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Key Words: Chance-Constrained Programming, Asymmetric Information, Farm Household, Safety-first, Payback, Liquidity, Absolute and Relative Risk Aversion

Abstract: The paper examines the problem of production allocation decisions, applied to the Moroccan experience, incorporating considerations of risk and information constraints to the basic hypothesis of efficiency. The pattern of factor allocation is evaluated for a group of small farmers Evidence is provided to support the chance-constrained programming approach and that farm household decisions are based not only on the marginal productivity postulate but on a substitution between expected income, probability of failure and safety income levels.

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I. Introduction

When confronted with incomplete insurance, output and capital markets in developing countries, analysis of individual behavior should be based on more than marginal productivity grounds that are narrowly defined (Hammer, Lipton). Binswanger and Rosenzweig argued that most of the models developed to examine farmer behavior have focused on the implications for economic efficiency of the assumptions, rather than the establishment of testable implications The focus of the present study is to establish a framework in which we can examine the kind of decision making the farmer may adopt as well as its implications. This requires that behavior of a group or individual farmers be explained in a household context The farm household is both a family unit and an enterprise, it simultaneously engages in both consumption and production, and is characterized by partial engagement in markets which tend to function with a high degree of imperfection (Ellis).

Asymmetric information accounts for a large part of the uncertainty facing the farm household (McPherson, Binswanger and Rosenzweig) The problem of asymmetric information arises when the information set available to a particular group of participants is superior to that available to other market participants, with farmers finding themselves at the lower end of the information spectrum (Haley and Schall). The implication of asymmetric information for the farmer is to further accentuate an already complex production-consumption decision and its perceived risk (associated with weather and technical factors) Under these circumstances, an obvious strategy the farmer may adopt is one of safety Under the assumption that farmers attempt to reduce the impact of the information asymmetry problem, this study examines production decision choices of a group of small farmers, assuming safety as an additional consideration to efficiency

The foundation of the safety considerations is motivated by the following assumptions and propositions. markets are highly unstable, in part due to the rapid technological adoption [Boussard], there are no regular output markets in every year [Binswanger and McIntire], there are market imperfections often created by institutional factors such as prices, exchange rates, interest rates, etc [Binswanger and Rosenzweig], a limited formal credit market exists

[Cuevas and Graham, Baydas et al , Binswanger and Rosenzweig] The presence of an informal credit sector suggests the existence of social factors justifying more appropriate insurance substitutes for specific risks such as health, crop failure, marriage[1], etc [Binswanger and McIntire] Livestock is the major form of wealth accumulation and insurance substitute [Binswanger and McIntire, Ellis]

Farmers surveyed in the Settat region of Morocco are assumed to prefer larger net incomes to smaller net incomes, suggesting that efficiency is an important criterion in their production decisions However, they also hold a high portion of their assets in cash equivalent forms. These include draft animals (such as oxen, camels and mules) and small ruminants, namely sheep and goats[2]. Livestock is treated as though it is cash equivalent, because it is easily converted into cash. Although its value is influenced by market conditions, the ease with which it is converted ensures the farm household the necessary liquidity for his short term needs. Thus, the relatively high proportion of farmers' assets held in quasi-liquid form suggests that, in the short-run, efficiency may not be the only consideration in crop production decisions by farmers. With the presence of asymmetric information in the market, this behavior could be explained by assuming that small farmers consider safety first. This safety consideration will affect the selection of crop mix and the overall asset composition of the farm household. Hence, the farmer may utilize a priori knowledge of natural hazards, market fluctuations, etc., to define the likelihood of occurrence of events which emerge from production activities [Boussard, Ellis; Kunreuther and Wright]

The "*a priori*" knowledge or state of information reflects the level of confidence the farm household places on the realization of returns from crop activities Such a priori knowledge is defined by previous experience; it enables the farm household to shape or adjust the outcome of current production decisions. Since acceptance of any allocation pattern is conditional upon compliance to farmers' current state of information, it is rational to suggest that Bayes' rule is an appropriate behavioral hypothesis within the traditional efficiency framework in selecting a crop mix [Levy and Sarnat][3] It follows that, for each crop return, a confidence interval can be constructed to evaluate its impact on planting decisions. The inclusion of safety considerations in the farm decision model, in the form of a payback and a liquidity constraint, seeks to reflect the value of this a priori knowledge

A chance-constrained programming (CCP) approach is used to examine various utility functions under the joint hypothesis of efficiency and safety [Charnes and Cooper] The results obtained from these utility approximations are compared with those derived from the traditional profit maximization and the actual crop mix Through CCP, we will capture the existence of safety considerations, if any To accomplish this, we will first solve a utility optimization model with a stochastic constraint capturing the safety issue By estimating risk restriction coefficients, we will ascertain whether the safety issue is relevant for the farmers in question Thus, our primary objective is to determine whether the outcomes of the CCP approach help reflect the safety rule advocated in the study As we compare the actual crop mix (for a representative farm household) with those obtained from the expected utility models, a secondary objective is to identify which functional form (quadratic, negative exponential, or power utility functions) yields the best approximation to the actual crop mix.

Examining the evidence supporting the efficiency hypothesis, in light of the asset holding patterns of the Settat farmers, we assume that these decision patterns are due to variations in farmers' attitudes to and perceptions of risk [McPherson][4] Safety income levels are calculated for each portfolio selected under alternative utility functions, and risk restriction coefficients are derived using the Chebychev Inequality. These risk restriction levels determine the likelihood of failure to achieve or exceed associated safety income levels. If these coefficients (upper bounds to probability of failure) are perceived to be large relative to the farmer's maximum acceptable level of failure, it would explain why individual farm households maintain a large portion of their wealth in cash-equivalents.

