend to overweigh small-probability outcomes and underweight high

[2] For a review of the literature on experimental testing of the expected utility model see Appleby and Starmer (1987).

probability outcomes. Psychologists (i.e. Edwards, 1962; Kahneman and Tversky, 1979) have proposed new models with decision weights to overcome this problem. In an experiment similar to ours, Sillers (1980) designed unequal-probability prospects[3] so as to «correspond» in expected utility to equal-probability prospects. Analysis of the preference patterns found no evidence of probability preferences.

Almost all of the violations of the expected utility hypothesis have been acquired through carefully planned experiments. Bar-Shira *et al.* (1997) refer to several studies (Rubinstein, 1988; Bar-Shira, 1992; Buschena and Zilberman, 1992) showing that the EU hypothesis will only be violated when either outcomes or probabilities are indistinguishable. In our experimental study, outcomes are distinguishable, and probabilities are constant. Thus using the EU hypothesis should be valid in our analysis.

When the decision maker's preferences are defined over prospects in final wealth states, we have what is often called asset integration. This means that the decision-maker will evaluate the utility of each prospect on the basis of the expected value of the final wealth states of each outcome. Asset integration makes it irrelevant whether we think of risk preferences relative to gains and losses or final wealth. Another controversy regarding the EU model is whether this assumption of «asset integration» holds. This controversy does not affect the validity of the EU-framework, but rather the implications for economic behaviour which may be drawn from the model. The EU model, as developed by von Neumann and Morgenstern (1944), assumes that the decision maker has a complete and continuous preference ordering over all prospects. Von Neumann and Morgenstern did not, however, specify whether the outcomes should be interpreted as alternative final wealth states or as gains and losses relative to the current wealth state. Economists have, on the other hand, usually chosen to express utility as a function of wealth. However, Markowitz (1952) noted that individuals of widely different income and wealth classes have quite similar preferences among risky prospects. If the utility function is regarded as a stable function in wealth, these preferences seem to imply a quite strong curvature of the utility-function in the neighbourhood of the current wealth position. It is difficult to explain how the strongly curved section of the utility function seems to

[3] Some prospects were designed with a large probability of small gains, and others with a small probability of large gains

consistently appear at the current wealth position for people in all different wealth categories, if the utility-function is in fact a stable function in wealth. Markowitz explained these patterns to an inflected segment of the utility function in wealth, which forms over time around the subject's «customary wealth». When wealth changes, «customary wealth» gradually adjust to the new wealth level, and the inflected segment adjust to this new level. Because of this and similar evidence, Markowitz (1952), Kahneman and Tversky (1979) and Machina (1982) have all proposed using different local utility functions of changes in wealth (gains and losses) instead of final wealth[4].

In an experimental study of Indian farmers, Binswanger (1981) found that absolute risk aversion was much more sensitive to changes in the payoffs of the prospects offered to the farmers than to similar differences in wealth measured across farm households. In a similar study in the Philippines, Sillers (1980) also found the assumption of asset integration to be inconsistent with the experimental evidence.

As Binswanger (1981) points out, the great advantage of asset integration is that it allows one to use knowledge about the shape of the utility function measured before a change in wealth to predict behaviour of an individual after such a change. Theoretical and analytical predictions of the effects of wealth on portfolio choices or savings behaviour have usually been derived in this way. If utility is a stable function over gains and losses, it is not possible to derive such conclusions, unless one also makes a specification of how utility changes when wealth changes.

Another consequence of assuming asset integration is that opportunity gains and losses will be treated in essentially the same way by the decision maker as real gains and losses.

[4] Kahneman and Tversky (1979) call this a value function instead of a utility function. A further deviation from the EU model is their use of decision weights instead of probabilities. They also propose a number of «editing» processes to make it simpler to evaluate prospects. Machina (1982) presents a local utility model (ultimately related to a utility function in wealth) which in addition to solving the problem of asset integration, also explains several observed failures of the independence axiom. He argues (p. 279) that as long as preferences are smooth, the implications and predictions of studies using EU analysis will be valid, even though the EU hypothesis may not be empirically valid.

2.1 Measures of risk aversion

Risk Aversion is defined with reference to the von Neumann-Morgenstern expected utility function. The three measures most commonly used are: (1) absolute risk aversion $A(W)$ (defined by Pratt (1964)); (2) relative risk aversion $R(W)$ (defined by Arrow (1970)); and, (3) partial risk aversion $P(W_0,\pi)$ (independently defined by Menezes and Hanson (1970) and Zeckhauser and Keeler (1970)):

$$A(W) \equiv -\frac{U''(W)}{U'(W)} = -\frac{U''(W_0)}{U'(W_0)} = -\frac{U''(\pi)}{U'(\pi)} \tag{1}$$

$$R(W) \equiv -W\frac{U''(W)}{U'(W)} = WA(W) \tag{2}$$

$$P(W_0,\pi) \equiv -\pi\frac{U''(W_0+\pi)}{U'(W_0+\pi)} = \pi A(W_0+\pi) \tag{3}$$

W indicates total wealth, U' and U'' indicate the first and second derivative of the expected utility function, W_0 denotes initial wealth and π denotes stochastic income. At the point ($W= W_0+\pi$) the three measures are related to each other as follows:

$$R(W) = W_0A(W) + P(W_0,\pi) \tag{4}$$

Absolute risk aversion is an appropriate measure to describe situations in which income or gain is fixed, and initial wealth is variable. It is commonly assumed that absolute risk aversion decreases as wealth rises (DARA), which implies that wealthier individuals should be more willing to accept a given fair gamble. When both income and initial wealth change proportionally, relative risk aversion is the appropriate measure. Arrow (1971) hypothesised increasing relative risk aversion (IRRA). This implies that an individual's willingness to accept a gamble decreases when both wealth and all outcomes of a fair gamble are increased proportionally. The measure of partial risk aversion is appropriate to describe situations when initial wealth is fixed and income is variable. Bar-Shira *et al.* (1997) show that decreasing absolute risk aversion (DARA) implies decreasing partial risk aversion (DPRA) with respect to initial wealth, and that increasing relative risk aversion (IRRA) implies increasing partial risk aversion (IPRA) with respect to income. The opposite does not necessarily hold. It is possible to have decreasing relative risk aversion (DRRA) and increasing partial risk aversion (IPRA) at the same time.

Empirical studies have generally rejected constant absolute risk aversion (CARA) in favour of decreasing absolute risk aversion (DARA), while there is no consensus on the nature of relative risk aversion[5].

In an experimental study similar to ours, Binswanger (1981) found (1) decreasing absolute risk aversion, (2) increasing relative risk aversion[6], and (3) increasing partial risk aversion.

3. Methodology.

3.1 The setting: a brief description.

The study was carried out in 110 randomly sampled households in 6 different villages in Northern Zambia[7]. Three villages were situated in a fairly densely populated area (26-82 persons/km^2) close to the province capital, Kasama. The remaining three villages were located in a rather sparsely populated area (<6 persons/km^2) approximately 60 km further north. All households except 4 were farming. Farmers in this area of Zambia participate in two main production systems. They produce several crops in a traditional slash and burn system called *chitemene*, and they produce monoculture maize in «permanent» fields. On average, each household cultivates 1.4 ha of land, out of which 0.6 ha is used for maize production. Average total income per capita (including own consumption of major subsistence crops) was very low, approximately 65,000 Kw[8], or roughly 108 US $.

(Table 1 about here)

[5] See Saha 1994, p. 174 for a list of papers focusing on risk preference structure, and their principal findings.
[6] In his original study, Binswanger (1981) concluded that the data displayed decreasing relative risk aversion. A later paper by Quizon, Binswanger and Machina (1984) showed that the inference of declining relative risk aversion was incorrect and that relative risk aversion was increasing rather than decreasing.
[7] The households included in this study were the same as the households interviewed in earlier surveys in this area. See Holden et al. (1994) for a description of the sampling procedure.
[8] US$ 1 ≈ Kw. 600

Household heads and their wives were invited to play the games. In total, 176 individuals participated, out of which 33 were excluded from the data-set because they had serious problems understanding the game.

3.2 Description of the experiment

In the experiment, subjects were confronted with a series of choices among sets of alternative prospects (gambles) involving real money payment. The amounts of money were relatively large compared to average income in the area. (The highest possible gain was approximately 30 percent of average total annual income per capita.) The subject's choice among these alternative prospects is taken as an indication of the degree of his/her risk aversion.

The experiment follows a method developed by Binswanger (1980). A series of «schedules of alternatives» (called games) similar to those shown in Table 2 were presented to each subject. Each game lists six alternative prospects or gambles, each with 50 % probability of winning. Each subject was asked to select one of six alternatives: 0, A, B, C, D, or E. Once they had chosen, a coin was tossed and they received the left-hand amount if the coin showed heads and the right hand amount if the coin showed tails. If the subject selected alternative 0, he received 100 Kw whether he got a head or a tail. If he chose alternative A instead of 0, his expected gain increased by 35 Kw., but a bad luck alternative (heads) would now give him 10 Kw. less in return than he would have received with the safe alternative 0. In other words, in choosing A instead of 0, the standard deviation in gain is increased from 0 to 45 Kw. For the successive alternatives, A to B, B to C, and C to D, the same is true: the expected gain increases, but so does the spread between the two outcomes. Alternative D and E have the same expected gain, but alternative E has a larger spread.

(Table 2 about here)

When risk is viewed in terms of uncertainty in gains, income or wealth, as in utility based choice theories, the alternatives involve more risk the further down you get in Table 2. This means that a decision-maker possessing a utility function concave in wealth, income or gain would demand a higher risk premium to accept prospect B rather than its expected outcome than he would demand to accept prospect A rather than its expected outcome. Whether he prefers prospect B over prospect A depends on the degree of concavity of his utility function. The different prospects are classified from extreme risk aversion (alternative 0) to neutral to preferring (alternative E). The classification is the same as the one used by Binswanger (1980) and Sillers (1980).

To get a unique risk aversion coefficient for each game level, we used the following utility function with constant partial risk aversion (CPRA):

$$U=(1-\gamma)x^{(1-\gamma)} \tag{5}$$

where x is the certainty equivalent of the prospect. The parameter γ will then be equivalent to the constant partial risk aversion coefficient. The fifth column of Table 2 shows the endpoints of the constant partial risk aversion coefficients implied by each possible choice. To calculate particular risk aversion coefficients for each alternative, we used geometric means of the endpoints of the parameter intervals for alternatives A to C. The intervals of the risk aversion coefficients consistent with preferences for the extreme alternatives 0 and E are unbounded. Since one endpoint value between choice D and E is 0, the arithmetic mean was used to calculate the risk aversion coefficient for alternative D. These risk aversion coefficients are shown in the last column of Table 2.

The games were played at different levels. Each individual played games 1 to 7 (Table 3) during the first visit, and games 8 through 14 during a visit two weeks later. All gains-only games (game 1 to 11) were derived from the 100 Kw game by multiplying all amounts by 10, 50 or 100. The 100 Kw game was played five times, the 1,000 Kw game three times, the 5,000 Kw game two times, and the 10,000 Kw game was played once.

(Table 3 about here)

Earlier research (Binswanger, 1980, 1981; Sillers 1980) have shown that subjects seem to get more risk averse when the gains are increasing. If this hypothesis holds, individuals have non-linear, risk averse utility functions, which exhibit increasing partial risk aversion (IPRA). To measure risk aversion coefficients, therefore, one should use an IPRA instead of a CPRA utility function. Such a function[9] has the disadvantage that its parameters must be estimated from the observed choices that an individual has made at two game levels. Sillers (1980) showed that the values using local risk aversion measures derived from fitting a CPRA function on observed choices offer very close approximations to the corresponding local risk measure values which would be computed directly from an expo-power IPRA function. He argued this is essentially because the partial risk aversion implicit in individual's choices increases rather slowly with the scale of the experimental prospects.

We saw above that the assumption of asset integration is not well supported. For this reason we devised an experimental game similar to the gains-only games, but involving both gains and real losses (Table 4). The games involving losses (games 12 to 14) were derived by subtracting all amounts by the certain amount of alternative 0. So instead of receiving 80 Kw. for choosing alternative B and throwing a «heads», the subject would have to pay 20 Kw. By using this gains-and-losses format, preferences among prospects involving losses as well as gains can be observed directly. The assumption that the subject would treat opportunity gains and losses as essentially the same as direct gains and losses is implied by the expected utility framework with asset integration[10]. We may assume that in the gains only format subjects view payoffs from each alternative as consisting of opportunity gains and losses relative to the certain payment attached to alternative 0. Thus if the hypothesis of asset integration holds, preferences revealed in the gains-only format (opportunity gains and losses) should not be significantly different from preferences revealed when playing games with real losses.

(Table 4 about here)

The CPRA utility function used to construct risk aversion categories, is not defined for games with losses. However, if asset integration is assumed, opportunity gains and losses would be treated in essentially the same way as real gains and losses. It would then be reasonable to regard the risk aversion coefficients imputed to the «gains and losses» alternatives as direct reflections of the partial risk aversion exhibited by the representative utility function for the gains-only alternatives.

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[9] An example of a utility function exhibiting increasing partial risk aversion is the expo-power utility function $U(x) = \Theta - e^{-\beta x^{\alpha}}$ defined over gains x and with parameter-restrictions $\Theta>1$, $\alpha>0$ and $\beta>0$.

Most of the games were real, i.e., the individual actually received the payment. Because of budget-restrictions, we also included some hypothetical games. Game 10 was played with real payment for one individual in the household and as a hypothetical game for the other. Before playing the gains-only games the individuals were told that a few of the games would be hypothetical, but they were not told which games would be hypothetical and which would be real. After each game they were paid the gain if the game was real, or otherwise told that the game was hypothetical. In this way we hoped the individuals would play all games as if they were real. We did, however, experience that some individuals late in the sequence in each village had been speaking with neighbours and friends who had already participated, and thus had learned that two of the games with highest payments (games 7 and 11) were not real. This could mean that the results from these games show a bit less risk averse behaviour than would have been the case if all individuals played as if the games were real. The first two games played during the first visit (games 1 and 2), and the first game (game 8) during the second visit were treated as practice-games and have not been included in the formal analysis.

The three gains-and-losses games were played, at 100, 1000 and 5000 Kw level. The first two games were real, and the last game was hypothetical. In this case, the subjects knew that the game was hypothetical. It is, however, difficult to ask poor peasants to participate in games with real losses and put their own money at risk. First, it is hard to defend morally. Second, it would often not be possible to carry out such an experiment, because many would not have sufficient cash to allow them to select one of the riskier alternatives if they so desired. In this case, the analyst would no longer be able to distinguish between pure risk aversion and the effect of liquidity constraints. To minimise this effect, we played the gains-and-losses games immediately after having played four rounds of gains-only games. We made sure the subjects had won enough money to be able to choose even the riskiest alternatives in these games.

