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Analysis of Uncertainty as Opposed to Risk: An Experimental Approach

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Abstract

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The paper illustrates the scope for enhancing the conceptual apparatus used by agricultural economists to analyse decision-making under conditions of uncertainty. Selected empirical results from experiments on student subjects from three universities are reported. Three issues are considered. First, the reasons for choice and the understanding of a choice problem are examined. Second, attitudes towards different levels of uncertainty are measured. Third, the possibility that apparently non-normative psychological factors influence choice is explored. The paper serves to illustrate and support a number of methodological points. The major points are that a risk-uncertainty distinction *is* useful (contrary to the aging conventional wisdom of economic theory), that laboratory experiments can potentially provide data of use to agricultural economists, and that predictive models of choice under uncertainty may be more accurate if they take account of psychological variables which influence the decision-making processes of human subjects.

Introduction

The question of uncertainty has been of interest to farmers no doubt since time immemorial. In agricultural economics, problems ranging from farm management (Webster, 1979), and innovation adoption (Roumasset, 1976), to government policy (MacLaren, 1983) have been the subject of analysis incorporating uncertainty. To the fore in this developing literature have been American and Australian agricultural economists who, over the past two decades, have followed a path set out for them by Dillon (1971) in his classic review.

In the main, the American–Australian school has looked to economics and subjective expected utility theory (SEUT) as the paradigm for analysing decision-making (e.g. Newbery and Stiglitz, 1981). Farmers' utility functions are

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measured (Hamal and Anderson, 1982), and subjective probabilities are elicited (Grisley and Kellogg, 1983), even if question-compatible incentives (Knight et al., 1985) are not always used. Despite an increasing band of heretics (Wright, 1983), it remains the conventional wisdom that SEUT dispenses with the need for the Knightian (Knight, 1921) risk-uncertainty distinction (Borch, 1968; LeRoy and Singell, 1987). SEUT has led to a conceptually and mathematically tractable theory of decision but it is not clear that it offers a comprehensive model of decision-making (Gardenfors and Sahlin, 1982; Heiner, 1983; Hey, 1983). This paper contributes to the growing re-examination of SEUT (Machina, 1982, 1988) and uses experiments to show how a risk-uncertainty distinction, similar to the contrast between probability and weight (Keynes, 1921, chapter 6), can be given operationalised.

Why use experiments?[1,2]

Few agricultural economists will need persuading that uncertainty is of central importance to the decision-making process (see, for example, the proceedings of the 19th International Conference of Agricultural Economists, Maunder and Renborg, 1986). However, it is worth mentioning the methodological justification for using an experimental approach for although the standard textbook view (e.g. Samuelson, 1976) is that economics (and by inference the subdisciplines) is non-experimental, a growing number of researchers in both applied and theoretical areas are using experimentation as part of their analytical tool-kit (Roth, 1987). Indeed, journal articles (Allais, 1953; Plott, 1982) show that the use of experimentation by economists is not so new or revolutionary as might be supposed.

In agriculture, experiments may be used to produce data (on attitudes to risk, multi-attitude preferences and so on) which governmental sources of agricultural data such as FADN (Lommez, 1984) do not regularly provide, despite the importance of this information for predictions of farmer behaviour and ultimately for the distribution of income within the agricultural sector. This information can also be obtained through field studies, but these are likely to take longer to plan and be more expensive to conduct. Agricultural economists are often in the fortunate position that the students who take part in their experiments are reasonably representative of the population of entrants

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[1]I am grateful to Ken Thomson (University of Aberdeen) for a suggestion which highlighted the need for this part of the introduction.

[2]This paper only reflects a proportion of the questions asked. Other issues considered included the relationship between 'risk' and 'uncertainty' attitudes (which was weakly positive), the effect of lucky numbers 7 and 3 (which appeared to have a strong effect on choices - see also Cohen, 1960), and choices given different amounts of information (which often seemed to trade off probability against the number of observations in the distribution). For a fuller description see Anand (1986).

into farm management and in many cases have already been socialised into agricultural decision-making processes. This is not to say that experiments cannot also be conducted with 'real' decision-makers as subjects but it indicates that where students are involved, inferences to the population of decision-makers may be more robust than, say studies of cognitive processes based on samples of psychology graduate students.