II. The Model and Estimation Problem

The CCP approach, unlike the mean-variance (E-V) and stochastic programming (SP) models, provides the flexibility for combining efficiency and safety rules in the farmer's decision analysis As an alternative, CCP attempts to circumvent some of the problems of the E-V and SP models, and to incorporate farmers' contingency plans, as reflected by the safety rule. The choice of this algorithm is first based on the evidence that the sampling properties, for the group of farmers under consideration, are not consistent with the standard assumptions of normality made in traditional portfolio models (E-V and derivative models)[5] In addition, the probability distribution of the return variable need not be known to represent the risk preference characteristics of the farmer, the normal approximation to these risk preferences, required by traditional portfolio models (E-V), is consistent with the farmer's long-term goals, but it ignores short-run behavior. An explanation of what is perceived as a safety rule of behavior describes the short-run strategy producers may adopt to maximize expected net income, and as such cannot be adequately captured by Mean-Variance decision rules Furthermore, the chance constrained algorithm avoids the imposition of monetary deviation costs (loss functions) often required in the stochastic programming with recourse (SPR) models Such deviation costs, not transparent in the market, cannot be adequately quantified for inclusion in the objective function as required in recourse models [Smith, Hogan et al] Thus, the chance-constrained criteria are reasonable for decision problems in which the consequences may not be economic (i e factors inherent to the informal sector, which tend to control farmer decisions). Finally, the CCP approach circumvents the need for extensive data that is often difficult and expensive to obtain in developing countries.

The proposed chance-constrained model assumes additive and separable utility functions The objective function is written as multidimensional in time rather than in the number of payoff factors, so that expected-utility maximization is subject to the requirement that expected utility of each time period be maximized [Rae; Featherstone et al]. The choice of utility functions in the proposed chance-constrained model will be limited to the family of single-attribute utility functions. Four utility functions are selected, each representing a functional form which depicts a broad range of relative risk aversion propensities (RRA ranging from 1 to 9) and behavior characteristics The functional forms considered are the quadratic, negative exponential, negative power, and natural log utility function[6]

The objective function attempts to maximize (or minimize as the case may be) the expected utility of the terminal wealth -- the value of all production activities at the end of each period[7]. The expected utility maximization of farmers' production decisions can be written as follows:[8]

$$E\ [U\ (R\ )] = \sum_{t=1}^{T} p_t\ U\ (R_t\ ) \tag{1}$$

where $U(R_t)$ is the value of the utility function for the portfolio return, R_t, observed at the end of period t,

p_t is the probability of occurrence for each portfolio return,

E( ) is the expectation operator

The relevant consideration in choosing among various utility functions has little to do with whether absolute risk aversion or relative risk aversion is appropriate for modeling a decision maker's preferences. Haley and Schall argued that hypotheses about risk aversion and wealth are not sufficient grounds for adopting or excluding any model of preferences, for a given current wealth A choice must be made on which utility function best describes the preferences of individuals toward alternative risky investments and how preferences change as wealth changes The chance-constrained formulation of the expected utility approximation attempts to focus on the latter

The technical constraint is limited to land availability Family unpaid and hired labor were found to be non-binding during the survey conducted by MIAC in the Settat region[9]. The technical constraint can be written as follows

$$\sum_{j=1}^{J} a_{ij} X_j \leq b_i \qquad where\ X_j \geq 0 \tag{2}$$

where a_{ij} is the resource requirement for a unit of activity j, b_i the amount of land, and X_j is the level (area in hectares) of each activity included in the farmer's portfolio

The payback constraint is a modified version of that developed by Byrne et al and is used to reflect the existence of asymmetric information Under the information asymmetry hypothesis, the farmer will maintain a level of activity that is smaller in value than his current liquidity, which is represented by his current net cash reserves The modified payback constraint can be written as follows.

$$\sum_{t=1}^{T} \sum_{j=1}^{J} c_{jt} X_j \leq \sum_{t=1}^{T} (M_t + B_t) \tag{3}$$

where M_t = Cash reserves available at the start of period, t.

c_{jt} = Variable cost for each activity j in period, t

B_t = Net funds borrowed for production activities in period, t

In addition to the payback constraint, the farmer faces a liquidity constraint, also called the safety-first condition. It requires that activities entering the decision scheme generate cash-flows in each period that will enable the farmer to also maintain the liquidity necessary to sustain future consumption and investment opportunities[10] That is, current cash reserve (including cash-equivalent), (M_t), and cash reserves required at the end of the current period, (L_t), work together to determine the contribution of current production to the formation of the farmer's equity base, represented by his holding in cash equivalents.

$$M_t + \sum_{j=1}^{J} R_{LO,\alpha,j} X_j \geq L_t \quad (4)$$

The minimum value of L_t necessary to satisfy equation (4) is M_t. Given that the likelihood of generating excess revenues (L_t - M_t) greater than M_t (i e doubling of current cash reserves and cash-equivalents) becomes impossible even abstracting from uncertainty and allocating all acreage to crops with highest net returns, one can then assume that the contribution of current production activities to the farmer's equity will yield at best a maximum value of M_t [$L_t - M_t \leq M_t$ or $L_t \leq 2M_t$] The safety-first condition therefore implies that a value $(L_t - M_t) \leq \gamma M_t$, where $0<\gamma<1$, will satisfy the liquidity constraint

The term $R_{LO,\alpha,j}$ represents the predicted lower bound of revenue per crop activity (j) This lower bound imposed by the farmer on the variability in gross return reflects the level of confidence (β_j) he places on the realization of returns from current crop activities given his previous experience. The term [γM_t] or [s] is the minimum safety income associated with a particular portfolio