3.3. Statistical model

Subjects have, through choosing between six different choices, revealed which choice gives the highest utility. Assuming a utility function with constant partial risk aversion, each

[10] See Sillers (1980, pp 67-70) for a more thorough discussion of opportunity gains and losses vs. real gains and losses.

observed response, I_i, should represent a category of risk aversion in which the true, but unobservable, risk aversion coefficient γ_i falls into:

$$I_i = \begin{cases} 0 \text{ if} & \gamma_i \geq 7.5 \\ \text{A if} \quad 7.5 > & \gamma_i \geq 2.0 \\ \text{B if} \quad 2.0 > & \gamma_i \geq 0.812 \\ \text{C if} \quad 0.812 > & \gamma_i \geq 0.316 \\ \text{D if} \quad 0.316 > & \gamma_i \geq 0 \\ \text{E if} \quad 0 > & \gamma_i \end{cases} \tag{6}$$

An appropriate model for these kind of data is a censored latent variable model (Carson, 1991; Cameron and Quiggin, 1994; Bergland, 1998). We use the notation and presentation of this model found in Bergland (1998). When the observations in the data-set are indexed by the set T, it is convenient to partition T into six disjoint subsets depending on which category the indicator variable I_i takes, i.e.:

$$T_k = (i \in T : I_i = k) \qquad k = 0, A, B, C, D, E. \tag{7}$$

Observations belonging to the set T_0 are right censored, those in T_E are left censored and observations in the other four categories are interval censored. The log-likelihood function for this model can be written as:

$$\begin{aligned} \ln L = & \sum_{i \in T_0} \ln(1 - F(7.5)) + \sum_{i \in T_A} \ln(F(7.5) - F(2.0)) + \sum_{i \in T_B} \ln(F(2.0) - F(0.812)) \\ & + \sum_{i \in T_C} \ln(F(0.812) - F(0.316)) + \sum_{i \in T_D} \ln(F(0.316) - F(0)) + \sum_{i \in T_E} \ln(F(0)) \end{aligned} \tag{8}$$

where F is the cumulative density function of the distribution of risk aversion across the population. The censored latent variable models in this paper were estimated using SAS version 6.12.

We cannot exclude the possibility of bias in the parameter estimates in the regression analysis. Several of the variables in the regression model are of an endogenous character and their parameters should therefore ideally have been estimated using a simultaneous equation system. Because we only had cross-section data, we were unable to identify sufficient instruments or lagged variables for a system estimation.

3.4 Risk aversion and personal characteristics.

In this section we will discuss why and how some socio-economic variables and personal characteristics might be correlated with some of the variation in risk aversion.

From theory and the common assumption of DARA, we would expect wealthier individuals to be less risk averse. We have included several different wealth variables in the model (income per capita, cash liquidity per capita and education). This is because asset market imperfections severely constrain substitution between different categories of wealth (Reardon and Vosti, 1995; Holden *et al.,* 1998). Under such conditions each asset category may have an independent correlation with risk aversion. If they only have indirect effects through the income and liquidity variables, this may cause problems of multicollinearity, making it necessary to omit variables. To test whether present wealth is correlated with risk aversion we included total income per capita (including market values of major subsistence crops) and cash liquidity per capita (total income minus total expenditures).

We also included education as one measure of human capital. We expect all the wealth variables to be negatively correlated with risk aversion.

Household size can have two opposing effects on risk aversion. On the one hand, household size can be viewed as a wealth variable. A larger family could represent an increased labour force for the household and thus have a negative effect on risk aversion. Furthermore, household size may also have an indirect negative effect on risk aversion in terms of providing insurance, diversification and coping opportunities. On the other hand, a larger family means more people to feed which may increase risk aversion. We believe that in poor peasant societies, where children start to work at a young age, the first effect is more prominent, while in a developed economy the second would be more common. Earlier studies are inconclusive. Moscardi and deJanvry (1977) and Feinermann and Finkelshtain (1996) found that increased family size is leading to more cautious and conservative behaviour, while Dillon and Scandizzo (1978) found that farmers with larger households were less risk averse.

In most cases, total farm area would represent a type of household wealth. In Northern Zambia, however, there was abundance of land and access to land was not considered a binding constraint. Since access to land is free (except for labour costs of cultivating and transactions costs due to distance from the homestead), we suppose cultivating more land could be a risk-coping strategy for the risk averse.

Farmers in this area of Zambia participate in two main production systems. They produce several crops in a slash and burn system called *chitemene*, and they produce monoculture maize in «permanent» fields. Maize production is dependent upon use of chemical fertilisers. This production requires access to credit and a supply of fertiliser. Maize production is considered a more risky activity by the farmers than the production of other crops in *chitemene* (Wik and Holden, 1996). We would therefore expect more risk averse farmers to have a relatively smaller area for maize-production than would less risk averse farmers. Both total farm land and area of maize are included in the model as per-capita variables.

Because of very different roles of men and women in this society, we included a gender dummy-variable in the model (men=0, women=1). We believe that different attitudes to risk might reflect gender differences in the society. In this society we expect women to be more risk averse than men. Women have more responsibilities for providing and preparing the food and for feeding and caring for the children. Traditionally, men were warriors, and supposed to engage in dangerous and risky activities. They should, according to Richards (1939), be brave and willing to take risk to achieve status in the society.

We also included a variable for the age of the decision-maker. Moscardi and deJanvry (1977) writes that «it is generally assumed that older farmers tend to be less prone to take risks than younger ones...» We find this to be an assumption without any theoretical grounding, and include the variable, without any *a priori* expectation of the sign.

To believe that past experience with a random process (such as tossing a coin), would influence a person's next choice, is not common in economic theory. Psychologists, on the other hand, would find it surprising to think that such past experience would not influence future choices. To check whether previous luck had a significant effect on subject's choices, we included a dummy variable defined as $\sum X_i$, where i is the game number of previous games (for game 11, i would be 1,2,3....10), and X takes the value of 1 when the person wins (tails) and -1 when he looses (heads). Binswanger (1980) found the effect of previous luck to be highly significant. We expect to find that previous luck does affect people's choices. Subjects who have experienced previous luck will be more willing to take risk than subjects who have experienced previous losses.

As we saw in the section on theory, it has been common in economics to consider risk by looking at changes in total wealth. We saw that another aspect of asset integration is that opportunity losses should be treated in the same way as real losses. Empirical evidence has shown that this is usually not the case. As the famous basketball player and coach Larry Bird remarked, «Loosing hurts more than winning feels good». Research in both economics and psychology have found this to be true (Markowitz, 1952; Kahneman and Tversky, 1979; Hershey and Schoemaker, 1980; Sillers, 1980). People are more risk averse when it comes to losses than to gains. In their prospect theory, Kahneman and Tversky (1979) proposed a convex utility for losses which was steeper for losses than the concave utility for gains. Markowitz (1952) and Hershey and Schoemaker (1980) proposed a utility function in gains and losses, which was concave for small losses and convex for larger ones. To test for a difference between gains-only and gains and losses games we have included a dummy-variable for losses were 0 is equal to gains-only games and 1 is equal to games with gains and losses. We expect to find that people are more risk averse in games with losses.

To test whether the level of gains in the games influenced individuals' risk aversion, we included a variable of overall expected outcome of each particular game. Other researchers (Binswanger, 1980, 1981; Sillers, 1980) have found evidence of people getting more risk averse when there are bigger gains/losses at stake, i.e., that their utility function exhibits increasing partial risk aversion (IPRA) with respect to the possible income of the games. We therefore expect the sign of this variable to be positive.

The survey in Northern Zambia also included hypothetical questions to measure people's rate of time preferences[11]. It seems clear that time and uncertainty are closely related in many ways. Prelec and Loewenstein (1991) say it this way: «Anything that is delayed is almost by definition uncertain. And since uncertainty takes time to resolve, uncertain outcomes are also typically delayed». Since EU theory is not intertemporal, it is not easy to combine EU theory with Discounted Utility (DU) theory. Therefore it is not easy to find a correct theoretical relationship between risk aversion and time preferences. The coefficient of relative risk aversion (in EU theory) is identical to the elasticity of marginal utility (in DU theory) (Nielsen, 1997). At first glance this means that risk aversion can be viewed as directly included in a discounted utility function. If the assumption of relative risk aversion decreasing with rising consumption holds, high relative risk aversion would therefore contribute to a higher discount rate. But Nielsen argues that since risk aversion coefficients from EU theory are not intertemporal, this ad hoc combination does not reflect weighting of risky choices over time. A few studies try to integrate theory on preferences towards risk and time, although these do not use the EU framework. Quiggin and Horowitz (1995) use Rank Dependent Expected Utility to get a derivation of a natural analogy between risk-aversion and impatience. Holden *et al.* (1998) argue that risk averse households will have higher rates of time preference if they expect a positive growth rate, while an expected negative growth may lead to lower rates of time preference. In their study, Holden *et al.* (1988) used the same data set as in the present study. They used rates of time preference as the dependent variable, and found that more risk averse individuals tended to have lower discount rates. Another study by Pender and Fafchamps (1997) from India found the opposite relationship, i.e., high estimates of both relative risk aversion and time preferences. To test whether there is a correlation between risk aversion and rates of time preferences, we included present value equivalents[12] as variables for the rates of time preference. We had no *a priori* expectations of the sign of this correlation.

We included a dummy variable to test whether real versus hypothetical games had an impact on individual's choices (0=real, 1=hypothetical).

[11] See Holden *et al.* (1998) for more insights on the data-collection and estimation of personal rates of time preference.
[12] The present value equivalent is the cut-off point where the subject said she was indifferent between an amount of money (or maize) today and a certain amount of money (or maize) in one year.

4. Results

4.1 The main experimental results.

The risk-aversion distributions corresponding to different game levels are given in Table 5. The first panel shows the distribution for the games with gains only, while the second panel shows the distribution for games with gains and losses. Note that the distribution was rather widely spread over all classes of risk aversion, but as the game level rose, the distribution shifted to the left, i.e., risk aversion increased. Even at the lowest level of the game, more than 20 percent chose the alternatives representing severe to extreme degree of risk aversion. When the game level increased to Kw. 10,000, more than 35 percent chose the two most risk averse alternatives. Considering the slight-to-neutral and neutral-to-preferring alternatives, the percentage choosing these alternatives was reduced from 28 percent at the Kw. 100 game level to only 11 percent in the Kw. 10,000 level. The share of responses falling into the intermediate and moderate risk aversion categories remained fairly stable at 45 to 50 percent for all game levels. It appears that the majority of people with initially low levels of risk aversion increase to moderate to intermediate risk aversion when game levels rise. For individuals who initially had moderate to intermediate levels of risk aversion, the level seemed to increase more slowly.

(Table 5 about here)

The second panel shows the distribution for the three games with gains and losses. Also for these games we see the tendency of increased risk aversion when game levels increase. In addition, we see an inclination of people being more risk averse in these games than in the games with gains only. At the Kw. 1,000 level, more than 45 percent chose the two most risk averse alternatives, while only 12 percent chose the two most risky alternatives. For the gains-only game at Kw 1,000 level, we found 29 and 24 percent in the respective risk categories. The peculiar result of finding more than 20 percent choosing the neutral to preferring alternative at the Kw. 100.- level, is difficult to explain. It could be the result of people being used to gambles where they put small amounts of money at risk.

The data in Table 5 seem to suggest that individuals are risk averse and that they tend to get more risk averse when the size of the gamble increases. Later in the study we will formally test the hypothesis of increasing partial risk aversion, i.e., that individuals get more risk averse when the size of the gamble increases. We will also test whether people are more risk averse in games with losses than in games with gains only

4.2 Comparison with other studies.

Similar games have been played with peasant farmers in other areas of the world. Sillers and Binswanger (1983) compared results from applying Binswanger's general experimental methods in farming communities in the Philippines (Sillers, 1980), El Salvador (Walker, 1980) and Thailand (Grisley, 1980). To facilitate comparisons among the experiments and to give a sense of the experimental pay-offs in terms of local incomes, all pay-offs were expressed in experiment-specific «daily wage» (DW) units, equal to the daily wage received by an unskilled agricultural labourer in the study area in question. These results are shown in Table 6 together with our results from Zambia[13].

(Table 6 about here)

Sillers and Binswanger (1983) suggest that with the possible exception of the El Salvador experiment, most villagers in farming communities hold rather similar pure preferences toward risk. They ask for more research to confirm this general pattern, but propose that a «universal 'moderate' risk aversion in such communities would appear to be a reasonable hypothesis on which to base our thinking about the agricultural investment and production behaviour of peasants». Our results from Zambia may indicate that the picture is possibly more complex. Farmers in our sample showed a much larger variation in risk aversion. A bigger incidence of farmers chose the alternatives representing extreme or severe risk aversion than in the Asian studies, and at the same time more farmers were choosing the risk neutral to risk preferring alternatives. These results are more in line with Walker's (1980) results from El Salvador, than the general pattern of moderate risk aversion found in studies in Asia. Though we cannot dismiss the possibility of the big spread in our data being a result of

[13] Daily wage rate in Northern Zambia was between 420 and 700 Kw. per day (Sjaastad, 1998). We used the average 560 Kw. per day. It should be noted that labour markets in Zambia are highly imperfect, and the wage-labour is only available to a small proportion of the population in short periods during the year.

subjects choosing alternatives randomly, these results could mean that risk preferences are indeed different from area to area. These results could also indicate a difference in attitudes toward and/or experiences with gambling, from culture to culture.

4.3 Results from the econometric estimation

In the results discussed below, all 11 games are included in the data-set. In the regressions in this section, we have assigned the same categories for the choices in the «gains and losses» alternatives as for the gains-only alternatives. To check for whether individuals actually treat real losses in the same way as opportunity gains and losses, we included a dummy variable for games with losses.

Results from running a censored latent variable model including variables discussed in Section 3.4, are presented in Table 7. The likelihood ratio test of this model showed that the model was highly significant. On the other hand, the very low likelihood ratio index may indicate that the parameters in the model, even though they are highly significant, do not explain very much of the variation in the sample. This could be a result of people chosing the game alternatives rather randomly, or because of errors in the model-specification. We believe it is a combination of not having been able to eliminate all the people who did not really understand the games, and that that the choices in the games are only very loosely tied to the real risk preferences of the individuals. Another possibility is that people's risk preferences when playing these types of games are related to personal traits not very much influenced by socio-economic factors.

(Table 7 about here).

In Table 7 we find that most of the variables are significant and with the hypothesised signs. The wealth variables - education and income per capita and household size - are significant at respectively 10 and 5 percent levels. Both variables have negative signs, indicating that higher wealth is correlated with lower degrees of risk aversion. This is consistent with the common assumption of DARA. The cash per capita variable was not significant.