Some economists (Binmore, 1987) have made light of experiments which search for facts ('fishing expeditions') but this attitude is unwarranted especially when theory is mute, makes non-unique predictions (Elster, 1988), or is known to be wrong. Game theory, used to model the kind of oligopolistic behaviour (which characterises many agribusiness input markets) provides examples of all three situations (Coleman, 1982). For instance, consider the three games structures in Fig. 1 for two players A and B, each with two strategies S_1 and S_2 suitably superscripted. The first pay-off in every cell pair is A's and it is understood that each player must pick a strategy without knowing how the other player will choose. Both know that the other player knows the payoffs, that the other player knows that each knows, and so on.

In Game I, known as 'Battle of the Sexes', there is no way of knowing from the description of the game, how each player will behave. In Game II, A's dominant strategy is to pick S_2^A but theory cannot predict whether the solution to the game is $\{S_1^A, S_1^B\}$ or $\{S_1^A, S_2^B\}$ will be the outcome. Finally, Game III represents the familiar prisoner's dilemma game in which theory appears to make a unique prediction $\{S_2^A, S_2^B\}$ though it is common knowledge that in experiments, many subjects, even in unrepeated games, choose S_1. There are, in short, a variety of instances where fact driven analysis supervenes over theory, and there are many agricultural economics contexts in which experiments may be used. In the first instance, experimental evidence may be helpful to those building models of agricultural markets. Instead of estimating expectation formations processes from noisy data, theories of expectation formation could be selected on the basis of experimental test results, and experimentation may even suggest ideas for new ways of theorising processes of interest – Roth (1987) calls this "speaking to theorists". Secondly, the subjects' experience of an experiment can sometimes be close to that of participation in a business game, and there may be considerable pedagogical and research advantages in combining the two activities. For example, different groups may be primed to use different decision procedures (e.g. marginal cost pricing, mark-up pricing etc.)

	s_1^B	s_2^B
s_1^A	1,1	3,2
s_2^A	2,3	0,0

Game I

	s_1^B	s_2^B
s_1^A	2,2	1,2
s_2^A	1,2	0,3

Game II

	s_1^B	s_2^B
s_1^A	1,1	2,-1
s_2^A	-2,-1	0,0

Game III

Fig. 1.

and then asked to compare their performances. Not only does this bring home the consequences following certain normative economic concepts, but it allows the collection of material potentially relevant to decision-making research. Finally the ability to simulate and evaluate the effects of policy changes ("whispering in the ears of princes") should not be ignored. Already, proposed legislation in the U.S. has been affected by the graphic results of experiment designed to model the effects of the legislative change (Plott, 1987), and it seems, therefore, that the experiment may become a useful tool in persuading legislators to pass laws which are rigourously *informed* by the consequences.

Adequacy of SEUT

Having claimed that decision-making under uncertainty is central to agricultural economics and that experiments should be regarded as generators of usable data which might not otherwise exist, the substantial issues of the paper are as follows. Issues 1 and 2 focus on the risk-uncertainty distinction[3] and are concerned with reasons for choice and attitudes to different levels of uncertainty. Issue 3 considers two examples of factors which determine choice under uncertainty though they are factors which until the 1980's would not appear in economic models. Although there have been substantial strides in the development of models of risk-taking (Fishburn, 1981; Schoemaker, 1982; Machina, 1983), two points will be made. The risk-uncertainty distinction can be operationalised and, as has been argued elsewhere (e.g. Anand, 1986; Lawson, 1985), such a distinction is useful to those trying to model or assist decision-making (e.g. farm management academics or consultants). Furthermore, anyone trying seriously to model or predict behaviour should take into account factors which determine choice regardless of the academic discipline in which they were conventionally studied.