The term [γM_t] can be set arbitrarily at various levels by specifying alternative fractions of cash reserves (γ), but the ad-hoc nature of this approach may never capture the true safety income level. Thus, [s] is introduced as an endogenous dummy variable in the model, it represents activity X_{n+1}, which must satisfy the following conditions

(i) $a_{i,n+1} = a_{i,s} = 0$ is the resource requirement of the (n + 1)th activity;

(ii) $R_{LO,\beta\, n+1} = R_{LO,\beta,s} = -1$,

(iii) $C_{n+1} = C_s = 0$ is the variable cost of the (n + 1)th activity

Equation (4) can be rewritten into a standard form:

$$\sum_{j=1}^{J} R_{LO,\beta,j} X_j - (s) \geq 0 \quad (4')$$

In this form the liquidity condition assures that selected activities yield an outcome which, from a safety standpoint, maintains or increases the initial equity base

The model is constructed in two steps First, the problem is to maximize (quadratic and logarithmic), or minimize (negative power and negative exponential) equation (1) subject to equations (2), (3) and (4'), which yield the optimal level of activities X_j in a given portfolio with an associated safety income level **(s)** Second, assuming that one of the three utility functions (quadratic, exponential and power) represents the risk preferences of the producer, an appropriate risk restriction coefficient will be derived This will give insight as to the likelihood of failure to achieve or exceed safety income levels generated for alternative relative risk aversion propensities. This risk restriction coefficient accounts not only for the farmer's relative risk aversion, but it also reflects the degree of confidence placed on the attainment of safety income levels from selected portfolios of crop activities. The fact that selected crop activities maximize farmer's expected income suggests that the farmer will choose a portfolio of activities, Γ, so that

$$\Pr [(E \leq s), \Gamma] \leq \alpha \tag{5}$$

where **(E)** is the portfolio expected income, **(s)** is the safety income level that is guaranteed by the portfolio selected, and **(α)** is the critical or rejection level assumed by the farmer. The Chebychev Inequality enables us to calculate an upper bound to the probability above, **Pr [.]**, even though the joint probability distribution associated with the set of activities included in the portfolio is not known. From (5) it follows.

$$Pr (E (\Gamma) \leq s) \leq \frac{V (\Gamma)}{E (\Gamma) - s} \tag{6}$$

This means that when the condition above is satisfied, **Pr (E ≤ s) ≤ α**. Consequently, the term **[V(Γ)/(E(Γ)-s)]**, or Θ, represents the estimated risk restriction coefficient where **V(Γ)** is the variance in portfolio returns. The selected portfolio **(Γ)** of crop activities thus can be represented as

$$\Gamma = \Gamma [\Theta \{V (\Gamma), E (\Gamma), s \} :\beta_j , \Theta \leq \alpha] \tag{7}$$

where θ is the estimated risk restriction coefficient for each crop portfolio selected, it represents the probability level of failing to achieve a given safety income level, that the farmer is willing to accept ($\theta \leq \alpha$). This risk restriction coefficient is a function of the safety income level **(s)** estimated for portfolio Γ, the portfolio's expected income E(Γ) and its variance **V(Γ)** Finally, the selected portfolio of crop activities reflects the farmer's state of information about the variability in gross returns for each crop (β_j) The state of information is assumed constant among crops. Farmers normally assess the historical performance of each crop individually, but no such information was available at the farmer level

III. Data

The physical characteristics of the sub-atlantic plain (386 millimeters of rainfall annually) have made the Settat region the grain belt of Morocco However, the low rainfall and its erratic distribution produces an extremely unstable environment Almost all available land in the Settat province of the Chaouia region is cultivated A secondary activity that is complementary to the crop activities is breeding. This section of Morocco raises sheep, goats and other ruminants, which ensure the liquidity and equity base of the farmers An inventory of resources under farmers' control reveals that draft animals are an important component of their asset holdings The average value of 16,149 dirhams is estimated per head (or 9,752 dirhams per farm household for the sample of 207 farmers) This value represents only a small fraction of animal wealth held by farmers (see *endnote 2*) The value of livestock, as liquidity and capital reserve, is determined by market conditions prevailing in the "souk" (which denotes the physical location where transactions of various forms - animals or produce - take place), but livestock prices have been more stable than crop prices in the short run [Rafsnider et al.]

In this survey, small farmers are those who farm less than ten hectares of land, possess no tractor, and rely primarily on animal traction [Rafsnider et al.] The survey for the Settat province involved 207 small farmers and was carried out during the 1988 crop season from a joint effort of Aridoculture Center scientists[11].

Cost data were estimated from an on-farm experiment in 1987, which involved ten small farmers, and were adjusted to price levels paid for variable inputs Revenues from crop enterprises were collected for the period 1974-87 (Table 1) Costs are assumed constant over the sample period and based on the 1987 estimates. It is also assumed that no borrowing takes place during the planting period

Three goodness-of-fit tests (Chi-Square, Kolmogorov-Smirnov and Anderson-Darling tests) were used to compare the exponential, gamma, logistic and normal probability distributions with the sample data [Averill and Vincent]. The tests reveal that only lentil returns are best approximated by the normal probability distribution, based on the Kolmogorov-Smirnov test (Table 2). Thus, the mean-variance decision rule of the E-V analysis may not be appropriate for estimating crop returns since the joint probability distribution of crop returns is not normal. Profit maximization was used to obtain a crop mix, and its resulting payoff represents the maximum attainable initial wealth position that the farmer must consider in evaluating his choices. Given that profit maximization implies risk neutrality, the resulting crop mix is compared with those selected under alternative relative risk aversion (RRA) coefficients, which vary from 1 to 9 for each of the utility functions under consideration