The household size variable is also significantly negatively correlated (at 1 % level) with risk aversion. This result indicate that the effect of household size as providing labour and improved possibilities of insurance, diversification and coping opportunities are more important than the effect of more people to feed. In this way it seems like farm households in this area behave as if household size is a wealth variable.

We also find that the total farm area variable is positively correlated with risk aversion, supporting our hypothesis that when land is abundant, cultivating more land would be a risk-coping strategy. The negative sign on the maize-area variable indicates that the more risk averse the farmer is, the less he engages in the risky maize production. The variable was only significant at 10 % level, however.

Gender differences seemed to be significantly correlated (5 % level) with differences in risk aversion. We found that women were more risk averse than men. We found no significant correlation between age and risk aversion.

Previous luck in random processes seems to influence a person's next choice. The prior luck variable was highly significant (at 0.1 % level). This suggests a strong impact of prior luck, and may thus imply that people are correcting their subjective probabilities as the game progress.

The dummy-variable for loss was also significant at 0.1 % level, and strongly supports the hypothesis that people are more risk averse in games with losses than in games with gains only. This result is also an indication that people do not treat opportunity losses in the same way as real losses, and thus, that asset integration does not hold.

We also found that the level of the game had a strong, significant impact on how large a risk people prefer to take in these types of games. People seem to be willing to take less risk when higher gains are at stake. This implies that people are revealing increasing partial risk aversion (IPRA) with respect to the game income level.

To test for any correlation between risk aversion and rates of time preferences, we did several regressions including different variables for time preferences. These results are not reported here, as they showed no significant effect. In addition to not being significant, the time preference variables did not show consistent signs. We therefore conclude that there is no empirical evidence for how time preferences and risk aversion are correlated. This contradicts the result of Holden *et al.* (1998), where risk aversion was found to be significantly negatively correlated with time preferences. This result was based on using risk aversion estimates from only one of the games. We therefore believe the results in this paper reflect the relationship (or lack of relationship) in a more comprehensive way.

The dummy variable for real and hypothetical games was not significant, and is not reported here.

5. Conclusion

This study measured attitudes toward risk for 143 persons in Northern Zambia, using an experimental gambling approach, similar to that of Binswanger (1980) and Sillers (1980), with real payoffs. The games were defined as both «gains-only» and «gains-and-losses» games. Highest possible real gain was approximately equal to 30 percent of average total annual income per capita.

Farmers in our sample revealed a wider spread in risk aversion as well as a more risk averse behaviour than farmers in similar studies in Asia, when playing similar types of games.

In the low levels of the games, individuals chose alternatives evenly spread from severe to slight-to-neutral risk aversion. When game levels rose, the distribution shifted towards a more risk averse attitude, and 80 % of the people revealed moderate to extreme risk aversion. We also found that people were more risk averse in games with gains and losses than in games with gains only.

These results indicate that utility functions should exhibit increasing partial risk aversion and that they should be defined over gains and losses. Wealth does, however, also have an effect on risk aversion. We found evidence of decreasing absolute risk aversion (DARA) when wealth increases. This effect is, however, not necessarily directly related to a utility function in ultimate wealth.

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Table 1.
Summary statistics for the participants of the study.

Variable	Mean	Standard Deviation
Household size (persons)	5.57	3.38
Total cultivated area (ha)	1.38	1.02
Maize area (ha)	0.55	0.49
Chitemene area (ha)	0.71	0.90
Total income per capita (Kw)	65,902	51,496
Cash liquidity per capita (Kw)	5,059	13,188
Age	42.08	15.03
Years of school	5.16	3.18

No. of observations = 143

Table 2.
The 100 Kw game for «gains-only».

Choice	*Bad luck payoff* "Heads"	*Good luck payoff* "Tails"	*Risk aversion class*	*Bounds on parameter of CPRA function*	*Partial risk aversion coefficient*
0	100	100	Extreme	> 7.5	> 7.5
A	90	180	Severe	7.5 - 2.0	3.873
B	80	240	Intermediate	2.0 - 0.812	1.274
C	60	300	Moderate	0.812 - 0.316	0.507
D	20	380	Slight to neutral	0.316 - 0	0.158
E	0	400	Neutral to preferring	< 0	< 0

Table 3.
Sequence and levels of games.

Day:	Gains-only or gains and losses	Game number:	Game level (Kwacha):	Real or hypothetical
Day 1:	Gains only	1	100 Kw	real
,,	,,	2	100 Kw	real
,,	,,	3	100 Kw	real
,,	,,	4	1,000 Kw	hyp
,,	,,	5	100 Kw	real
,,	,,	6	1,000 Kw	real
,,	,,	7	5,000 Kw	hyp
Day 2:	,,	8	100 Kw	real
,,	,,	9	1,000 Kw	real
,,	,,	10	5,000 Kw	real/hyp
,,	,,	11	10,000 Kw	hyp
,,	Gains and losses	12	100 Kw	real
,,	,,	13	1,000 Kw	real
,,	,,	14	5,000 Kw	hyp

Table 4.
The 100 Kw game for «gains and losses»..

Choice	*Bad luck payoff "Heads"*	*Good luck payoff "Tails"*	*Risk aversion class*
0	0	0	Extreme
A	-10	80	Severe
B	-20	140	Intermediate
C	-40	200	Moderate
D	-80	280	Slight to neutral
E	-100	300	Neutral to preferring

Table 5. Percentage distribution of risk aversion in different types of games and different game levels and corresponding constant partial risk aversion coefficient.

		Extreme	Severe	Intermediate	Moderate	Slight-to-neutral	Neutral-to-Preferring	No. of observations
		0	**a**	**b**	**c**	**d**	**e**	
(I) Games with only gains:								
Bad luck payoff		100	90	80	60	20	0	
Good luck payoff		100	180	240	300	380	400	
100 Kw. (game 3 and 5)	real	5.9	16.8	26.2	23.1	20.6	7.3	286
1000 Kw (game 4, 6 and 9)	real	10.9	18.2	23.9	22.5	16.1	8.4	423
5000 Kw (game 10)	real/hyp	17.9	22.4	25.4	20.1	12.7	1.5	134
10000 Kw (game 11)	hyp	15.3	21.2	27.7	24.8	9.5	1.5	137
Implied bounds on parameter of CPRA function		> 7.5	7.5-2.0	2.0-0.812	0.812-0.316	0.316-0	< 0	
Partial risk aversion coefficient		> 7.5	3.873	1.274	0.507	0.158	< 0	
(II) Games with gains and losses								
Bad luck payoff		0	-10	-20	-40	-80	-100	
Good luck payoff		0	80	140	200	280	300	
100 Kw. (game 12)	real	19.0	14.6	25.5	9.5	8.0	23.4	137
1000 Kw (game 13)	real	21.9	23.4	23.4	19.0	5.1	7.3	137
5000 Kw (game 14)	real/hyp	18.2	46.7	21.2	8.0	2.9	2.9	137

Table 6.
Percentage distribution of revealed risk preferences in five experimental studies at two levels of payoff.

	Extreme or severe risk-aversion	*Intermediate or moderate risk-aversion*	*Risk-neutral to risk-preferring*	*(No of responses)*
Gains only:				
India (Binswanger, 1980)				
50 Rupee (14.3 DW)	8.4	82.2	9.4	(107)
500 Rupee[H] (143 DW)	16.5	82.6	0.9	(115)
Philippines (Sillers, 1980)				
50 Peso (7.1 DW)	10.2	73.5	16.3	(49)
500 Peso (71 DW)	8.1	77.6	14.3	(49)
El Salvador (Walker, 1980)				
10 Colon (2.5 DW)	9.7	58.3	30.5	(36)
50 Colon[H] (12.5 DW)	30.6	40.3	29.2	(72)
Thailand (Grisley, 1980)				
66.6 Baht (2.7 DW)	0	92.3	7.7	(39)
200 Baht (8 DW)	2.6	97.4	0	(39)
Zambia				
1000 Kw (1.8 DW)	29.1	46.4	24.5	(423)
10000 Kw[H] (18 DW)	36.7	52.5	11.0	(137)
Gains and losses:				
Philippines (Sillers, 1980)				
50 Peso (7.1 DW)	10.2	79.6	10.2	(49)
Zambia				
5000 Kw (9 DW[1])	45.3	42.4	12.4	(137)

[H] Game used hypothetical pay-offs.
[1] It should be noted that labour markets in Zambia are highly imperfect, and wage-labour was only available to a small proportion of the population (less than one third of the households) in short periods during the year.

Table 7.
Censored latent variable model, results for risk aversion categories.

Variable name	Estimate	Std.Dev.	Chi-Square	Probability
Intercept	-0.54856	0.5767	0.905	0.3415
Sex	0.38850	0.1724	5.078	0.0242*
Game-level	5.779E-5	1.5E-5	15.54	0.0001***
Dummy for loss	0.914663	0.1578	33.56	0.0001***
Previous luck	-0.10613	0.0248	18.28	0.0001***
Age	-0.00034	0.0053	0.004	0.9487
Years of school	-0.05393	0.0282	3.647	0.0562[a]
Income pr. capita	-2.657E-6	1.3E-6	3.973	0.0462*
Cash pr. capita	-3.348E-6	5.9E-6	0.319	0.5720[a]
Household size	-0.06334	0.0222	8.118	0.0044**
Farm area per capita	0.00010	0.4E-4	5.395	0.0202*
Maize-area per capita	-0.00014	0.8E-4	3.012	0.0827[a]
Scale	2.18873	0.0633		

Log likelihood value = -2573.02
Likelihood Ratio Index = 0.021
No. of observations = 1,353
[a],*,**,*** refer to significance at 10, 5, 1 and 0.1 % level respectively.

Risk, Market Imperfections and Peasant Adaptation: Evidence from Northern Zambia[1]

Abstract

In the literature, considerations of risk and risk aversion have played central roles in understanding processes of technology adoption and choices of crop portfolios. Market imperfections are also frequently used to explain production decisions of farm households. This paper presents a theoretical framework for analysing how risk aversion and market imperfections may influence cropping decisions of farm households. Our econometric analysis using household data from northern Zambia indicates that both household specific variables, such as gender and education, market imperfections in commodity and credit markets, and, to a smaller degree individual risk aversion, influence cropping decisions of farm households.

1. Introduction

A considerable amount of literature is devoted to the study of production decisions by farm housholds in developing countries. A common finding is that these farmers often use less fertiliser and other inputs than if they maximised expected profits. It is also common to find that farm households do not adopt or only partially adopt new technologies (including new crops) even when these technologies provide higher returns to land and labour than the traditional technologies (Goetz *et al.*, 1988; von Braun *et al.*, 1989). Considerations of risk and risk aversion have played central roles in understanding such production decisions. Sandmo (1971) established that a risk averse firm facing output risk will produce less output than a risk neutral firm. The optimal solution under certainty and perfect competition, equality between expected revenue and marginal cost ($C'(x) = p$), does not hold for the risk averse firm when facing price uncertainty. Instead, the risk averse firm will produce an optimal output characterised by marginal cost being less than expected price. Furthermore, a risk averse firm will reduce output when risk increases. The Sandmo result has very often been used to explain why poor farm households produce less than the level that maximises expected profits.

[1] Stein Holden and Ed Taylor have been supervising this research, and will be co-authors when the paper is submitted to a Scientific Journal. The Research Council of Norway provided funds for the «Ecology and Development» project from which fieldwork for this research received funding. The authors wish to thank Colin Cameron for helpful advice.

Sandmo's model was developed for a single-product firm, facing price-uncertainty only for its final product. He assumed the firm to be a price-taker, and that all commodity and factor markets were well functioning. He made use of the expected utility hypothesis, combined with an assumption that utility depends on only one random variable, the level of final wealth. The farm household unit of production differs from a firm in several distinct ways. The most important distinction for our discussion is the interaction of consumption and production within the household. This dual economic character of the farm household creates a form of decision making which is unique (Ellis, 1993). Widespread empirical evidence of market imperfections for credit, food, insurance and labour also exists. These market imperfections will, as we will see later, often make production and consumption decisions non-separable. Another important difference from the Sandmo model is that farm households in developing countries faces production as well as price risks.

This paper examines the importance of both risk and market imperfections for farm household decisions in northern Zambia. Farm households in this area participate in two main production systems. They produce several crops, in a traditional slash and burn system called *chitemene*, and they produce monoculture maize in «permanent» fields. Maize is generally considered to be a cash crop, while the *chitemene* crops are mainly used for consumption. The *chitemene* shifting cultivation system requires a large amounts of woody biomass for crop production, and has a very low carrying capacity in terms of people per km^2. The carrying capacity has been exceeded in large parts of northern Zambia. This has led to accelerated deforestation (Holden, 1997). To ease this development, maize production was stimulated through government sponsored programmes. This resulted in a rapid adoption and expansion of maize production in northern Zambia from the late 1970s to the late 1980s (Holden, 1997).

Maize has been considered the most profitable crop (Holden *et al.,* 1994; Christiansen and Sæther, 1995)[2], but it was also considered the most risky crop (Wik and Holden, 1996). Maize production is dependent upon access to credit and to supply of fertiliser. In a risk-free

[2] Profitability in maize production was, however, decreasing. In our 1994 survey, only 28 % of the farmers ranked maize as the most profitable crop, and 42 % thought that the trend in profitability for maize was decreasing (Wik and Holden, 1996).

world with perfect markets and homogeneous land quality, the profit-maximising farmer would produce only maize. If maize is a risky crop, and the farmer is risk-averse, he will, according to Sandmo, produce less maize than in the pure profit-maximising case. If labour, credit or commodity markets are imperfect, farm households might face resource constraints, and thus, endogenous shadow-prices which may also cause reduced maize production. Using farm household survey data, we test the hypothesis that farm households' allocations of land to maize and *chitemene* are influenced by individual risk aversion as well as market imperfections in credit, labour and/or commodity markets.

The paper is organised as follows. In Section 2, we present a framework for analysing farm households' allocation of land to maize and *chitemene*. Using simple farm household models, we identify key variables to be used in the econometric analysis. Section 3 presents a description of the data and our empirical results. The paper concludes in Section 4 with a summary of findings and their policy implications.

2. Theoretical framework.

Models which incorporate consumption goals of households into micro-economic models of farm household decision making are called household models. A commonly used basic farm household model is the Barnum-Squire model (Barnum and Squire, 1979)[3]. This model maximises utility through consumption of a number of commodities (i.e. leisure, home-produced goods and market purchased goods). Utility is maximised subject to a full income constraint. The model shows that if all markets exist and all goods are tradables, all prices are exogenous and production decisions are taken independently of consumption decisions. This is the standard case of a separable household model. Separable models have several advantages when it comes to econometric estimation. Its econometric estimation can be divided into two independent parts, the production and the consumption systems. Thus far most household models developed have assumed separability between production and consumption.