In sum, the claim is that SEUT is insufficient as a model of decision-making because it excludes the risk-uncertainty and psychological determinants of choice. If the SEUT account were to be believed, the risk-uncertainty distinction was an interesting episode in the history of ideas but of little analytical use to students of decision-making. Savage (1954) argued that, where no objective probabilities exist, subjective ones can be imputed thereby reducing uncertain situations to ones of risk – albeit subjectively perceived. However, the imputation process relies on the assumption that a subject has preferences for decisions over stochastic options which can be represented as a (utility) function and therefore adhere to certain axioms. The evidence that subjects violate the axioms is widespread (Machina, 1983), though, in defence, Savage

[3]For the purpose of this paper it will be assumed that uncertainty exists whenever there is no exact probability distribution either because the agent's information is incomplete or because of some physical indeterminacy. Where such probabilities exist the situation is one of risk.

and others have claimed that the axioms involved should be regarded as rules for rational choice. Whilst this view is still widely accepted, a number of researchers have questioned the adequacy of SEUT's preference axioms (Allais, 1953; Aumann, 1962; Anand, 1982, 1987; McClennen, 1983; Sen, 1985; Sugden, 1985).

In addition to the objections aimed at the axioms which serve to justify the thesis that the risk-uncertainty distinction is analytically unnecessary, researchers have also considered more directly whether such a distinction might actually be useful. There is little empirical work in this area, though Webster and Kennedy (1975) and Hey (1985) have operationalised one such non-probabilistic concept of credence, namely potential surprise[4]. Though potential surprise is not the same as uncertainty, the concepts share the understanding that the 'risks as probabilities' doctrine is not enough to model choice under uncertainty. Arguments supporting this view are give in Anand (1985); here experimental support for that work is provided.

The paper reports on a selection of experiments conducted on students at the universities of Oxford, Göttingen and York. Table 1 summarises the samples used by geographical location, sample size, method of recruitment and main subject.

All subjects in S_1 are in S_2 but answered questions additional to those answered in the larger sample. Only subjects in S_4 received financial incentives, which are described below.

It is worth noting that financial incentives are no guarantee of properly motivated responses just as their absence does not prevent meaningful experi-

TABLE 1

Geographical location, sample size, method of recruitment and main subject of experiments

Sample	Origin	Size	Recruitment	Main academic subject of study
S_1	Oxford	30	Volunteers	Agriculture, Agricultural economics, and Psychology
S_2		50		
S_3	Göttingen	221	By class	Agriculture
S_4	York	5	Fixed and contingent payment	Economics

[4]Shackle's concept of potential surprise is founded on an intuitive notion of surprise, unlike probability which is based on likelihood. The axioms are different to those required for probabilities (see Shackle, 1961).

mental results being produced. It may, for example, be that incentive compatible experimental designs are misunderstood. Conversely, it may be that subjects make an effort to co-operate even though there is no monetary reward for so doing. Indeed Grisley and Kellogg (1983) provides a classic example of an experiment in which co-operation seems to have been achieved *despite* the financial incentives which mitigated against it (see Anand, 1986; or Knight et al., 1985)[5]. This paper is therefore predicated on the assumption that financial incentives are not necessary for experimental results to be indicative of the sort of findings which might occur outside a laboratory[6].

The question of uncertainty

Although there is something of revival of interest in theories in which no probabilities are assumed (Kelsey, 1987), much of the early work (for a summary see Luce and Raiffa, 1957) has been disregarded on the grounds that in practice complete uncertainty is rare. However, consider a situation in which a farmer has to make an investment decision which depends on the change in interest rates next year. The farmer may easily accept that a usurous rate is less probable than a rate of 15%. But insofar as he (or she) has to decide whether the rate will go up or down, it is quite plausible and consistent to think that he has no real idea. In short, the existence of probabilistic information may not be sufficient to ensure that the decision problem itself is not essentially a problem of choice under uncertainty. With this in mind, the starting point for the work reported here is Ellsberg's (1961) paper on uncertainty in which he posed, inter alia, the following problem.

Ellsberg's decision problem

Consider an experiment in which an agent is offered two urns containing red and black balls, from one of which will be drawn a ball at random. The following information is available. The ratio of red and black balls in urn I is unknown, whilst in urn II it is 50:50.