IV. Empirical Results

Table 3 shows actual crop activities for the 1987-88 season and the optimal crop activity decisions from alternative utility functions The results of the expected utility models (EUM) are presented for a RRA equal to 2 and 8 All EUM approximations, without exception, exclude three activities. corn, soft wheat and peas. When the result of the profit maximization is compared with the EUM approximations, it is clearly seen as deviating the most from the actual production plan (Table 3)

As the relative risk aversion (RRA) coefficient is changed from 1 to 9, returns decrease with risk aversion, but the profit maximization solution remains unchanged, yielding a combination of hard wheat and chickpeas in the proportion of 40 and 60 percent, respectively. Production plans with the natural logarithm function are identical for all risk aversion levels The logarithm utility function provides a check for the results obtained with the remaining functional forms and checks the consistency and appropriateness of the algorithm developed for the study (see *endnote 5*) The logarithm utility exhibits a constant relative risk aversion of one (RRA=1) and the results are consistent with this characteristics of the function Crop activities selected remain hard wheat, barley, faba bean, chickpeas and lentils, and their acreage is unaltered as the RRA coefficient is increased.

With the quadratic utility or (E-V) function, crop activities selected include hard wheat, chickpeas and lentils Greater risk aversion propensities under this utility function cause lentils to be substituted for chickpeas in production plans. The greatest difference between the E-V model and actual production activities is the disproportionate fraction of acreage allocated to both hard wheat and lentils, but little can be said at this point regarding the implication for efficiency of this approach The outcome of chickpea production is somewhat consistent with the actual production plan, suggesting that farmers in the sample are very risk averse

Under similar scenarios and assuming a negative exponential preference behavior, selected crop activities increase from three to five These activities include hard wheat, barley, faba bean, chickpeas and lentils. Additional acreage is committed to lentils and less to hard wheat and chickpeas, the latter being excluded completely from the model at higher risk levels Although there are differences between the actual and predicted acreage, they are not as large as those with the quadratic utility function

The negative-power-utility hypothesis yields outcomes similar to those of the negative exponential utility Crop activities selected are hard wheat, barley, faba bean and lentils in various proportions depending on the risk levels With increasing RRA coefficients, proportions of hard wheat and lentils in the portfolio decrease, replaced by increased acreage for barley and faba bean. Much like the negative exponential, the acreage predicted by the power utility function for faba bean is quite large (tenfold greater than actual acreage). Overall, most of the crop areas predicted for selected activities fall within reasonable percentages

Figure 1 illustrates the risk-efficient E-S (portfolio deviation of returns) frontiers based on tables 4 through 6 for the representative farmer The efficient frontier based on the quadratic utility (E-V) approximation lies above that of the other models and is associated with the largest return deviations, consistent with previous studies [Featherstone et al] The E-S frontiers generated by the quadratic, negative exponential and negative power utility functions converge at lower risk aversion level, and yield similar outcomes when approaching the net payoff estimates obtained from the direct profit maximization model. The differences are more noticeable in the lower tail of the efficient frontiers, consistent with greater risk aversion propensities There is a rather high "lower limit" imposed on the efficient frontier by the quadratic model (a deviation of deviation in portfolio returns of 240 dirhams, compared to 160 dirhams for the exponential and power functions) This is due to the inherent characteristic of the quadratic model to select activities with large earning potential based on historical performance The upward bias in portfolio variance exhibited by the quadratic function may render this model of preference inappropriate for the small farmer with limited capital resources and inability to withstand large income variability By contrast, one could infer that the exponential and power utility function are more consistent with the small farmer case, for which high earning potentials may be limited Such inferences are supported somewhat by the outcomes of the EUM approximations, which reveal that both the exponential and power functions are the best predicting models for the actual production plan

The additional consideration for efficiency-- safety-- is defined as the combination of an expected level of income and the probability that such level of income will be attained To calculate a safety level of income for the farmer we define three states of information Thus, we construct a confidence interval for each crop return that corresponds to a 90, 95 and .99 level of probability, and derive the corresponding safety income levels for various relative risk aversion levels Tables 4 through 6 show these safety income levels estimated for the portfolios selected under alternative utility functions Using the Chebychev Inequality, the safety income levels are used to estimate risk restriction coefficients, which are associated with selected portfolios Table 7 presents risk restriction coefficients calculated for the quadratic, negative exponential and power functions Risk restriction coefficients are estimates of failure rate for selected portfolios, as such they determine the upper bounds the utility functions impose on the likelihood of failure to achieve or exceed associated safety income levels.

The effect of the safety rule, which is described through the risk restriction coefficients, is summarized in figures 2 and 3. Each figure shows the relationship between estimates of failure rate and the risk aversion coefficients (RRA) for two states of information ($\beta_j = .95$ and $\beta_j = .99$). The resulting curves decrease over the range of RRA for all functions This tendency is more pronounced for the exponential and power functions Estimated risk restriction coefficients range between 14 and 18 percent for these functions, while the quadratic function exhibits values of failure rate between 16 and 21 percent, for a confidence level of $\beta_j = 95$ assumed for each activity (j) (Figure 2) Figure 3 shows similar relative magnitudes with a confidence interval $\beta_j = 99$ (9 to 14 percent for the quadratic and 8 to 12 for the remaining functions). The implication for safety thus suggests that the exponential and power utility functions yield the lowest probabilities that a given portfolio income will fall below a specified level -- the minimum or safety income level the portfolio generates.