[3] For a lucid description of this model, see Singh *et al.* (1986).

In most developing countries, however, market imperfections exist due to high transaction costs and imperfect information. Markets may be missing, seasonal (partly missing), selectively missing (rationing), or thin (imperfect competition). These market imperfections are particularly common in relation to land resources, labour, credit, risk/insurance, and some basic food commodities (Hoff *et al.,* 1993; de Janvry *et al.,* 1991).

When the commodities of the model are exposed to severe market imperfections, errors will occur when the model is specified as if markets are perfect with exogenous prices. If a credit market or some commodity or labour market does not exist, production and consumption decisions are usually linked together through endogenous prices. When the model is not separable, reduced form functions for production and consumption may be estimated (Sadoulet and de Janvry, 1995). In these reduced form functions, production decisions also depend on characteristics of the consumption decisions.

In northern Zambia typical market imperfections include (Holden, 1997):

- Missing land markets (usufruct rights to land only);
- Seasonal, rationed or missing labour markets;
- Missing or very thin (and seasonal) commodity markets with limited competition;
- Missing or very limited insurance markets;
- Rationed credit markets interlinked with input supply (fertiliser and seeds);
- Missing or incomplete information.

In the following sections we present theoretical farm household models which explore what happens when: a) labour markets are imperfect, b) credit markets are imperfect, c) commodity markets are imperfect, and d) there is risk in production of maize and *chitemene* crops and no insurance markets. These models help identifying relevant variables for the econometric estimations.

2.1 Household model with missing labour markets

In the extreme, when there is no labour market, a farm's labour input should depend on family composition (Chayanov, 1966). Benjamin (1992) developed a test for separation using the observation that in the absence of labour markets, household composition is an important determinant of farm labour use. Both Lopez (1984) and Benjamin (1992), have used this approach and estimated labour demand functions and tested for the significance of demographic variables. They show that if the demographic variables jointly are significantly different from zero, separability can be rejected. Lopez found, using data from Canada, that production decisions are indeed not separable from consumption decisions, while Benjamin, using data from Indonesia, found that the separability hypothesis could not be rejected.

In a study from the same area of northern Zambia, Holden (1991) found that a Chayanov model could explain a great deal of the variation in peasant behaviour. Area cultivated per worker was used as dependent variable. This dependent variable was found to respond positively to the consumer-worker ratio of the household. Furthermore, he found that the household labour force, and particularly the male labour force, was important for the capacity to farm. In his analysis, Holden (1991) used cross section data, and the analysis may have endogenous variable problems.

In this section we use a simple model with no labour market to illustrate the case. The farm household maximises utility based on consumption of produce from *chitemene* (x_c), maize (x_m), market purchased goods (x_z) and leisure (x_l) (1), subject to a budget constraint (2) and two time constraints (3 and 4):

$$MaxU[\sum_i x_i(\alpha)] \qquad i=c,m,z,l_j, \quad j=1,2 \qquad \text{subject to:} \tag{1}$$

$$Y=\sum_{i\neq l_j} p_i x_i(\alpha) = A_c p_c q_c(l_c) + A_m(p_m q_m(l_m, f_m) - p_f f_m) \tag{2}$$

$$A_c l_c + x_{l_1} = T_1 \tag{3}$$

$$A_m l_m + x_{l_2} = T_2 \tag{4}$$

Consumption is a function of household variables (α), such as household size, sex of household head, age and education. Our main focus is, however, on land allocation decisions. The survey was done in an area where land is relatively abundant. In our model we therefore assume that the farm households can choose how much land to put into *chitemene* cultivation (A_c) and maize production (A_m). Production (q_i, $i=c,m$) is a function of labour inputs (l_i, $i=c,m$) in both systems and fertiliser (f_m) in maize production. Holden (1991) showed that most of the work with the *chitemene* system came during the dry season, while most of the work in the maize system came in the early rainy season. Since the prevalent pattern is that demand for labour in these two systems does not compete, we have included two time periods (1 and 2) for the labour constraint. T_1 is the household's total endowment of time for labour and leisure during the dry season, while T_2 is the time endowment during the rainy season. In a model where all markets are perfect, all prices would be exogenous ($p_c=\bar{p}_c$, $p_m=\bar{p}_m$, $p_z=\bar{p}_z$ and $p_f=\bar{p}_f$) and the wage rate (ω) in a perfect labour market would represent the opportunity cost of leisure ($\omega=\bar{\omega}$) (Singh *et al.*, 1986). In this case of no labour markets, the wage rates will be endogenous and possibly differ in the two periods. Setting up the optimisation problem we get the following Lagrangian function (L):

$$\underset{x_i, A_c, A_m, l_c, l_m, f_m, \lambda, \mu_1, \mu_2}{Max} \quad L = U[\sum_i x_i(\alpha)] + \lambda[A_c p_c q_c(l_c) + A_m(p_m q_m(l_m, f_m) - p_f f_m) \\ - \sum_{i \neq l_j} x_i(\alpha) p_i] + \mu_1[T_1 - A_c l_c - x_{l_1}] + \mu_2[T_2 - A_m l_m - x_{l_2}] \qquad (5)$$

The first order conditions are:

x_i: $\quad U_{x_i(\alpha)} = \lambda p_i \qquad i=c,m,z,l_j \qquad (6)$

$\quad p_i = \bar{p}_i \qquad i=c,m,z$

$\quad p_i = \omega_j = \dfrac{\mu_j}{\lambda} \qquad i=l_j,\ j=1,2$

A_c: $\quad p_c q_c(l_c) = \dfrac{\mu_1}{\lambda} l_c \qquad (7)$

A_m: $\quad p_m q_m(l_m, f_m) - p_f f_m = \dfrac{\mu_2}{\lambda} l_m \qquad (8)$

l_c: $\quad p_c \dfrac{\partial q_c}{\partial l_c} = \dfrac{\mu_1}{\lambda} = \omega_1 \qquad (9)$

l_m: $$p_m \frac{\partial q_m}{\partial l_m} = \frac{\mu_2}{\lambda} = \omega_2 \quad (10)$$

f_m: $$p_f \frac{\partial q_m}{\partial f_m} = p_f \quad (11)$$

λ: $$\sum_{i \neq l_j} x_i(\alpha)p_i = A_c p_c q_c(l_c) + A_m(p_m q_m(l_m, f_m) - p_f f_m) \quad (12)$$

μ_1: $$A_c l_c + x_{l_1} = T_1 \quad (13)$$

μ_2: $$A_m l_m + x_{l_2} = T_2 \quad (14)$$

The farm household will now put land into *chitemene* (and maize) cultivation until profits in *chitemene* (maize) equals the shadow cost of labour in *chitemene* (maize). When the time constraint is binding ($\mu_j>0$), the model is no longer recursive. It is a complex model where production decisions are affected by consumption decisions. The endogenous shadow price of labour ($\frac{\mu_j}{\lambda}$) is affected by trade-offs between leisure and labour and substitutability between leisure and other goods. When the labour constraint is binding, a change in demand for leisure will cause a change in available time for production, which again will bring about a change in land use. From the first order conditions we see that the amount of land used for *chitemene* is a function of the following variables:

$$A_c^* = A_c(\overline{p}_c, \overline{p}_m, \overline{p}_z, \omega_1) \quad (15)$$

$$A_m^* = A_m(\overline{p}_c, \overline{p}_m, \overline{p}_z, \omega_2) \quad (16)$$

and

$$\omega_j^* = \omega_j(\overline{p}_c, \overline{p}_m, \overline{p}_z, \alpha, T_j) \quad (17)$$

In a cross-section econometric model, we assume that all exogenous prices are the same for all households. Since we do not know the household shadow price of labour, we substitute (17) in for ω and get:

$$A_c^* = A_c(\alpha, T_1) \quad (18)$$

$$A_m^* = A_m(\alpha, T_2) \quad (19)$$

Because the model is no longer recursive, household characteristics and availability of family labour should now affect production decisions. The area put into *chitemene* and maize will, under these conditions, be a function of household characteristics (α), and total available time for labour and leisure (T_j). From the first order conditions (13 and 14) we may hypothesise that an increase in total available time for labour and leisure, will lead to an increase in cultivated area of maize and *chitemene*. But because of the non-separability of the model it is, however, difficult to give precise analytical comparative statics answers to these questions.

2.2 Household model with missing credit markets

Survey studies tend to find substantial differences in fertiliser applications and use of other purchased inputs among farm households of the same village, with larger farmers using more purchased inputs per hectare than small ones. Using the Sandmo-hypothesis this could be taken as evidence that risk aversion declines systematically with increased wealth. But Binswanger (1980) found in an experimental study in India, that differences in risk aversion were too small to explain the full differential investment behaviour between small and large farm households in the same environment. He then postulated that such differences in behaviour among farm households facing similar technologies and risks would have to be explained by differences in their constraint sets such as access to credit, marketing and extension, etc..

Credit availability has also been considered relevant on the consumption side. Masson (1972) offered the insight that imperfections in capital markets can induce a risk-neutral individual to behave as if he were risk averse. The idea was that if a household can smooth out consumption over time with their own wealth, or through access to consumption credit, they will have greater capacity to absorb risk. This means that even if all agents have identical risk preferences, different behaviour would still occur if the agents have different access to capital. Morduch (1995) finds that in certain areas where credit markets are especially poor, households are more likely to choose lower mean, lower variance production methods to smooth consumption. Eswaran and Kotwal (1990) demonstrated theoretically that differences in risk-behaviours need not arise from differences in risk preferences. They may rather be due to differences in abilities to pool risks across time. Access to credit for consumption provides households with the facility to absorb random shocks in income, thus preventing drastic fluctuations in consumption. To the extent that large and wealthy farm households tend to have greater access to credit, it follows that they behave as if they were less risk averse than smaller farm households.

We use the basic model from the previous section, without the time-constraints (to keep it simple), but with a credit constraint, to illustrate how a cash liquidity constraint may influence farm households' decisions. The credit constraint is only affecting production, i.e., credit is used for purchases of inputs only. This assumption is relevant for Zambia, where the only formal type of credit available to farmers, was given in the form of fertiliser and hybrid seeds. The farm household now maximises utility (1), subject to a full income constraint (20) and a credit constraint (21):

$$Y = \sum_i p_i x_i(\alpha) = wT + A_c(p_c q_c(l_c) - wl_c) + A_m(p_m q_m(l_m, f_m) - wl_m - p_f f_m) \tag{20}$$

$$A_m p_f f_m \leq \bar{B} \tag{21}$$

where $\bar{B}$ is a set level of savings, exogenous income, or credit available to buy fertiliser. Setting up the optimisation problem we get the following Lagrangian function (L):

$$\begin{aligned} \underset{x_i, A_c, A_m, l_c, l_m, f_m, \lambda, \mu}{Max} \quad L = {} & U[\textstyle\sum_i x_i(\alpha)] + \lambda[wT + A_c(p_c q_c(l_c) - wl_c) + A_m(p_m q_m(l_m, f_m) \\ & - wl_m - p_f f_m) - \textstyle\sum_i x_i(\alpha) p_i] + \mu[\bar{B} - A_m p_f f_m], \end{aligned} \tag{22}$$

The first order conditions are:

$$x_i: \quad U_{x_i(\alpha)} = \lambda p_i \qquad i = c, m, z, l \tag{23}$$

$$A_c: \quad \lambda[p_c q_c(l_c) - wl_c] = 0 \tag{24}$$

$$A_m: \quad p_m q_m(l_m, f_m) - wl_m - p_f f_m = \frac{\mu}{\lambda} p_f f_m \tag{25}$$

$$l_c: \quad p_c \frac{\partial q_c}{\partial l_c} = \omega \tag{26}$$

l_m: $$p_m \frac{\partial q_m}{\partial l_m} = \omega \tag{27}$$

f_m: $$p_f \frac{\partial q_m}{\partial f_m} = \frac{\lambda + \mu}{\lambda} p_f \tag{28}$$

λ: $$\sum_i x_i(\alpha) p_i = wT + A_c(p_c q_c(l_c) - wl_c) + A_m(p_m q_m(l_m, f_m) - wl_m - p_f f_m) \tag{29}$$

μ: $$\mu(\overline{B} - A_m p_f f_m) = 0, \quad \mu \geq 0, \quad \overline{B} - A_m p_f f_m \geq 0 \tag{30}$$

The model shows that as long as the credit constraint is binding ($\mu > 0$), the farm will put land into maize production until profits in production equals the shadow cost of buying fertiliser (shadow value of credit or liquidity ($\frac{\mu}{\lambda}$) multiplied by the market value of fertiliser). Marginal value product of fertiliser is equal to the market price of fertiliser plus the shadow mark up value of fertiliser caused by the liquidity constraint. The model is still recursive, as no endogenous consumption variables appear in the first order condition for A_m. This would not, however, have been the case if credit could also have been used for consumption goods.

As earlier, we assume that all exogenous prices are the same for all households in a cross section econometric model. From the first order conditions we have:

$$A_m^* = A_m(\overline{B}) \tag{31}$$

The area used for maize production is, under these assumptions, a function of access to credit ($\overline{B}$). If a household gets better access to credit it will increase the area allocated to maize. As long as all other markets are perfect, there should be no effect from improvements in credit markets on *chitemene* production.