Now imagine that an experimenter is trying to use the individual's choice patterns to derive (infer) subjective probability estimates. To do so he would ask the following questions[7]:

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[5]Financial incentives can mitigate against co-operation where the incentives used are not consistent with the narrative instructions given, or the experimenters intentions. For example, Grisley and Kellogg wanted subjects to reveal their subjective probability distributions for particular weather states but gave an incentive in which risk-averters might appear to believe that all were events equally possible.

[6]Logically, it would be possible to advocate experimentation and yet reject the use of students as subjects.

[7]For shorthand, Red UI will be used to denote a red ball from urn I, and similarly for other outcomes.

(1) Would you prefer to bet on Red UI or Black UI, or are you indifferent?
(2) Would you prefer to bet on Red UII, Black UII, or are you indifferent?

The answers to these questions, so the subjectivists' claim, should allow certain ordinal inferences to be made about an individual's beliefs, namely that:

Either (a) $p(\text{Red UI}) > p(\text{Black UI})$
or (b) $p(\text{Red UI}) < p(\text{Black UI})$
or (c) $p(\text{Red UI}) = p(\text{Black UI})$

Perhaps not surprisingly, Ellsberg found that a common response to both (1) and (2) was that of indifference. But now consider two further questions which Ellsberg suggests:

(3) Would you prefer to bet on RED UI or RED UII or are you indifferent?
(4) Would you prefer to bet on Black UI or Black UII or are you indifferent?

Though there are no 'objective' probabilities for Red UI and Black UI, we do have revealed probabilities derived from (1) and (2). If the inferences about *beliefs* from *choices* are valid (as the subjectivists claim) then we can use them to predict the responses to (3) and (4). Individuals who are indifferent between options in (1) and (2) should be indifferent to options in (3) and (4); if they are not, the axioms of subjective probability are violated. Consider the inferences which would be drawn from the choice pattern of preference for Red UII over Red UI, and for Black UII over Black UI. As the probabilities (both objective and revealed from indifference in 2) of Red UII are 0.5, and Red UII is preferred to Red UI, then we should infer that the subjective probability of Red UI is <0.5. Similar reasoning applies to preference for Black UII over Black UI. However, if the inferred probabilities of Red UI and Black UI are both less than 0.5 then they will not sum to unity, thus violating the axiom that the total probability of mutually exclusive and exhaustive events is one. This shows one of two things: either the inferential system used to elicit subjective probabilities does not work, or that such a constellation of preferences is irrational. Ellsberg (1961) claimed that the system did not work because subjects were averse to what he called vagueness (which is called uncertainty in this paper). Superficially, Ellsberg's interpretation is attractive; however, it could be said that the choices which Ellsberg reported were not the results of rational deliberation but rather were products of mistaken perception.

Issue 1

The first concern was to examine the relations between choice, reasons for choice and problem understanding in an uncertain choice problem. In particular, an attempt was made to correct Ellsberg's experimental design to avoid the kinds of problems identified by Roberts (1963).

Motivation (Q_1)

Roberts (1963) made some six criticisms of Ellsberg's (1961) experiments and despite Ellsberg's (1963) spirited theoretical defence of his work, none of the subsequent empirical studies in this area (Becker and Brownson, 1964; Yates and Zukowski, 1976; Einhorn and Hogarth, 1986) have addressed the issues Roberts raised. His arguments are at times ingenious but can be summarised broadly in terms of the claim that Ellsberg's subjects choose for reasons other than preferences for, or aversion to, uncertainty and/or that they misperceived the statistical structure of the choice problem.

Experiment (Q_1)

In order to measure empirically the validity of Roberts' points, subjects in S_1 were given a simple hypothetical three-urn choice problem in which one urn was marked and contained five black and five white balls whilst the other two unmarked urns contained ten black and white balls in the ratios 7:3 and 3:7, respectively. (In statistical terms, used by SEU, the marked urn is equivalent to the chance to pick from an unmarked urn.) The question (Q_1) subjects were asked to respond to is reproduced in the appendix.