These results, in conjunction with the EUM approximations of actual production plans (Table 3) reveal that farmers in question are very risk averse, and seem to confirm the existence of a safety tendency among farmers surveyed Furthermore the results seem to imply that there is a substitution between expected income, probability of failure, and safety income levels. Along with Ellis and Lipton, one could conclude that the decision making within the safety-first framework is constrained by farmers' unwillingness to risk obtaining a net income below a certain level, unless the probability of it falling below that level is very low (*confer endnote 4*) These results also imply that the quadratic model of preference is the worst predicting model within the safety-first framework, a framework which purports to reflect farm household behavior in a market environment dominated by information asymmetry Finally, the analysis of risk restriction coefficients helps explain the safety rule of behavior exhibited by the Settat farmers, it provides one explanation of their wealth accumulation patterns in quasi-liquid assets or other cash equivalents

V. Conclusion

Approximations of farm household decision choices under the safety-first hypothesis offer two conclusions. First, the prediction of optimization plans by the chance-constrained method does not undermine the validity of the efficiency criterion sought in traditional portfolio models and yields a clearly closer approximation to the actual crop mix than the profit maximization Second, the model provides a vehicle for examining the sensitivity of alternative utility functions to the safety rule As optimum plans selected by the three utility functions are compared with the farm's 1987 plan, the test criterion consists of two elements. the closeness of the prediction and the consistency of these functions with what is perceived to be the safety-first behavior of the Settat farmers

Of the three objective functions examined in the study, the quadratic utility function showed the largest difference from the representative farm plan The discrepancy is in both the type of activities selected and crop area cultivated The result offered by the risk restriction coefficients is consistent with the inability of the quadratic function to capture the safety concern of these farmers, in part because of the large variability associated with portfolio return One would also infer that these probabilities, which are found to be between 8 and 12 for the negative exponential and power functions and 9 and 14 for the quadratic function for β_j = 99, are higher relative to what farmers are willing to assume. These probabilities, jointly with crop predictions by both the exponential and power functions, suggest that the level of probability or type I error assumed by these farmers is very small, and likely to be less than 10 percent Thus, the outcomes of the models, in light of farmers' behavior and asset holding patterns, reinforce the notion of safety advanced throughout this paper.

The analysis allows the inference that there is a substitution between expected income, probability of failure and safety incomes The farmer can always avoid loss by holding cash or its equivalent to ensure that expected income is maximized for a given probability and safety level. This behavior is consistent with what was observed among the small farmers surveyed and supports earlier findings concluding that security is more important than income in choices of crops. They tend to follow cultivation practices and choice of crops designed to ensure security rather than their income Given the problem of asymmetric information, which characterizes the market and the variability of returns facing small farmers in the Settat region, the exponential and power functions best approximate their risk preference characteristics Although solutions of the CCP model with these functions are closer to actual farm plans and returns within the safety framework, they help explain their holdings of cash equivalents, whose purpose is to ensure financial security and which are very vital in the short-run.

Endnotes

1. Marriage, much like illness, has an impact on farm household sustenance (i e. dairies), which ultimately affects farm production decision Such an event adds to the risk the farmer must bear.

2. Inventory of other resources held by the group of Settat farmers show a total number of 109 piecess of light machinery and implements (hauling, plows, and harrows) for the sample of 207 farmers surveyed, this represents about 5 unit per farm household A total of 125 draft animals was inventoried, with an average value of 16,149 dirhams per head This animal count represents only a small fraction of animal resource held by these farmers Data on sheep and goats, which are the primary animal resource, were not collected during the primary survey (Rafsnider et al)

3. Few studies have addressed the subjective theory of risk, concluding that farmers are risk-averse [Dillon and Scandizzo, Binswanger and Sillers], and farmers follow cultivation practices, and choices of crops designed to increase security rather than their income [Norman].

4. Disaster avoidance was expressed by Lipton as the survival algorithm of small farmers. Small farmers are of necessity risk-averse [Lipton] They cannot afford not to cover their household needs from one season to the next, since if they fail to do so they will starve to death [Ellis]. Decision making within the safety-first approach to risk analysis is constrained by the farmer's unwillingness to risk obtaining a net income below a given level, unless the probability of it falling below that level is very low indeed [Ellis, Roumasset].

5. Using UNIFIT, four probability distributions (exponential, gamma, logistic and normal) were tested with the X^2, Kolmogorov-Smirnov and Anderson-Darling goodness of fit tests. From the eight crops considered only lentil returns could be approximated by the normal distribution (Table 2).

6. Functional forms.

Utility Functions		Absolute Risk Aversion	Relative Risk Aversion
Logarithm:	$U(R) = Log_e(R)$	$1/R$	1
Negative Exponential	$U(R) = -Exp^{-\lambda R}$	λ	λR
Negative Power	$U(R) = -R^{-\delta}$	$(\delta + 1)/R$	$(\delta + 1)$
Quadratic.	$U(R) = \bar{Z} - 1/2(R - \bar{Z})^2$	$1/(R - \bar{Z})$	$R/(R - \bar{Z})$

where $\bar{Z}$ is the expected payoff for a return variable R, λ is the absolute risk aversion coefficient, and δ is a function of the relative risk aversion coefficient.

7 Risk, based on the decision maker's personal strength of beliefs about the occurrence of uncertain events and his/her personal evaluation of the potential consequences, is firmly rooted in the economic concept of expected utility maximization [Anderson et al., Ellis]

8. In the study we assume that the time when the activity is started does not influence the chance variable No distinction is made between early and late planting, and all farmers are assumed to enjoy the same likelihood of success once engaged in a given activity, regardless of the time of cultivation.

9 MIAC is an acronym for the consortium of the Mid-American universities in charge of the project in Settat It is a consortium of 7 Midwestern American Universities which, under the USAID Contract N.608-0136, has the primary objective to assist the government of Morocco in the introduction of high yield varieties and mechanization in the Settat province.