2.4 Household model with missing commodity markets

Farmers in Northern Zambia grow *chitemene* crops mainly for consumption. There exist markets for these crops in the towns. But far away from the towns, markets for *chitemene* crops are generally very thin and seasonal (Holden, 1997). To illustrate the effect of a missing food market, we will now use the basic model with a market constraint for *chitemene* crops. In this situation the household must produce all the *chitemene* crops it intends to consume. The farm household maximises utility (1), subject to a full income constraint (32) and a food consumption constraint for *chitemene* crops which have no market (33):

$$Y = \sum_{i \neq c} p_i x_i(\alpha) = wT - A_c w l_c + A_m (p_m q_m(l_m, f_m) - w l_m - p_f f_m) \tag{32}$$

$$x_c \leq A_c\, q_c(l_c) \tag{33}$$

Setting up the optimisation problem, we get the following Lagrangian function (L):

$$\underset{x_i, A_c, A_m, l_c, l_m, f_m, \lambda, \mu}{Max} \quad L = U[\textstyle\sum_i x_i(\alpha)] + \lambda[wT - A_c w l_c + A_m(p_m q_m(l_m, f_m) - w l_m - p_f f_m) \\ - \textstyle\sum_{i \neq c} x_i(\alpha) p_i] + \mu[A_c q_c(l_c) - x_c], \tag{34}$$

The first order conditions are:

x_i: $\quad U_{x_i(\alpha)} = \lambda p_i \quad i=c,m,z,l$ (35)

$\quad p_i = \overline{p}_i \quad i=m,z$

$\quad p_i = \overline{w} \quad i=l$

$\quad p_i = \dfrac{\mu}{\lambda} \quad i=c$

A_c: $\quad w l_c = \dfrac{\mu}{\lambda} q_c(l_c)$ (36)

A_m: $\quad \lambda[p_m q_m(l_m, f_m) - w l_m - p_f f_m] = 0$ (37)

l_c: $\quad \dfrac{\mu}{\lambda}\dfrac{\partial q_c}{\partial l_c} = \omega$ (38)

l_m: $\quad p_m \dfrac{\partial q_m}{\partial l_m} = \omega$ (39)

f_m: $\quad p_f \dfrac{\partial q_m}{\partial f_m} = p_f$ (40)

$$\lambda: \qquad \sum_{i \neq c} p_i x_i(\alpha) = wT - A_c w l_c + A_m (p_m q_m(l_m, f_m) - w l_m - p_f f_m) \qquad (41)$$

$$\mu: \qquad \mu(A_c q_c(l_c) - x_c) = 0, \quad \mu \geq 0, \quad A_c q_c(l_c) - x_c \geq 0 \qquad (42)$$

As long as the farm household demands *chitemene* crops, the *chitemene* constraint is binding ($\mu > 0$), and the model is nonseparable. Demand for *chitemene* crops is a function of household characteristics, its own price, the price of other consumption goods, and total income. Since the model is nonseparable, the endogenous shadow price of chitemene ($\frac{\mu}{\lambda}$) is determined by the equilibrium between supply and demand within the household. The endogenous shadow price is affected both by the substitutability between *chitemene* crops and other goods (cross-price elasticities) and by the income elasticity. When the *chitemene* constraint is binding, a change in the price of any of the other consumption goods will cause a change in the shadow price for *chitemene*. This will induce a change in demand for *chitemene*, which in turn will bring about a change in land use.

Sadoulet and de Janvry (1995) argue that only in the extreme case does the market not exist at all. Typically some type of market does exist. However, «*a market may fail*[4] *for a particular household when it faces wide price margins between the low price at which it could sell a commodity or factor and the high price at which it could buy that product or factor. Faced with this wide price band, the household may be better off choosing self-sufficiency in that good or factor if its subjective price (defined as the price which equates its supply and demand) falls inside the band*». (Sadoulet and de Janvry, 1995, p. 149). Sadoulet and de Janvry list the following factors which may increase the magnitude of the price band: (a) transaction costs, which, among other factors, include distance to markets and poor infrastructure; (b) shallow local markets, which imply high negative covariance between household supply and market prices; and (c) price risks and risk aversion which influence the effective price used for decision making. The greater the level of price risk and the greater the aversion to risk, the wider the effective price band becomes. When the subjective equilibrium price falls within the price band, equilibrium of supply and demand within the household determines a shadow price that serves as the decision price for the household. When the market is used for transactions, the subjective equilibrium falls outside of the price band. Market prices then serve as decision prices, and production and consumption decisions are made separately. If the household is a net seller, the internal equilibrium falls below the lower band and sale price is the relevant price. For the net buyer, the internal equilibrium falls above the upper price band, and the relevant price is the purchase price. The wider the effective price band is, the higher the likelihood is of market imperfections.

As above, we assume that in a cross-section econometric model all exogenous prices are the same for all households. From the first order conditions above, and from the discussion about when markets are imperfect/missing, we have:

$$A_c^* = A_c(\alpha, p_c, \Theta) \tag{43}$$

The area used for *chitemene* crops is a function of household characteristics (α), the endogenous shadow price of *chitemene* (p_c), and the size of the price band (Θ). Since we do not know the household's internal price for *chitemene* and the price-band we will have to use proxies for these variables. Since *chitemene* crops are basic staples in Northern Zambia, we can use a household characteristic variable such as household size (which is in α) or consumer units as a proxy for how much *chitemene* the household demands. Distance to markets can function as a proxy for the size of the price band.

2.4 Household model with production risk

This section discusses household land allocation decisions under production risk. At the time the survey was carried out, less than 10 percent of the farm households considered price risk as an important source of variation in profitability (Wik and Holden, 1996). Therefore, we have not included price risk in the formal analysis. (However, we do discuss some implications of price risk at the end of this section.)

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[4] Sadoulet and deJanvry have been criticised for their use of the concept «market failure», when a more appropriate concept would be «market imperfection». I will, however, not get into this discussion here.

Output per acre q_i (i=c,m), is now determined by a non-stochastic term, $\bar{q}_i$, and a non-household specific stochastic disturbance in production, ε_i:[5]

$$q_i = \bar{q}_i + \varepsilon_i \qquad i=c,m, \qquad (44)$$
$$\varepsilon_i \sim N(0,\sigma_i^2)$$
$$cov(q_c,q_m)=\sigma_{cm}$$

We propose that farm households maximise expected utility of wealth at the end of each season:

$$\underset{A_c}{Max}\, EU(W) \qquad \text{where} \qquad (45)$$
$$W = \bar{W}_0 + Y = \bar{W}_0 + A_c(\alpha)\Pi_c + A_m(\alpha)\Pi_m + wT$$
$$\Pi_i = p_i q_i - wl_i = \bar{\pi}_i + p_i\varepsilon_i, \qquad i=c,m$$

$\bar{W}_0$ is fixed wealth at the beginning of the period, and q_i is defined in (44). To simplify this model, fertiliser is not included in maize production. In the previous sections we have seen that in a land abundant economy with possible market imperfections, areas of land used for maize and *chitemene* production are functions of household characteristics. The first order condition is:

$$\frac{\partial U}{\partial A_i} = E[U'\frac{dW}{dA_i}] = E[U'\Pi_i] = 0 \qquad (46)$$

Following Just and Zilberman (1983), we consider a first-order Taylor series approximation of U' about expected wealth, $\bar{W}$:

$$U'(W) \approx U'(\bar{W}) + U''(\bar{W})(W - \bar{W})$$
$$= \bar{U}' + \bar{U}''[A_c(\alpha)p_c\varepsilon_c + A_m(\alpha)p_m\varepsilon_m] \qquad (47)$$

[5] A similar framework is used by Just and Zilberman (1983) for discussing the importance of farm size for adoption of new technology.

Let the Arrow-Pratt measure of absolute risk aversion at mean wealth be denoted $\varphi = -\frac{U''}{U'}$. Then, using (47) in (46), the first order condition is approximated by:

$$\bar{\pi}_c = \varphi[A_c(\alpha)p_c^2\sigma_c^2 + A_m(\alpha)p_c p_m \sigma_{cm}] \quad (48)$$

$$\bar{\pi}_m = \varphi[A_m(\alpha)p_m^2\sigma_m^2 + A_c(\alpha)p_c p_m \sigma_{cm}] \quad (49)$$

The farm household will put land in *chitemene* and maize until the marginal effect on expected profits equals the marginal effect on profit-risk (variance of profits) weighted by the farm households' absolute risk aversion coefficient.

Rewriting (48) and (49) we have:

$$A_c^*(\alpha) = \frac{\bar{\pi}_c}{\varphi p_c^2 \sigma_c^2} - \frac{A_m(\alpha) p_m \sigma_{cm}}{p_c \sigma_c^2} \quad (50)$$

and

$$A_m^*(\alpha) = \frac{\bar{\pi}_m}{\varphi p_m^2 \sigma_m^2} - \frac{A_c(\alpha) p_c \sigma_{cm}}{p_m \sigma_m^2} \quad (51)$$

From (50) and (51) we see that the amount of land used for *chitemene* crops maize are a function of:

$$A_c^* = A_c\,(p_c, p_m, w, A_m, \alpha, \varphi, \sigma_c^2, \sigma_{cm}) \quad (52)$$

$$A_m^* = A_m\,(p_c, p_m, w, A_c, \alpha, \varphi, \sigma_m^2, \sigma_{cm}) \quad (53)$$

As above, we assume that in a cross-section econometric model all exogenous prices are the same for all households. We have also assumed that variances in yields are non household-specific, thus the variances should not be included in a cross section model. In Northern Zambia, it is reasonable to assume that the covariance between yields in the maize and *chitemene* systems was close to zero. Variance in yields in maize production was mainly related to lack of credit and/or lack of or late supply of fertilizer, while variance in *chitemene* cultivation was mainly a result of pests or other agronomic conditions (Wik and Holden, 1996). Furthermore, *chitemene* crops are drought resistant, while maize production is more vulnerable to drought. Drought is, however, rarely a problem in the area and was not so when the surveys were carried out. We see from (50) and (51) that if the covariance between maize and *chitemene* cultivation is zero, the area put into maize production should not influence the area in *chitemene* cultivation and *vice versa*. From these assumptions, we have:

$$A_i^* = A_i(\alpha,\varphi) \tag{54}$$

The areas used for *chitemene* crops and maize production are functions of fixed household capital variables (α), and decision-maker's level of risk aversion.

So far we have discussed risk in production only. If the household is facing price-risk, however, this analysis can result in erroneous conclusions if the producing household is also consuming large parts of its output. Finkelshtain and Chalfant (1991) discuss how price-risk affects farm households which consume parts of their own production. They show that, as both a producer and consumer of the output, the household must deal with multivariate risk from both prices and income. They demonstrate that Sandmo's findings can be reversed when consumption risk is taken into account. That is, a farm household's optimal response to price risk can be an increase in its production of the risky crop in order to protect itself from price risk on the consumption side.

Fafchamps (1992) used a similar approach to show why larger farm households in developing countries are more cash crop oriented and smaller farm households more food crop oriented. This is because rural food markets are thin and isolated, leading to high variance in food prices and a high covariance between individual and market supply. Staple consumption is essential for survival, thus demand for food has a low income elasticity. The combination of the two elements lead to a situation in which food security at the household level is best achieved by a high degree of food self-sufficiency. His model showed that larger farm households can sustain the price risk because of the low share of staple foods represented in their total consumption expenditures, and this alone can account for the observed regularity between farm size and cash crop cultivation.

2.5 Theoretical summary

In the sections above we have discussed variables affecting land use choices under different theoretical assumptions. This discussion has resulted in a list of variables which may influence choices of farm households regarding how much land they will use for *chitemene* crops and maize. To test which variables did affect land use choices and the direction of these effects[6], we specify a reduced form regression equation of the following form:

$$C_{ij} = \beta_0+\beta_1\alpha_j+\beta_2B_j+\beta_3T_j+\beta_4H_j+\beta_5D_j+\beta_6\varphi_j \qquad (55)$$

C_{ij} denotes the crop choice i (i=*chitemene* or maize) on farm j. The other variables include a vector of household characteristics (α_j) (excluding household size), credit or other funds for buying seeds and fertilisers (B_j), household work-force (T_j), household size (H_j), distance to markets (D_j), and the level of risk aversion (φ_j). Table 1 gives an overview of the variables which should be significant for each of the theoretical models.

(Table 1 about here)

3. Allocation of land to maize and *chitemene*

As we have seen, farm households in northern Zambia combine two main production systems. They produce several crops (fingermillet, beans, groundnuts and cassava) in the *Chitemene* traditional slash and burn system, and they produce monoculture maize in more «permanent» fields. On average, each household cultivates 1.37 ha of land, of which 0.52 ha is used for maize production and 0.74 ha for *chitemene* crops (Table 2). While the *chitemene* crops are mainly grown for consumption, maize is primarily a cash crop using hybrid seeds and fertiliser. These inputs have only been available through government-sponsored credit programs and their quantities have been limited. Average total income per capita (including consumption of major subsistence crops) was very low, approximately Kw.[7] 69,000, or roughly US$ 115. Average off-farm income per capita was less than US$ 6, and not even one third of the farm households had access to off-farm income.

(Table 2 about here)

The study utilised data collected during field research carried out in 1993 and 1994. The field research in 1994 surveyed 110 randomly sampled households in six different villages in northern Zambia[8]. During this survey we collected data on household demographics, the level of risk aversion, and on income and expenditures. In the 1993 survey, fields were measured and production data were collected. When combining the two surveys, we had complete data-sets for 92 households. Of these 92 households, six did not cultivate land, and were, therefore, omitted in the econometric analysis. The majority of the farm households (52) were growing both maize and *chitemene* crops (Table 3). Of these 52 farmers, seven were also growing crops in other cultivations systems[9]. In total, 33 farmers were growing crops in other systems. Most of these farmers (23) practised these other systems in combination with maize production, and instead of *chitemene* cultivation.

(Table 3 about here)

Of the six villages, three were situated in a fairly densely populated area (26-82 persons/km^2) close to the province capital, Kasama. Farm households in these villages had a reasonably good access to major markets for food crops. The remaining three villages were

[6] Because of non-separability in most of the theoretical models it was not possible to tell the direction of these effects analytically. This was only possible for the credit-constraint model, where we found that improved access to credit, would increase the area allocated to maize production.

[7] US$ 1 ≈ Kw. 600 (August, September 1994)

[8] See Holden *et al.* (1994) for a description of the sampling procedure.

[9] The most common of these other cultivations systems was the cassava garden. In the villages close to the provincal capital Kasama, cassava was usually grown in separate gardens. While in the more distant areas cassava was grown as part of the *chitemene* system. The grassmound or *fundikila* system was also used by some farmers (see Holden (1991), p. 31, for a description of this system).

located in a rather sparsely populated area (<6 persons/km^2) approximately 65-80 km. north-east of Kasama.

In the 1994 survey we measured individuals' attitudes to risk using an experimental gambling approach similar to Binswanger's (1980). In the experiment, subjects were confronted with series of choices among sets of alternative prospects (gambles) involving real money payment.[10] Each gamble lists six alternative prospects or gambles, each with a 50% probability of winning (see Table 4). The subjects were asked to select one of the six alternatives. The alternatives represented increased expected gains, but at the cost of increased spread between the two outcomes. The six alternatives were classified from extreme risk aversion to neutral to preferring. The subject's choice among these alternative prospects was taken as an indication of the degree of the decision-maker's risk aversion. The individuals played 11 games with different levels of possible gains, and three games at different levels with both gains and losses.

(Table 4 about here)

To get a unique risk aversion coefficient for each game level, we used the following utility function with constant partial risk aversion (CPRA):

$$U=(1-\varphi)x^{(1-\varphi)} \qquad (56)$$

where x is the certainty equivalent of the prospect. The parameter φ will then be equivalent to the constant partial risk aversion coefficient.[11] In this study we use the average of the constant partial risk aversion coefficients for 11 games as a measure of the households' level of risk aversion.[12]

3.1 Econometric findings

[10] see Wik and Holden (1998) for a detailed description of the experiment
[11] See Wik and Holden (1998) for a discussion of the use of a CPRA utility function, and for the experimental results.
[12] The gambles were played during two visits. The first two gambles of the first visit, and the first gamble of the second visit were treated as practise-gambles and were omitted in the formal analysis.