Note that (1a) was deliberately left open-ended ('Response...') to allow for indifference in recognition of Roberts' suggestion that subjects might have felt obliged to declare a preference even when they were indifferent between options; (1b) provided information on reasons for choice, and (1c) indicated the subject's understanding of the problem.

Results (Q_1)

In response to (1a), 19 subjects (63.3%) chose the marked urn, eight the unmarked option (26.6%), with two indicating indifference and one response being unusable. Of those who expressed a preference, there appear to be more uncertainty averters than preferers (significant at the 5% level). Answers to (1b) are summarised in Table 2[8].

Though it is necessary for the experimenter to make a subjective judgement in allocating (1b) to reason categories in this way, the procedure seems preferable to listing verbatim the responses. In most cases, for example, uncertainty avoidance and uncertainty preference, there is little scope for disagreement about the proper interpretation. It was difficult to ensure that some of the 'misinterpretations' were genuine misinterpretations but fortunately the number of such answers is reasonably small. There are some 16 individuals (out of 30) giving an uncertainty-related explanation for their choice, though, as Roberts surmised, indifference had motivated a number of non-indifferent choices in (1a) despite the open-ended nature of (1a). Answers to the final

[8]Answers to question (1b) were categorised by the experimenter according to the type of a reason a subject gave.

TABLE 2

Responses to question (1b)

Reasons for choice	No. of responses
Uncertainty avoidance	12
Uncertainty preference	4
Indifferent	7
Instinct	2
Don't know	4
Misinterpreted question	4
Total	33

question, (1c), gave most support of all to Roberts' suggestion for only 21 out of the 30 subjects correctly guessed the probability as 0.5. This is a notable finding because the problem is trivial. Lack of motivation is an unlikely explanation for this result given the sometimes extensive 'rough workings' which appeared on response forms of the five who gave a wrong answer or the four who gave no final reply. *Some* of Roberts' hypotheses are supported yet the procedure resulted in producing 16 individuals out of 30 who made a positive choice, for an uncertainty-related reason which was choice-consistent and was not based on a misunderstanding of the statistical structure of the problem.

Issue 2

The second concern was to examine how people react to different levels of uncertainty. Here responses to two questions are reported: Q_2 was given to S_3 whilst Q_3 was subsequently presented to S_4.

Motivation and experiment (Q_2)

Q_2 was motivated by a desire to ask subjects for hypothetical willingness-to-pay (WTP) values over different levels of uncertainty and Q_2 therefore took a similar form to that of Q_1. There were five versions of which each student received one chosen randomly. Each version had a different number of balls of particular colours and/or a different number of urns as summarised below (see Table 3).

Subjects in this case were asked for their maximum WTP for the version they were presented with; the prizes were notionally DM [9]400 if they picked a black ball and nothing otherwise. Answers were recorded by marking a value category and then giving a precise figure; 218 usable responses were obtained.

[9]Standard abbreviation for Deutsche mark.

TABLE 3

Problem variants used in Q_2

Version	No. of urns	Black balls	White balls
A	1	5	5
B	2	7	3
		3	7
C	3	8	2
		5*	5
		4	6
D	3	4	6
		5*	5
		8	2
E	3	4	6
		5*	5
		6	4

*Denotes the fact that the urn was marked and therefore the contents were, in principle, known to subjects.

Given the design, expected utility theory (and any decision theory which is linear in second-order probabilities) makes the following hypotheses:

H1 Versions A, B and E are of equal value, because whichever version a subject gets (and whichever choice the subject makes in the case of version E) the *probability* of winning DM 400 is $p(0.5)$ in each case.

H2 Versions C and D are of equal value because it is assumed that choices are extensional, that is independent of the actual form of the description used. In this case the descriptions varied because the order of the urns was reversed between C and D.

H3 Versions $C \cup D$ are more valuable than $A \cup B \cup E$. This is because versions C and D both offer a choice to pick from two unmarked urns giving a twelve out of 20 chance ($p=0.6$) of winning which dominates the $p(0.5)$ chance of winning given by A, B or E.