10. The safety-criterion here imposed differs from that of Roy, who describes that risk portfolio selected from a specified set of constraints be the one that maximizes $(E(R) - d)/\sigma$ where E is the expected value operator, σ the coefficient of dispersion and d the disaster level Thus Roy's model implies a priori knowledge of the disaster level by the farmer and allows negative payoffs

11. The Aridoculture Center is composed of MIAC and national researchers, and other Moroccan institutions such as INRA (Institut National de la Recherche Agronomique), a branch of the French research institute for agriculture

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Table 1

Average Crop Gross Revenues for Sample Period (1974 - 1987)

Year	Corn	Hard wheat	Soft wheat	Barley	Faba bean	Peas	Chickpeas	Lentils
			(in Dirhams per hectare)					
1974	112.5	714.0	336.0	451.4	284.2	167.0	.	
1975	555.2	1056.0	828.0	918.0	588.5	497.1	.	.
1976	327.8	799.2	390.1	429.2	429.0	287.1	.	.
1977	733.9	1308.0	648.0	1093.0	558.0	521.6	.	.
1978	264.0	981.2	788.5	607.2	457.3	584.8	2069.4	1690.0
1979	235.9	1030.8	624.2	742.6	323.4	174.0	1896.0	1457.3
1980	316.0	884.3	478.4	704.0	521.1	140.0	468.7	450.7
1981	491.4	743.6	644.1	1017.9	1145.6	726.3	0.0	36.0
1982	178.6	322.2	159.3	805.6	8.8	11.6	379.6	1102.0
1983	633.6	829.9	316.0	462.0	802.2	325.3	217.6	145.2
1984	997.6	1738.8	1415.1	1537.0	858.6	1347.1	720.0	862.5
1985	811.2	1974.0	918.0	1439.9	1445.4	983.6	5612.0	3624.0
1986	654.2	562.5	390.0	792.3	308.5	705.6	3419.1	1869.6
1987	1920.0	2525.2	1904.4	2030.0	832.0	2063.6	1276.8	693.1
1987*	69.23	170.90	135.36	87.60	126.01	186.45	227.68	105.80
Mean	587.98	1105.0	702.86	930.79	611.61	609.76	1147.1	852.17
Median	523.29	932.75	634.14	798.95	539.55	509.37	424.14	571.89
Std. Deviation	463.57	597.49	468.93	463.90	376.30	553.90	520.38	329.39
Coefficient of Variation	.7885	.54106	.66717	.49836	.61523	.90840	0.454	0.387
Skewness	1.544	.99441	1.224	.92465	.60057	1.254	1.487	1.247
Kurtosis	5.094	2.975	3.683	2.843	2.610	3.833	4.239	3.856

* Variable Costs estimated for 1987 crop season (Source: Rafsnider et al.)

Table 2

Model Test Comparison with Sample For Selected Probability Distributions[@] (*UNIFIT* ESTIMATES)

Crop Activities	Exponential χ^2_a	Exponential K-S_b	Exponential A-D_c	Gamma χ^2_a	Gamma K-S_b	Gamma A-D_c	Logistic χ^2_a	Logistic K-S_b	Logistic A-D_c	Normal χ^2_a	Normal K-S_b	Normal A-D_c
Corn	.2857	.1212	.2768	.2857	.1288	.2934	0.	.1365	.4356	.2857	.1722	.7887
Hard wheat	.2857	.2632	.8067	0.	.1665	.3787	.2857	.1851	.5986	2.571	.2469	.7337
Soft wheat	.2857	.1952	.4627	.2857	.1250	.2683	.2857	.1419	.4362	1.143	.1894	.7592
Barley	.2857	.1504	.0606	1.143	.2071	.5049	.2857	.1419	.4362	1 143	.1778	.5452
Faba bean	2.571	.3367	1.503	0.	.1392	.2784	.2857	.1337	.2858	1.143	.1673	.3371
Peas	.2857	.1313	.2395	.2857	.1177	.2072	.2857	.1339	.4723	1.143	.2024	.7041
Chickpeas	1.143	.3493	5.227	0.	.2337	.6062	1.143	.2576	1.106	1.143	.2453	1.336
Lentils	0.	.3154	7.134	.2857	.2057	.8680	.2857	.2104	.7056	.2857	.2066	.8540

Probability Density Functions Checked Against the Sample of Crop Returns

[@] Values based on 14 observations: 1974-1987
$_a$ χ^2 = Chi-square goodness of fit test having 2 intervals, each with equal probability of .5
$_b$ K-S = Kolmogorov-Smirnov goodness of fit test
$_c$ A-D = Anderson-Darling goodness of fit test

Table 3

The 1987 Production Plan and EUM Solutions for Relative Risk Aversion Coefficients of 2 and 8

Crop Activities	Actual Production Plan, 1987[a]	Profit Max.	Natural Log.	Expected Utility Model Solutions: Quadratic RRA = 2	Quadratic RRA = 8	Negative Exponential RRA = 2	Negative Exponential RRA = 8	Negative Power RRA = 2	Negative Power RRA = 8
				(percent of cropland)					
Corn	6.0	0.	0.	0.	0.	0.	0.	0.	0.
Hard wheat	20.0	40.0	30.6	40.0	40.0	37.2	17.6	30.6	17.6
Soft wheat	4.0	0.	0.	0.	0.	0.	0.	0.	0.
Barley	43.0	0.	9.4	0.	0.	2.8	22.4	9.4	22.4
Faba bean	1.5	0.	6.2	0.	0.	10.5	29.0	6.2	30.8
Peas	10.0	0	0.	0.	0.	0.	0.	0.	0.
Chickpeas	0.5	60.0	26.3	25.4	2.3	2.4	0.	26.3	0.
Lentils	15.0	0.	27.5	34.6	57.7	34.6	31.0	27.5	29.2
Expected Return[b] (Dhs)	950.5	1246.988	1099.010	1133.115	1054.268	1007.943	898.399	941.593	890.286
Standard Deviation[b] (Dhs)	185.6	293.553	275.693	293.553	242.047	215.282	160.771	180.913	157.623