Data from the 1993 and 1994 household surveys were used to estimate the equation (46) and test the hypothesis that farm households' land use decisions are influenced by market imperfections as well as risk aversion. Estimation of the equation poses special problems stemming from the presence of farmers not producing one of the crops (7% did not grow maize, 35% did not grow *chitemene* crops), and from farmers not receiving credit (32% did not receive credit). Furthermore equation (55) could possibly constitute endogenous variables problems, as both the level of risk aversion and access to credit could cause endogeneity in variables bias. The two possible endogenous variables were defined as:

$$\varphi_j = \gamma_0+\gamma_1 \bar{A}_j+\gamma_2\alpha_j+\gamma_3 b_j+\gamma_4 T_j+\gamma_5 H_j+\gamma_6 Wh_j \quad (57)$$

$$fert_j = \delta_0+\delta_1 \bar{A}_j+\delta_2\alpha_j+\delta_3 b_j+\delta_4 T_j+\delta_5 H_j+\delta_6 Wh_j \quad (58)$$

Some type of household wealth or sources of certain income is usually needed as collateral to get access to credit. Wealth is also commonly believed to have an effect on the subject's degree of risk aversion. Wealthier people are assumed to be able to take more risk, than poorer people. In the regression equations for the endogenous variables we therefore included off farm income (b_j) and a vector of wealth indicators (Wh_j). The dependent variable $fert_j$ is the amount of fertiliser used at the farm. The farm households receive credit in the form of seeds and fertilisers. Since we did not have data on the amount of credit received by individual farm households, we use the amount of fertiliser the farmers applied as a proxy for how much credit they received.

We were not able to identify different instruments for the two endogenous variables. As a second best solution, we did a Hausmann specification test (Hausmann, 1978), to test for the presence of endogeneity bias in the risk aversion and credit-proxy variables. Under the hypothesis of no measurement error, both the least square estimator (b) and the instrumental variables estimator (b_{IV}) are consistent estimators, although least squares is efficient, while b_{IV} estimator is inefficient. But if the hypothesis is false, only the b_{IV} estimator is consistent (Green, 1993). A Hausmann test for the risk aversion variable concludes that the null hypothesis cannot be rejected (1% level of significance). The null hypothesis could, however, be rejected for the credit-proxy variable. These results indicate that the risk aversion variable will not introduce endogeneity bias, as its error is not correlated with that of the area of maize and *chitemene* equations. There is, however stronger evidence that the credit-proxy variable will introduce endogeneity bias. We will therefore treat risk aversion as an exogenous variable, while the credit-proxy variable is treated as an endogenous variable in the Three Stage Least Square regression (3SLS) analysis below.

A two-step simultaneous-equation method was used to estimate the equations given by (55). This method utilises Lee's (1978) generalisation of the Amemiya (1974) two-step estimator to a simultaneous-equation model. It produces an estimator that is both consistent and asymptotically efficient relative to other two-step estimators (Lee, 1978). In the first step, a new variable is defined as $d_{mj}=1$ if farm j planted at least some maize and $d_{mj}=0$ otherwise. A 0-1 probit model was estimated for the maize to obtain an inverse Mills ratio (IMR) for maize production $(\lambda_{mj} = \phi(z_j) / \Phi(z_j))$ and non-production of maize $(\lambda_{mj} = \phi(z_j) / [1 - \Phi(z_j)])$ for each farm household *j*, where z_j is a vector containing the right-hand side variables in equation (55) except the endogenous variable, and $\phi(.)$ and $\Phi(.)$ are the density and cumulative distribution functions, respectively. Similar estimations were made for production of *chitemene* crops (λ_{cj}), and for the use of fertiliser (λ_{fj}). The z_j in λ_{fj} is a vector containing the right hand side variables in equation (58).

In the second step, the inverse Mills ratios were included as right hand side variables in (55) and (58), and the three equations are estimated jointly using three-stage least squares (3SLS) to exploit the information contained in the cross-equation error correlation. The inverse Mills ratios serve as instruments to control for censoring latent variables in the equations where a considerable proportion of farm households did not apply, or had access to, the option in the equation (Lee, 1978; Heien and Wessells, 1990; Brush *et al.,* 1992). The model assumes that the error terms are distributed as approximately normal with zero means and a finite variance-covariance matrix. Lee (1978) argues that even though the estimates in the three-equation system are not efficient, this method gives estimates that are consistent and asymptotically more efficient than other two-step estimators.

The results of the censorship-corrected estimation of the model with the endogenous credit proxy as the dependent variable are shown in Table 5. The regression model yielded no big surprises. All the wealth variables, except the number of big animals, have positive estimates, some of which are significant. Total farm area, total income, and number of bicycles are all variables with significant parameter estimates at the 0.01 level.

(Table 5 about here)

The results of the censorship-corrected estimation of the maize model are summarised in Table 6, while the results of the *chitemene* model are summarised in Table 7. The dependent variables in these models are the share of maize (and *chitemene*) area of total planted area. The results from the 3SLS regression systems with the credit proxy as endogenous are also compared with a 2 equation system of Seemingly Unrelated Regression (SUR). Several patterns emerge from these regressions:

(Table 6 about here)
(Table 7 about here)

Variable estimates from the two systems are very similar. This can be taken as an indication of a relatively small endogeneity bias. In the models with <u>total</u> land of maize and *chitemene* as dependent variables (Tables 8 and 9), we therefore present only the results from the SUR models.

All the systems have high system R-squares, while the coefficient estimates' t-values are relatively low. We have tried to correct for possible multicollinearity problems by omitting some variables, without gaining any improvements in the results.[13]

The shares of maize and *chitemene* crops seem to be sensitive to some of the household fixed capital variables. Other things being equal, female headed households appear to put a smaller share of land into maize cultivation than male headed households and a higher share into *chitemene* cultivation. These variables were only slightly significant. This result is consistent with general findings from other parts of Africa, where men are found to be cash-crop producers, while women are more often responsible for subsistence crops (Jiggins,

[13] Total cultivated land and available labour at the farm could be possible sources of multicollinearity. Sex of household head and female labour force was another possible source. Omitting the variables for total cultivated land and/or sex of household head did not however improve the econometric results.

1989; Ellis, 1993). However, looking at the results in Table 8 and 9, female headed households do not seem to differ much from male headed households when it comes to total areas of maize and *chitemene* cultivation. The level of education also seems to influence how much land the farm households allocate to maize, both in relative and total areas. The more educated farmers, *ceteris paribus*, appear to put more land into maize production than farmers with less education. The estimates on this variable were not significant, but had the expected signs, in the *chitemene* models. For relative production of *chitemene* crops, age seems to be a significant factor. Not surprisingly older farmers, other things being equal, appear to put a bigger share of their land into the traditional cultivation system. Older farmers did not, however, seem to put more land into *chitemene* cultivation in absolute terms.

(Table 8 about here)

(Table 9 about here)

A total land variable was included in the regressions as a proxy for long run farming investments. Since access to land is not limited, it can be argued that the total land variable could also cause some endogeneity bias, as it is probably dependent upon the household's access to family labour to clear land. However, most of this land has been cleared in previous seasons, and we argue that even though total land is endogenous in the long run, it is correct to treat it as exogenous in the short run. We find no significant associations between total land under cultivation, and the share of maize and *chitemene* crops. Experimentation with total areas of maize and *chitemene* crops instead of shares as the dependent variables, yielded different results (Table 8 and 9). Total farm area was a positive and significant variable in both the total maize area and the total *chitemene* area models. This is consistent with the theoretical finding by Just and Zilberman (1983) that under certain conditions larger farms will devote more land in absolute terms but not in proportionate terms to a new technology.[14]

[14] Larger farms will devote less land proportionately if there is a low or negative correlation between outputs under the old and new technologies, if the modern technology is perceived to be sufficiently more risky than the traditional technology, and if relative risk aversion increases and absolute risk aversion decreases with farmers' wealth.

In the study area, there is a relatively strict gender division of labour. Clearing land is a male task, while the women do much of the planting, weeding and harvesting. Total household workforce was therefore split into male and female work force variables. Contrary to our expectation, the work-force variables did not have significant estimates in any of the share dependent variable models. In the total area models, the female workforce variable was positively correlated with total maize area and negatively correlated with total *chitemene* area, while the male work force variables did not yield significant estimates in any of these models. These results could have been taken as evidence of imperfect markets for female labour, as well as complete and competitive markets for male labour. The results are, however, different from the results of earlier studies from the same area (Holden, 1991), where male workforce was found to be a significant determinant of both maize and *chitemene* areas, while female labour was not significant. Furthermore, labour markets in this area are highly imperfect (Holden, 1997). Thus, we rather take our results as an indication of male labour supply being unconstrained, while access to female labour may be a constraint in maize production.

The estimates on the credit-proxy variable are positively significant for the maize share models, while it is not significant in the *chitemene* share models. The estimated coefficient on the credit-proxy variable in the maize share models does not change much from the SUR to the 3SLS regressions systems models. Still the t-values are different in the two systems. The estimate on the credit proxy variable is significant at a 1% level in the SUR model, but only at a 10% level in the 3SLS regression model. This is probably a result of a poor instrument for the endogenous credit-proxy variable in the 3SLS model. We were, however, not able to find other explanatory variables which would make a better instrument for the endogenous credit variable. In the total area models, the credit proxy variable had a positive estimate (1% level of significance) in the maize model (Table 7), and a negative significant estimate (5% level) in the *chitemene* model (Table 8). These results may reflect that access to credit is a binding constraint in maize production, and that farmers would grow more maize and less *chitemene* if they had better access to credit. Off farm income was not significant in any of the models.

There seems to be a significant correlation between distance to town and how much land the farm households allocate to the two different production systems. Farm households in the distant area produce less maize relative to *chitemene*, than do the farm households in the area close to town. The distance to main market variable is significant at 0.1% level in all the models. This could be an indication of higher transactions costs in the distant area, and, therefore, that farm households in this area are better off producing more subsistence crops. However, we believe that this result is also a consequence of much higher population pressure, and hence, less land available for *chitemene* production in the area close to town. Thus, an indication of a missing commodity market, based purely on the significance of this variable, would be erroneous. Yet, the estimates on the household size variables are also significant with expected signs. The bigger the household is, *ceteris paribus*, the smaller is the share of land allocated to maize and the larger the share of land allocated to *chitemene*. Thus, households with high consumption needs tend to allocate a smaller proportion of their land to cash crop production and a higher proportion to cultivation of subsistence crops. These results were robust to the definition of the dependent variable, and appear to give an indication of missing commodity markets.

There is a significant negative association (10% level) between risk aversion and the share of land allocated to maize. This indicates that the more risk averse a farmer is, other things being equal, the smaller amount of his land he will allocate to maize cultivation. Since maize is the most risky crop, this seems to be consistent with the Sandmo model. Though the risk aversion variable has a positive sign in the *chitemene* model, it is not significant. In the models using total areas as dependent variables (Tables 8 and 9), the estimates on the risk aversion variables had the expected signs (negative for maize, positive for *chitemene*), but were not significant. Assuming that our risk aversion variable is a good measure of the farm households' true preferences, these results indicate that individual risk aversion coefficients are not influencing the farm households' total area under maize and *chitemene* cultivation, but do possibly influence the relative shares of maize and *chitemene* .

The estimates on the inverse Mills ratios were highly significant in all the three models of the 3SLS and in the two SUR models for the share of maize and *chitemene* dependent variables. Thus, we can reject the null hypotheses of no selectivity biases in the models. In the total area dependent variable models, the IMR was significant at 5% level in the maize model, but not significant in the *chitemene* model. Farm households with an ex-ante high likelihood of growing maize seem to put more land into maize production both in relative and absolute terms than farm households with lower ex-ante likelihood of growing maize. For *chitemene* cultivators the results indicate that farm households with higher ex-ante probabilities of growing *chitemene* crops put higher shares of total land into *chitemene*, but not more land in absolute terms, than farmers with lower ex-ante probabilities of cultivating *chitemene* crops. From Table 5 we see that the same argument holds for the farm household with an ex-ante high probability of receiving credit: farm households with higher ex-ante probabilities of receiving credit, obtain more credit than households with lower ex-ante likelihood of receiving it.

4. Conclusions

The findings reported in this paper provide empirical evidence that both household specific socio-economic variables and market imperfections influence farm households' cropping decisions in northern Zambia. We also found some week evidence that farmers who revealed a high degree of risk aversion chose a smaller share of maize in their crop portfolio, other things being equal, than farmers who revealed a low degree of risk aversion. However, other constraints, rather than differences in risk preferences, appeared to explain most of the variation in crop portfolios.

The findings provide evidence of imperfect credit and commodity markets. Access to credit seems to be an important determinant of how much land farm households allocate to maize production. Distance to markets and size of the household appear to be important factors in deciding how much subsistence crops to grow. Farm households living far away from town and farm households with big families to feed, put a relatively bigger area into *chitemene* cultivation, other things being equal, than do farm households living close to town and farm households with small families to feed.

Surprisingly, the empirical analysis provided no evidence of access to male labour having a significant impact on farm households' decisions about how much land to allocate to maize and *chitemene* cultivation. However, female labour was found to be a significant binding constraint in maize production. Other studies (Holden, 1997) have documented highly imperfect labour markets in this area of Zambia. We therefore take these results as evidence of slack male labour in the households.

This study concludes that many circumstances seem to influence cropping decisions. Missing credit and commodity markets were found to be important determinants of how much (or how little) maize and *chitemene* crops the farm households decide to grow. Differences in risk preferences, however, seemed to have only a minor effect on cropping decisions. High degrees of risk aversion may influence farmers to have a smaller share of the mix devoted to maize. The results of structural adjustment policies during the last four to five years have been decreased profitability, increased risk, and reduced access to credit in maize production, which have probably further limited maize production in this area. Expansion of *chitemene* cultivation and more rapid deforestation are consequences of this. One important reason behind the government sponsored programs to stimulate maize production in northern Zambia from the late 1970s to the late 1980s, was to ease the population pressure and the successive deforestation through a shift from *chitemene* cultivation to maize production. If this development path is still desired, the results from this study indicate that policy options to increase maize production and reduce *chitemene* cultivation should recognise the importance of development of commodity markets and infrastructure, and improved access to credit.

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Table 1.
Variables with estimates significantly different from zero in different theoretic household models.

	Model with imperfect labour markets	Model with imperfect credit markets	Model with imperfect commodity markets	Model with risk in production
H.hold fixed capital	*	*	*	*
Credit[1)]	0	*	0	0
H.hold work-force	*	0	0	0
H.hold size	0	0	*	0
Distance to markets	0	0	*	0
Risk aversion	0	0	0	*

[1)] Including other funds for buying fertilizer.