However, if it is allowed that uncertainty (and other 'psychological' factors) may determine choice then deviations from the above predictions can be explained. Just to give one example, if uncertainty aversion causes subjects to choose the marked 50 : 50 option, and therefore value E the same as A, the existence of a preference for uncertainty would cause the average value of E to be higher than that for A as uncertainty preferers would place a higher value on the 60 : 40 option than on the 50 : 50 urn.

Results (Q_2)

Results are presented below in Table 4. Using Bartlett's chi-square test (Quenouille, 1966), the variances proved not significantly different at even the 10% level. It was therefore accepted that they were estimates of a common population variance which was derived by creating a weighted pooled estimate. In fact, no differences were significant which supports H1 and H2 but not H3. Though there may, in principle, be any number of explanations for these findings, the uncertainty based explanation would be that at the level of uncertainty in versions C and D, no-one or virtually no-one would have chosen the unmarked option and therefore C and D were of equal value, in effect, to A, B and E.

Motivation (Q_3)

To complement the cross-sectional approach above and to try to measure more specifically individual attitudes towards uncertainty, a further series of questions, Q_3, were given to sample S_4. Q_3 was designed to provide willingness-to-pay (WTP) responses to a number of probability ranges, (p_{min}, p_{max}), of receiving a payoff which could be modelled by the equation (1):

$$\text{WTP} = \beta_0 \tfrac{1}{2}(p_{max} + p_{min}) + \beta_1 (p_{max} - p_{min}) + \beta_2 (p_{max} - p_{min})^2 \qquad (1)$$

Graphically this can be represented as a set of indifference curves in (p_{min}, p_{max}) space as per Fig. 2.

Indifference curves perpendicular to $p_{min} = p_{max}$ indicate indifference to uncertainty whilst those sloping upwards denote uncertainty aversion. The motive for testing an equation including the $(p_{max} - p_{min})^2$ variable was that agents might reasonably prefer small amounts of uncertainty and yet give smaller WTPs for high levels of uncertainty. Alternatively, they might be cautious over small levels of uncertainty and then reach a level where they implicitly behave in a 'what-the-hell' manner and exhibit uncertainty preference.

The classic paper in indifference curve estimation is the Toda and MacCrimmon (1969) study of seven individuals. However, like Thurstone before

TABLE 4

Willingness-to-pay responses to Q_2

Version	Mean	Standard deviation	Observations
A	41.81	61.88	46
B	44.77	64.97	45
C	33.22	51.04	43
D	43.12	64.01	43
E	43.58	75.52	41
Combined	41.32	63.82	218

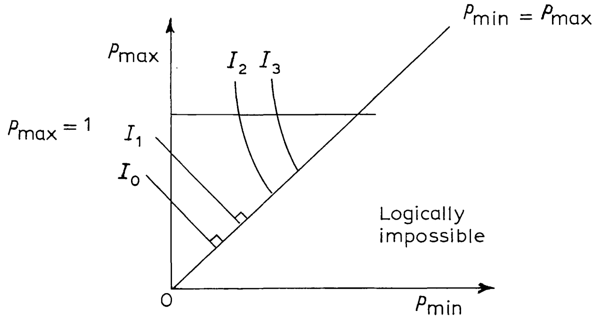

Fig. 2. Probability interval space gamble.

them, they chose a questioning procedure which iterates to an indifference line by a series of conditional (and sometimes actual) binary preference questions. An alternative and more data conservative method is to ask for responses from subjects to a given lottery where the bound parameters are varied. This procedure (which was used here) also avoids some estimational problems associated with chaining (see Knowles, 1984).