[a] Crop activities estimated for the representative small farmer from a sample of 207 farmers (i.e. average acreage for the sample)
[b] Returns are estimated in dirhams (dhs), the country's local currency unit

Table 4

Expected Returns and Safety Incomes Levels for Various Levels Relative Risk Aversion Under the Quadratic Utility Objective Function

Relative Risk Aversion	Expected Returns	Standard Deviation	Safety Income Levels		
			0.90	0.95	0.99
1	1234.230	367.707	549.387	424.126	249.981
2	1133.115	293.553	546.586	440.658	254.137
3	1099.401	270.070	545.652	446.170	255.523
4	1082.548	258.661	545.185	448 926	256.216
5	1072.025	251.939	544.905	450.579	256.632
6	1065.695	247.513	544.718	451.681	256.909
7	1060.879	244.380	544.585	452.469	257.107
8	1054.268	242.047	544.485	453.059	257.255
9	1054.459	240.243	544.407	453.518	257.371

Table 5

Expected Returns and Safety Incomes Levels for Various Levels Relative Risk Aversion Under the Negative Exponential Utility Objective Function*

Relative Risk Aversion	Expected Returns	Standard Deviation	Safety Income Levels		
			0.90	0.95	0.99
1	1159.355	312.333	547.312	436.368	253.059
2	1007.943	215.282	549.209	465.406	286.345
3	951.433	185.269	543.731	468.839	305.083
4	928.214	174.060	541.750	470.403	314.397
5	915.381	168.160	541.142	471.759	320.049
6	907.426	164.634	540.984	472.821	323.779
7	902.118	162.344	540.972	473.625	326.365
8	898.399	160.771	541.005	474.228	328.218
9	895.708	159.650	541.048	474.686	329.580

* The same confidence intervals used for the quadratic utility function, were also used in the derivation of safety income levels with the remaining utility functions. The method used to estimate such confidence intervals is independent of the form of the utility function (Averill and Vincent).

Table 6

Expected Returns and Safety Incomes Levels for Various Levels
Relative Risk Aversion Under the Negative Power Utility Objective function

Relative Risk Aversion	Expected Returns	Standard Deviation	Safety Income Levels		
			0.90	0.95	0.99
1	1159 355	312.333	547.312	436.368	253 059
2	941.593	180.913	547.517	474.179	313.818
3	914.618	168.213	544.281	475.050	323.671
4	902 853	162.965	543.130	475.694	328.239
5	896.823	160.353	541.142	476.125	330.684
6	893.435	158.919	540.984	476.423	332.114
7	891.452	158.096	542.341	476.647	333.002
8	890.286	157.623	542.345	476.829	333.576
9	889.607	157.357	542.397	476.987	333.963

Table 7

Risk Restriction Levels Calculated for
the Quadratic, Negative Exponential and Power Utility Functions

Relative Risk Aversion	Quadratic			Negative Exponential			Negative Power		
	0 90[i]	0 95[i]	0 99[i]	0 90	0 95	0 99	0 90	0 95	0 99
1	288	206	140	.260	187	.119	260	187	119
2	250	180	112	.220	157	.089	.211	150	083
3	238	171	102	.206	147	082	206	146	081
4	232	167	098	203	145	080	204	.145	080
5	228	164	.095	.203	.144	080	203	.145	080
6	226	162	094	202	143	080	203	145	080
7	224	161	.092	.202	.144	080	205	145	080
8	225	162	092	202	144	.080	205	.145	080
9	222	160	091	202	144	080	.205	145	080