Table 2.
Summary statistics for the participants of the study.

Variable	Mean	Standard Deviation
Total cultivated area (ha)	1.37	0.98
Maize area (ha)	0.52	0.47
Chitemene area (ha)	0.74	0.86
Total annual income per capita (US $)[1)]	115.98	93.21
Off farm income per capita (US $)	5.86	19.20
Cash liquidity per capita (US $)[2)]	10.86	27.89
Household size (persons)	4.71	3.19
Household workforce	2.88	1.82
Age	47.97	14.84
Years of school	5.09	3.56

No. of observations = 86
[1)] Including values of major subsistence crops
[2)] Total income minus total expenditures

Table 3.
No. of farm households in the sample growing maize, *chitemene* crops and crops in other cultivation systems.

	No maize	**Maize**	**Total**
No *chitemene* crops	2 (2)	28 (23)	30 (25)
***Chitemene* crops**	4 (1)	52 (7)	56 (8)
Total	6 (3)	80 (30)	86 (33)

The numbers in parentheses are the no. of farm households growing crops in other cultivation systems.

Table 4.
The 100 Kw game for «gains-only» and «gains and losses»..

	Gains only.			**Gains and losses.**	
Choice	***Bad luck payoff "Heads"***	***Good luck payoff "Tails"***	***Risk aversion class***	***Bad luck payoff "Heads"***	***Good luck payoff "Tails"***
0	100	100	Extreme	0	0
A	90	180	Severe	-10	80
B	80	240	Intermediate	-20	140
C	60	300	Moderate	-40	200
D	20	380	Slight to neutral	-80	280
E	0	400	Neutral to preferring	-100	300

Table 5.
Censorship-corrected 3SLS systems estimates for the endogenous credit-proxy variable (dependent variable = use of fertiliser in the 1992-93 season).

Variable name	Estimated coefficient	t-ratio	Probability
Sex of household head	-0.7007	-0.608	0.544
Age	0.0420	1.117	0.268
Years of school	0.0362	0.211	0.833
Female workers	-0.7115	-1.080	0.284
Male workers	0.3730	0.657	0.513
Total income (1993-94 season)	0.95E-05	3.648	0.000***
No. of bicycles	2.4113	3.064	0.003**
No. of houses	0.2229	0.461	0.646
No. of big animals	-0.1140	-1.137	0.259
Distance to town	-0.57E-03	-0.028	0.977
Household size	-0.1402	-0.499	0.619
Total farm area	0.14E-03	2.732	0.008**
Inverse Mills ratio (fertiliser-use)	3.8432	6.071	0.000***
Constant	-0.9280	-0.251	0.802

No. of observations	86
System R^2	0.98
Chi-square (df)[a]	350.55 (37)
Equation R^2	0.64

*, **, *** refer to significance at 10, 1, and < 0.1 % level respectively.
[a] corresponding to a likelihood ratio test of the null hypothesis that all slope coefficients in the equation system are zero.

Table 6.

Censorship-corrected SUR and 3SLS systems estimates for relative area of maize (dependent variable = share of maize area of total planted area).

	Seemingly Unrelated Regressions System			Three Stage Least Squares Regressions System		
Variable name	**Estimated coefficient**	**t-ratio**	**Proba-bility**	**Estimated coefficient**	**t-ratio**	**Proba-bility**
Sex of household head	-0.0953	-1.704	0.093*	-0.0957	-1.722	0.089*
Age	-0.0018	-0.999	0.321	-0.0018	-0.971	0.344
Years of school	0.0156	1.902	0.061*	0.0158	1.932	0.057*
Total farm area	-0.28E-05	-1.110	0.270	-0.26E-05	-0.985	0.328
Female workers	0.0445	1.320	0.191	0.0432	1.268	0.209
Male workers	0.0343	1.255	0.213	0.0341	1.257	0.213
Off farm income	0.19E-06	1.043	0.301	0.18E-06	0.984	0.328
Credit-proxy	0.0117	2.637	0.010***	0.0105	1.757	0.083*
Distance to town	-0.0053	-5.552	0.000***	-0.0053	-5.549	0.000***
Household size	-0.0274	-1.973	0.052*	-0.0267	-1.904	0.061*
Risk aversion	-0.0289	-1.804	0.075*	-0.0297	-1.866	0.066*
Inv. Mills ratio (maize)	0.2091	6.014	0.000***	0.2157	6.306	0.000***
Constant	0.8061	4.615	0.000***	0.8095	4.663	0.000***
No. of observations	86			86		
System R^2	0.95			0.98		
Chi-square (df)[a]	263.98 (24)			350.55 (37)		
Equation R^2	0.72			0.74		

*, **, *** refer to significance at 10, 5, and 1 % level respectively.

[a] corresponding to a likelihood ratio test of the null hypothesis that all slope coefficients in the equation system are zero.

Table 7.
Censorship-corrected SUR and 3SLS systems estimates for relative area of *chitemene* (dependent variable = share of *chitemene* area of total planted area).

	Seemingly Unrelated Regressions System			Three Stage Least Squares Regressions System		
Variable name	Estimated coefficient	t-ratio	Probability	Estimated coefficient	t-ratio	Probability
Sex of household head	0.0717	1.725	0.089*	0.0684	1.643	0.105
Age	0.0034	2.494	0.015**	0.0036	2.644	0.010***
Years of school	-0.0032	-0.527	0.600	-0.0029	-0.483	0.630
Total farm area	0.39E-06	0.209	0.835	0.87E-06	0.437	0.663
Female workers	-0.0288	-1.148	0.255	-0.0326	-1.280	0.205
Male workers	-0.0112	-0.533	0.582	-0.0087	-0.426	0.671
Off farm income	-0.25E-07	-0.182	0.856	0.46E-07	0.334	0.739
Credit-proxy	-0.0005	-0.157	0.876	-0.0022	-0.489	0.626
Distance to town	0.0118	16.770	0.000***	0.0118	16.580	0.000***
Household size	0.0185	1.792	0.077*	0.0179	1.708	0.092*
Risk aversion	0.0098	0.812	0.419	0.0122	1.029	0.307
Inv.Mills ratio (*chitemene*)	0.1493	5.567	0.000***	0.1493	5.567	0.000***
Constant	-0.3119	-2.401	0.019**	-0.3257	-2.507	0.014*
Equation R^2,[a]	0.91			0.91		

*, **, *** refer to significance at 10, 5, and 1 % level respectively.
[a] System test statistics appear at bottom of Table 6.

Table 8.
Censorship-corrected SUR systems estimates for total area of maize (dependent variable = total maize area).

Variable name	Estimated coefficient	t-ratio	Probability
Sex of household head	-327.21	-0.373	0.710
Age	-10.329	-0.372	0.722
Years of school	272.39	2.120	0.037**
Total farm area	0.3914	9.729	0.000***
Female workers	1346.6	2.544	0.013**
Male workers	-4.7622	-0.011	0.991
Off farm income	0.0020	0.700	0.486
Credit-proxy	186.25	2.682	0.009***
Distance to town	-65.967	-4.449	0.000***
Household size	-615.87	-2.822	0.006***
Risk aversion	-263.80	-1.050	0.297
Inverse Mills ratio (maize)	731.30	2.332	0.022**
Constant	2224.9	0.8115	0.420
No. of observations		86	
System R^2		0.99	
Chi-square (df)[a]		451.33 (24)	
Equation R^2		0.72	

*, **, *** refer to significance at 10, 5, and 1 % level respectively.
[a] corresponding to a likelihood ratio test of the null hypothesis that all slope coefficients in the equation system are zero.

Table 9.
Censorship-corrected SUR systems estimates for total area of *chitemene* (dependent variable = total *chitemene* area).

Variable name	Estimated coefficient	t-ratio	Probability
Sex of household head	530.48	0.506	0.614
Age	17.523	0.507	0.613
Years of school	-213.35	-1.390	0.169
Total farm area	0.5414	11.27	0.000***
Female workers	-1299.4	-2.055	0.043**
Male workers	524.03	1.024	0.309
Off farm income	0.0006	0.160	0.873
Credit-proxy	-171.87	-2.073	0.042**
Distance to town	121.13	6.839	0.000***
Household size	495.32	1.900	0.061*
Risk aversion	117.85	0.393	0.419
Inverse Mills ratio (*chitemene*)	559.37	1.495	0.139
Constant	-5567.3	-1.700	0.093*
Equation R^2,[a]	0.89		

*, **, *** refer to significance at 10, 5, and 1 % level respectively.
[a] System test statistics appear at bottom of Table 8.

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ECOLOGY AND DEVELOPMENT RESEARCH PROJECT

QUESTIONNARE **HOUSEHOLD SURVE**

HOUSEHOLD DATA:

DATE
INTERVIEWER
1. Village:
2. Household No.
3. Ethnic group:
4. Religion:

NO.	NAME	AGE	SEX	RELATION TO HEAD	PRESENCE	YEARS OF EDUCATION	SKILLS	WORK FORCE	MAIN OCCUPATION
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

DEPENDENTS NOT STAYING IN THE HOUSEHOLD.

1D									
2D									
3D									
4D									

SEX: 1=MALE, 2=FEMALE
RELATION TO HEAD: 1=WIFE, 2= CHILD, 3= CHILD-IN-LAW, 4= GRAND CHILD, 5=SISTER, 6= BROTHER, 7= OTHER
Presence: Months present in the household last year.
Skills: 0= No skill, 1= Carpenter, 2= bricklayer, 3= Driver, 4= Bicycle repairer, 5= Blacksmith, 6= Others.

6. MIGRATION:

Have any of the household members or the whole household for a longer period stayed somewhere else in the past?

Who	Where?	Purpose	Period	Time of arrival in this village

Who=Number above

7. Are some of the household members of the whole household considering to migrate to another area?

Yes
No

If yes,

Who?
Where?
Why?

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT (P2)

Q1

QUESTIONNAIRE HOUSEHOLD SURVEY

Date:	
Interviewer:	
1.Village:	
2.Household no.:	

HOUSEHOLD DATA:

CONSUMPTION PATTERN: EXPENDITURE

TOTAL FOR ALL HOUSEHOLD MEMBERS

COMMODITY	USE PATTERN			Unit	Quantity per month	Price range per unit	Expenditure per month	Annual Expenditure
	Usually	Occas	Never					
Salt								
Soap								
Washing powder								
Paraffin								
Matches								
Mealie-meal								
Sugar								
Cooking oil								
Kapenta								
Fish								
Other food:								
Grinding								
Vaseline								
Chitenge								
Clothes (specify)								
Shoes								
School uniforms								
School fees								
School expenditure								
Transport								
Medical care								
Social exp.(beer etc.)								
Relatives								
Farm tools (specify)								
Other equipment:								
Building materials:								

Farm inputs:	Credit	Unit	Quantity	Price/unit	Exp.91/92
Fertilizer:					
D-Compound					
X-Compound					
Urea					
Amm. nitrate					
Seeds					

Labour:	Crop	Type of work	Persons	Period	Rate	Exp. 91/92

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT

Questionnaire Household Survey
Household Data: 1992

Q1

Date
Interviewer
Village
Household No.

INCOME SOURCES: 1992

Activities	Unit	Quantity	Price per unit	Marketing Co	Where	Who sells	When	Income 1992
Farm produce:								
Sale of Beer								
Sale of millet								
Sale of beans								
Sale of Soyabeans								
Sale of Groundnuts								
Sale of Maize								
Sale of Green Maize								
Sale of Vegetables								
Sale of Bananas								
Sale of other products								
Forest Produce:								
Caterpillar								
Fruits								
Mushrooms								
Cikanda								
Charcoal								
Game meat								
Others								
Relatives								
Friends								
				Input Cost				
Handicraft								

Off-Farm Activities	Unit	Quantity	Price per unit	Where	Who	When	Income, 1992
Piecework (Specify)							
Emloyment(Specify)							

Trading(Specify)	Unit	Quantity	Price per unit	Input Cost	Where	Who	When	Net Income
Beer Business								
Other Business								

Trading: Specify where bought and where sold.

Does the household use barter system?

	Commodity sold	Quantity	Commodity bought	Quantity
Yes				
No				

Production of Crops, 1992 (P4)

Q1

INPUT USE

Crop	Cropping System	D- Comp Qty xPrice	X-Comp Qty xPrice	Urea Qty xPrice	Amm./Nitrate Qty xPrice	Seed Qty xPrice	Labour Qty xPrice	Total Expenditure

Disposal of Output

Crop	Total Qty. produced	Unit	Quantity Sold	Price per unit	Marketing Cost (transport etc.)	Net Incme from sale	When sold

Credit Obtained in the past

Season	Crop	Size (Hectare)	From whom	when received	Production	Prodction after credit repaid	Net Income
1988-89							
1989-90							
1990-91							
1991-92							

Wealth Indicators of Household

Particulars	Number	Description
House(s)		
Beds		
Radio(s)		
Bicycle(s)		
Wrist watch(es)		
Animal(s):		
cattle		
Goats		
Sheep		
Chicken		
Farm implements		
Large hoe(s)		
Small hoe(s)		
Panga(s)		
Axe(s)		
Sickle(s)		
Slasher(s)		
Spear(s)		
Others:		

Q1

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT

QUESTIONAIRE HOUSEHOLD SURVEY

HOUSEHOLD DATA:

LAND USE: PLOT OBSERVATION SHEET

Date:
Interviewer:
1.Village:
2.Household no.:

31.Plot number:			
32.Cropping system:			
33.Soil type:	Clay		1
	Clay loam		2
	Loam		3
	Sand		4
34. Slope:	No:		1
	0-5%:		2
	5-10%		3
	>10%:		4
Position in catena:	Top:		1
	Middle:		2
	Bottom:		3

36. Estimated distance from house:

Minutes walk:

Meters/km:

37. Site history:

Period:	Crop/Fallow	Fallow vegetation description

38. Input, output and sale of farm produce:

Year	Crop	Yield in kg shelled produce	Inputs		Produce sold		
			Type	Quantity	Quantity	Price	Where

39. Map of field: Area measurement, north direction, direction to house, slope direction

Ecology and Development Project
Questionnaire: Production systems

Village:	
Household number:	
Interviewer:	
Date:	

Q2

CHITEMENE

1. Have your household opened new chitemene this year?

Yes	
No	

2. If yes, how many plots have been made?

1	
2	
3	
4 or more	How many?

3. Is the total area you have opened this year

a.	about the same size
b.	smaller
c.	larger

as compared to the area you opened last year?