Experiment (Q_3)

In this experiment five subjects were recruited. They were asked to give WTPs for 31 possible probability bound pairs defined on a one outcome lottery for £1.50 (so called because only one outcome is non-zero). Subjects were paid £1.50 for participation and given a response-contingent incentive calculated in the following manner. At the end of the experiment two items were chosen at random and the subject was allocated the choice for which a higher WTP had been declared. (Subjects were not told how this would be played out but random numbers were used by the experimenter.) The intention was to give subjects an ordinally correct scoring rule. It should be noted that the rule does, in principle, allow any positive monotonic mapping of actual WTPs but it should also be noted that all WTPs satisfied the dominance constraints, £0 ≤ WTP ≤ £1.50. The correctness of the scoring rule may be 'proved' by contradiction as follows. Consider an agent who ranks the response items 1 to 31. Let him or her also place WTP values in this order except for one pair so that (2) holds:

$$r\{p_{\min}(e_1), p_{\max}(e_1)\} > r\{(p_{\min}(e_2), p_{\max}(e_2)\} \tag{2}$$

and

$$\text{WTP}\{(\text{p}_{\min}(\text{e}_1), \text{p}_{\max}(\text{e}_1)\} < \text{WTP}\{<p_{\min}(e_2), p_{\max}(e_2)\}$$

Now if an adjacent pair is ranked wrongly (by WTP values) there is an non-zero positive probability $(2/(31 \times 30))$ that the pair chosen by the experimenter will 'reveal' a reversed ordering compared with that given by the preference ranking. We note also that if there are more than two items for which (2) is true then it must be true for at least one pair. To show that only ordinality is *assured*, define (WTP) as any positive monotonic function and follow the above reasoning.

Results (Q_3)

The equations estimated on the basis of responses to Q_3 are presented in Table 5.

It is worth noting that only one out of five subjects is uncertainty preferring, a finding which is of no significance on its own but which does concur with the other findings reported here and in related experimental papers cited earlier. Note also that two students used calculators. Subject 1 did so almost immediately and seemingly with a purpose. Subject 3 observed subject 1's behaviour and said 'that's a good idea'. He began to use a calculator but after a few minutes he dejectedly acclaimed that "it didn't help".

Issue 3

The third concern here is the extent to which socio-psychological factors may play a role in determining subject response, particularly in questions con-

TABLE 5

Willingness to pay for 31 probability intervals defined on the <£1.50, £0> gain-loss pair

Estimated equations (OLSQ)			ADJ r^2	DW
$W_1{}^*$	$=1.47\,p_{mid}$		0.94	2.10
	(50.4)			
W_2	$=1.46\,p_{mid}$	-0.51 UNC	0.91	2.12
	(25.9)	(97.3)		
$W_3{}^*$	$=1.00\,p_{mid}$	$+0.11$ UNC	0.92	1.87
	(30.7)	(2.7)		
W_4	$=1.53\,p_{mid}$	-0.11 UNC	0.92	1.79
	(31.5)	(1.8)		
W_5	$=1.02\,p_{mid}$	-0.10 UNC	0.87	1.52
	(23.8)	(1.8)		

W_i Willingness to pay expressed by subject i.
* Denotes subjects who gave calculator assisted responses.
$p_{mid}\ \frac{1}{2}\ (p_{max}=p_{min})$.
UNC$=p_{max}-p_{min}$.
DW Durbin-Watson statistics.
Critical 'p' value with 29 degrees of freedom is in the interval (0.05, 0.025).
Figures in parentheses indicate t-statistics.
The above equations were the best estimates out of different linear forms which included successively p_{mid}, UNC and UNC^2.

cerning choice under uncertainty. Under this issue we consider two sorts of such effect, one of a more conscious nature that the other.

Motivation and experiment (Q_4)

Rogers (1965) observed that peasant farmers seemed to react to risk depending on the social context of that risk. In addition, experimental evidence by Shoemaker (1982), indicates that subjects choose differently according to whether choice problems are called 'insurance' problems or 'gambles'. Though Shoemaker's risk problems were identical, it is arguable that the design was not an adequate test of the differences due to social context because insurance risks also give payoffs which are usually negatively correlated with an agent's asset position – a fact which is not usually true of gambles. A risk vs. uncertainty choice similar to (Q_1) was therefore presented to subjects but using a less abstract formulation. The 'realistic' variation which was given to all students in both S_1 and S_3 is given in the appendix (Q_4).