[i] Probability levels specified for the states of information

Figure 1

E-S Frontiers for Alternative Utility Functions

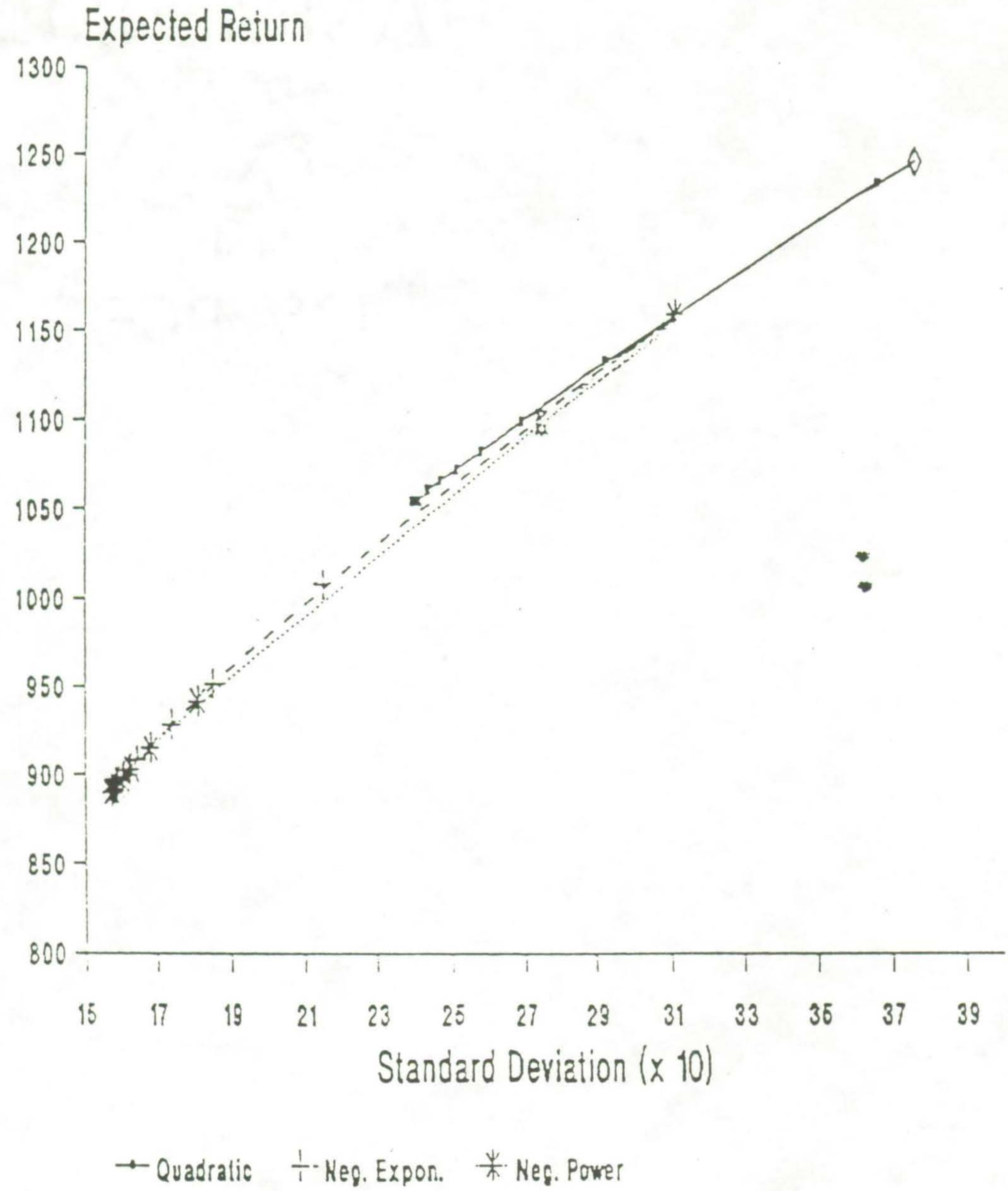


FIGURE 2

Probability of Expected Revenue < Minimum Revenue
State of Information = .95

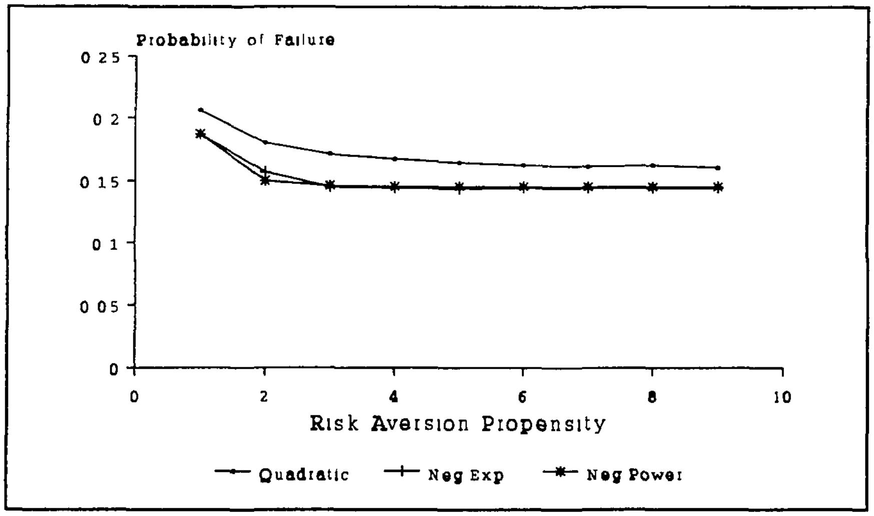
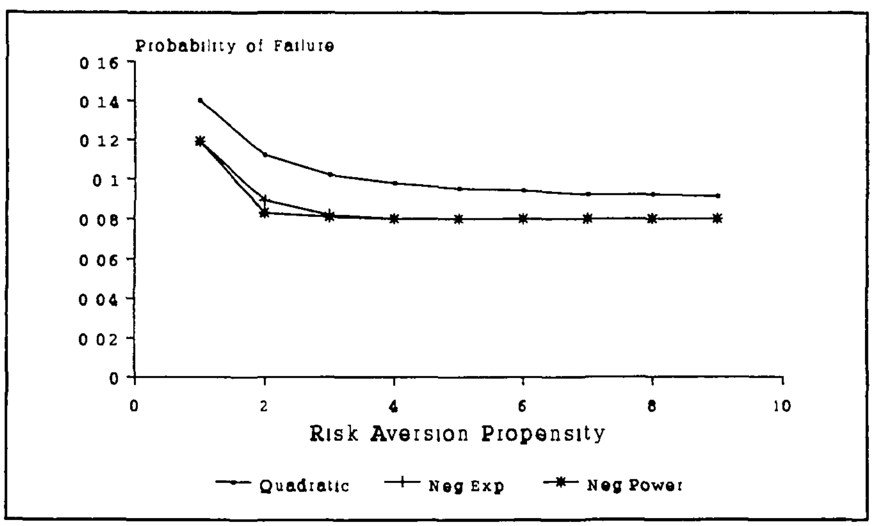


FIGURE 3

Probability of Expected Revenue < Minimum Revenue
State of Information = .99



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