4. If there is a change, explain why.

____
____
____
____

MAIZE

5. Are you planning to grow maize this coming season?

Yes	
No	

6. Did you grow maize last year?

Yes	
No	

7. If you had maize last season and plan to have maize this season, will you plant

the same area (size)	
a larger area	
a smaller area	

than last year?

8. If there is a change, explain why:

____
____

9. Does a change in maize production influence the size of your chitemene plot?

Yes	
No	

10. Explain why/why not:
Credit supply/access:
Input supply (fertilizer & seed):
Price uncertainty/expectations
Maize delivery problems
Other:

Ecology and Development Project Questionnaire

Village:
Household number:
Interviewer:
Date:

Household changes:

Household size 1992/93:

Total	Males	Females

1.Has there been a change in household composition during the last year?

Yes	
No	

2. If yes, explain changes (including name, sex and age of persons involved):

3. Current household composition:

Total	Males	Females

OFF-FARM INCOME

4. Are there changes in access to off-farm sources of income (employment, business, piece-work,etc.) during last year?

Yes	
No	

5. If yes, explain:

6. Has there been any changes in access to piece-work during the last 5-10 years?

Yes	
No	

Specify changes:

Change in types of work

Change in availability

Change in payment (real value)

Change in accessability for males vs females?

7. Has there been a change in general standard of living of the household during the last 5-10 years?

	No change
	Improved conditions
	Worsened conditions

8. If there has been a change, explain how and possibly why:

MARKET FOR BEER

9. Has there been a change in the market for beer during the last 5-10 years?

Yes	
No	

10. If yes, explain how/why:

Change in customers:

Change in demand:

Change'in real price/profitability:

Other:

Ecology and Development Project Questionnaire

Village:	
Household number:	
Interviewer:	
Date:	

Credit:

1. Did you obtain credit last season (1992/93)?

Yes	
No	

2. '2. If yes, how much? ______ bags of fertilizer
______ bags of seed
From whom? ______
Production ______ bags of maize
Net price/bag ______ Kwacha
Loan repayment: ______ bags of maize ______ Kwacha
Net surplus/profit after repayment: ______ bags of maize ______ Kwacha

3. Have you applied for credit this season (1993/94)?

Yes	
No	

4. If no, why not?

______

______

5. If yes, specify: Size of loan:

Applied for	Obtained	
		bags of fertilizer

______ Kwacha
______ Interest rate

Credit organization: ______

Production of crops 1993

INPUT USE

Crop	Cropping System	D-Comp Qty*Price	X-Comp Qty*Price	Urea Qty*Price	Amm.Nitrat Qty*Price	Seed Qty*Price	Labour Qty*Price	Total Expenditur

DISPOSAL OF OUTPUT

Crop	Total Qty produced	Unit	Quantity sold	Price per unit	Marketing Cost	Net income from sale	When sold	Where sold

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT

CHITEMENE FIELDS: CASSAVA YIELD MEASUREMENTS

Village:	
Household number:	
Date:	
Enumerator:	

Yields should be measured in fields where households are currently harvesting cassava. The roots of 3 "typical" plants be dug up and weighed individually (unpeeled).
*It is important to identify the exact time of planting of cassa the type of variety planted, and the plant density.

Plot number:
(SAME AS IN INTERVIEWS)

Soil type	Clay	
	Loam	
	Sand	
Slope	0-5%	
	5-10%	
	>10%	
Position in catena	Top	
	Middle	
	Bottom	

Site history

Year	Month	Main crop	Secondary crops	

Cassava:

Time of planting	Variety	Plant number	Weight of roots

Plant density estimation:
Measure a "typical" area of 20m*20m (400 sq.m) and count the number of plants inside

Area size	No of. plants

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT (P1)

QUESTIONNAIRE HOUSEHOLD SURVEY

HOUSEHOLD DATA:

DATE
INTERVIEWER
1. Village:
2. Household No.
3. Ethnic group:
4. Religion:

No	Name	Age	Sex	Relation to head	Years of education	Presence	Skills	Work Force	Main Occupation	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
Dependents not staying in the household										Where
1D										
2D										
3D										
4D										

SEX: M=MALE, F=FEMALE

Presence: Months present in the household last year.

Relation to head: 1=wife, 2 = child, 3= child-in-law, 4= grand child, 5=sister, 6= brother, 7= other (specify)

Skills 0= No skill 1= Carpenter, 2= bricklayer, 3= Driver, 4= Bicycle repairer, 5= Blacksmith, 6= Others (specify)

MIGRATION:

Have any of the household members or the whole household for a longer period stayed somewhere else between 1/7-93 to 1/94 ?

Who	Where?	Purpose	Period

Who=Number above

Have any of the household members or the whole household for a longer period stayed somewhere else in the 1985-86 season ?

Who	Where?	Purpose	Period

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT (P2)

Interviewer:	Date:
Village:	Household no.:

Commodity	Unit	Quantity per month	Price range/ unit	Exp. per month	Annual Exp.	This village	Yunge/ Chambeshi	Others
Salt								
Soap								
Washing powder								
Parafin								
Matches								
Mealie-meal								
Beans								
Groundnuts								
Vegetables								
Tomatoes								
Bananas/orange								
Sugar								
Cooking oil								
Kapenta								
Fish								
Other food								
Other farm produce (maize, millet, cassava etc.)								
Grinding								
Vaseline								
Chitenge								
Blankets								
Clothes (specify)								
Shoes								
School uniforms								
School fees								
School exp								
Medical care								
Trad. medical care								
Social exp.(beer)								
Relatives								
Church								
Farm tools (Handles for hoes, panga, axes, sickles, slasher, spear,etc)								
Repaid credit NB								
Blacksmith								
Other equipment:(spec.)								

Q3

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT (P3)

Interviewer	Date
Village	Household No.
Where: TV, YC, NCU, CUSA,, ZCF, Other(specify)	

Fertilizer:	Where	Credit nr	Unit	Q'ty	Fee/ unit	Price/ unit	Exp.93/94	Loan 93/94
D-Compound								
X-Compound								
Urea								
Amm. nitrate								

Other input:	Specify	Where	Unit	Q'ty	Fee/ unit	Price/ unit	Exp.93/94	Loan 93/94
Seeds								
Livestock								

Hired labour:	Crop	Work-type	Persons	Period	Rate	Exp. 93/94	In village	Other
Commodity pay								
Money								
Ukutumya								
Unpaid								

Activities	Unit	Quantity	Price/ unit	Marketing Cost	Who sold	When (month)	Income 94	In village	To others
Sale of Farm produce 1/7-93 to 1/7-94:									
Beer									
Millet									
Beans									
Soyabeans									
Groundnuts									
Maize									
Cassava (fresh)									
Potato									
Sweet potato									
Others									
Sale of garden produce 1/7-93 to 1/7-94									
Vegetables									
Bananas									
Green maize									
Beans									
Fruit									
Other									
Livestock income 1/7-93 to 1/7-94 (spec)									
Chicken									
Goat									
Rabbit									
Pig									
Duck									
Other									
Forest Produce 1/7-93 to 1/7-94:									
Caterpillar									
Fruits									
Mushrooms									
Cikanda									
Charcoal									
Game meat									
Poles									
Others									
Relatives									
Friends									

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT (P4)

Q3

Interviewer	Date
Village	Household No.

Off-Farm act.	Who	Employ	Specif	Since	Grad	Where	Income 93/94
Employment 1							
Employment 2							
Pension							

Trading (spesify)	Bought input	Exp.	Where	Own input	Sold	Price	Income	This village	Other
Beer bus									
Handicr.									
Other Business									

Output from 92/93 season disposed between 1/7-93 to 1/7-94

Produce 92/93 used 7/93-7/94	Farm system	Land area	Q'ty 92/93	disp. 'til 7-93	Disposed in the period 7-93 to 7-94: Sold	Beer	Barter	Labour	Consume	Loan	Relative	Seeds
Maize 92/93												
Millet 92/93												
Beans 92/93												
Others 92/93												

Output 93/94 disposed 1/7-93 to 1/7-94

Produce 93/94 used 7/93-7/94	Farm system	Land area	Q'ty 93/94	Disp aft 7-94	Disposed in the period 7-93 to 7-94: Sold	Beer	Barter	Labour	Consume	loan	Relative	Seeds
Farm produce 7/93 to 7/94												
Beer (5 ltr)												
Maize (90kg)												
Cassava (fr. 50 kg)												
Millet (90 kg)												
Beans (90kg)												
Soyabeans (90 kg)												
Gr.nuts (90 kg)												
Potato												
Sweet potato												
Others												
Garden produce 7/93 to 7/94												
Vegetables (25 kg)												
Bananas (bunch												
Green maize (fr.50kg)												
Beans												
Fruit (10 kg)												
Other												
Forest Produce 7/93 to 7/94												
Caterpillar												
Fruits												
Mushrooms (kg)												
Cikanda												
Charcoal												
Game meat												
Poles												
Others												

Livest. 93/94	Q'ty 7-93	Q'ty 7-94	Sold	For barter	For labour	Consume	For relatives	Other (specify)
Chicken								
Goat								
Rabbit								
Pig								
Duck								
Other								

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT (P5)

Interviewer	Date
Village	Household No.

Wealth Indicators of Household

Particulars	Nr/Value 93	Nr/value 94	Description	Farm implements	Nr/Value 93	Nr/Value 94
House(s)				Large hoe(s)		
				Small hoe(s)		
Radio(s)				Panga(s)		
Bicycle(s)				Axe(s)		
Wrist watch(es)				Sickle(s)		
				Slasher(s)		
Money savings				Spear(s)		
Loan				Shavel		
				Others		
Other						

Piecework (specify)	Who	Employer	Period	Income 93/94	In village	Yunge/Chamb	Other

Barter last month	Commodity given			Commodity received		
From where (TV, YC, ROW)	Specify	Unit	Q'ty	Specify	Unit	Q'ty

Special barter last year	Commodity given			Commodity received		
From where (TV, YC, ROW)	Specify	Unit	Q'ty	Specify	Unit	Q'ty

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT

1994 RISK SURVEY

DATE
INTERVIEWER
1.Village
2.Household No.
3.Name

Q4

4. CAUSES OF VARIATION IN PROFITABILITY

Rank for each production activity according to importance

Causes	Maize	Finger millet	Cassava	Beans	Groundnuts		
Weather							
Pests							
Diseases							
Bad soil							
Bad seeds							
Fire							
Theft							
Witchcraft							
Management problems							
Bad health							
Lack of fertilizer							
Lack of credit							
Late supply of fertilizer							
Transport costs							
Cost of bags							
Interest rate							
Price variation							
Late payment							

5. RANK CROPS ACCORDING TO RISKYNESS/UNCERTAINTY AND PROFITABILITY + TRENDS

CROPS	Rank According to Riskyness/ Uncertainty	Trend Risk/Uncert. Increasing=1 Constant=2 Decreasing=3	Rank According to Profitability	Trend Profitability Increasing=1 Constant=2 Decreasing=3	Comments
Maize					
FingerMillet					
Cassava					
Beans					
Groundnuts					
Banana					

6.HOUSEHOLD CROP PRODUCTION AND RISK

Crops Grown 1993/94	Total Production	Yield: Good=1 Average=2 Bad=3	Production Good Yield	Production Bad Yield	Production Average year	How many Years of 10: Bad Yield	How many Years of 10: Good Yield	How many Years of 10: Average Yield
Maize								
Finger Millet								
Beans								
Groundnuts								

ECOLOGY AND DEVELOPMENT RESEARCH PROJECT

1994 RISK SURVEY

Q4

DATE
INTERVIEWER
1.Village
2.Household No.

7. If high risk in production of one crop, do you grow more or less of that crop or more or less of other crops?

Crops	More or Less	If less, what other crops do you grow more of?	Comments
Maize			
Finger Millet			
Cassava			
Beans			
Groundnuts			

8. Correlation between variation in yields
p 1:Good Yield and Crop 2:Good Yield= +
Crop 1:Good Yield and Crop 2:Bad Yield= –
No Correlation: 0

	Maize	Finger Mille	Cassava	Beans	Groundnuts		
Maize							
Finger Millet							
Cassava							
Beans							
Groundnuts							

9. Correlation between prices
Crop 1:High price and Crop 2:High price = +

	Maize	Finger Mille	Cassava	Beans	Groundnuts	Beer	
[illegible]e							
Finger Millet							
Cassava							
Beans							
Groundnuts							
Beer							

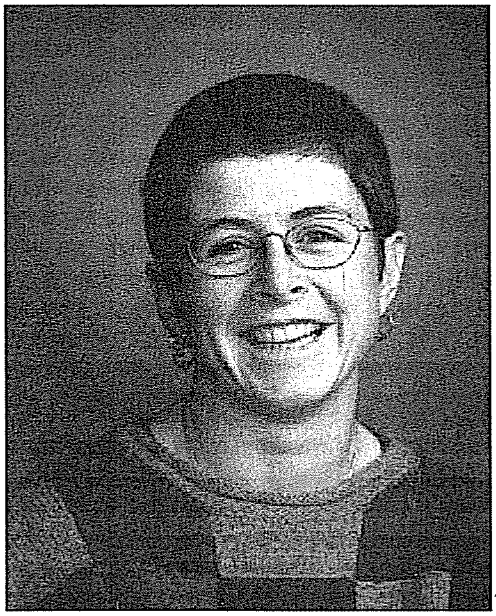
10. Time preferences:

If you have the choice between Kw.10 000 paid to you in exactly one year from now, and a cash amount today, how big must this cash amount be for you to prefer the cash today?

If you have the choice between Kw.100 000 paid to you in exactly one year from now, and a cash amount today, how big must this cash amount be for you to prefer the cash today?

If you have the choice between 15 bags of maize given to you in exactly one year from now, and a number of maize bags today, how many bags must you get for you to prefer the bags today?

Mette Wik



Mette Wik was born in Tønsberg, Norway, in 1961. She holds a Cand Agric in Agricultural Economics fra NLH (1987), and a M.Sc. in Agricultural Economics from University of California - Davis (1992).

Attitudes toward risk were measured using an experimental gambling approach with real payoffs. The experiments indicate that on average more than 80% of the farmers are moderately to extremely risk averse; that they exhibit decreasing absolute risk aversion and increasing partial risk aversion, and, that they are more risk averse in games with gains and losses than in games with gains only. Farmers in northern Zambia showed both a wider spread in risk aversion and a more risk averse behaviour than farmers in similar studies in Asia.

A theoretical framework for analysing how risk aversion and market imperfections may influence cropping decisions of farm households, was developed. Econometric analysis indicated that households specific variables, such as gender and education, market imperfections in commodity and credit markets, and to a smaller degree individual risk aversion, influence cropping decisions of farm households.

Associate Professor Stein T. Holden was the advisor.

Mette Wik currently works as a researcher at the Department of Economics & Social Sciences at the Agricultural University of Norway.

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