Results (Q_4)

Results are summarised in Table 6. Whilst there is a movement away from uncertainty-averse responses as the context becomes realistic, this is not statistically significant according to the standard chi-squared test. Nevertheless the direction of change between contexts was similar for both German and English samples. Had the response been cardinal rather than binary this difference may have been judged more statistically significant.

Motivation and experiment (Q_5)

Arrow (1982) reported work conducted by psychologists in which surgeons were found to make recommendations dependent on the way in which options were described (i.e., were 'intentional'). In particular, when told the chance of survival was 0.9, 84% recommended surgery. But when told that the chance of death was 0.1 (logically and factually equivalent) only 50% recommended surgery. Disturbing as this may be, it is not clear why this should be the case. Two possibilities, however, stand out. It might be that in normal practice, surgeons use a loss-focussed description (e.g., chance of death) when they recommend not operating and this extra-experimental socio-psychological effect deter-

TABLE 6

Uncertainty preferences in abstract and realistic contexts

	Abstract	Realistic	
Certain	19 (70.4)	151 (56.5)	170
Uncertain	8 (29.6)	116 (43.4)	124
Total	27 (100)	267 (100)	294

TABLE 7

Preference for heads over tails

Survey	Heads	Tails	Indifferent	Unusable
Oxford	32 (66.6%)	16 (33.3%)	-	2
Göttingen	132 (62.5%)	79 (37.5%)	8	2
Total	164	95		

mined the surgeons' choices. Secondly, it could be that some psychological phenomenon relating to the actual descriptions is determining the subjects' choices (and these possible explanations need not be mutually exclusive). In this experiment we sought to examine the possible influence on choice of a factor of the second sort, in this case the preference for heads over tails. Q_5, given to samples S_2 and S_3, asked subjects to indicate a preference for heads or tails in a one-off hypothetical coin-tossing game with a contingent reward of £100 or DM 400 for a correct guess.

Tails, like left-handedness (the Latin word 'sinister' refers to the ill-omened and left-handed alike), has negative, undesirable connotations. The devil has a tail whereas we talk about the Godhead. The head in Western society is a symbol of authority. It was therefore hypothesized that subjects would favour heads over tails. The German for 'tails' is 'number' a more neutral term so that whilst we expected to see a preference for heads over 'tails' it was hypothesized that the preference would be less pronounced for the German sample.

Results (Q_5)

The results (Table 7) which show a highly statistically significant bias (the critical '*p*' value is less than 1%) in favour of heads also show a difference between the British and German samples and though this is not significant, it is in the direction predicted.

Summary and conclusions

The main conclusions of this paper are as follows. Experiments can be designed which show that subjects express a preference between uncertain options where SEUT predicts indifference. Even after allowing for those who misunderstood Q_1 (p_7), more than half of subjects had a coherent reason for choosing and of those, the majority were uncertainty-averse (defined in terms of attitudes to range-defined probabilities) rather as findings suggest most subjects are risk-averse (defined in terms of the concavity of the utility function). The weak tendency towards uncertainty aversion was mirrored in a total of 155 responses by five individuals to a series of problems with incentive compatible financial rewards. Whilst a realistic question setting yielded less uncertainty-aversion than an abstract formulation, the shift was not statistically significant. It also appeared that the psychological impact of heads and tails ('numbers' in German version) caused subjects to express a preference where economic decision theory would predict indifference; the finding proved highly significant in standard statistical terms.

The consequence for analyses of economic behaviour of those concerned with agriculture are that psychological factors may play a decisive predictive role (see also Gladwin, 1980) and that utility functions can be elicited over ranged-defined probabilities. It is hoped that the distinction between risk and uncertainty or something like it (see for examples Keynes, 1921 on the 'weight' of evidence; also Anand, 1985; Brady, 1985) will be useful particularly in agricultural decision contexts such as those considered by Roumasset (1976). Indeed Cancian (1980) has already proposed an application of a similar distinction to the analysis of innovation adoption.

Although the paper has made use of experimental material to provide data relevant to uncertainty, it is possible that the risk-uncertainty distinction can be used to interpret standard data. The main concern for future research, which applies to decisions ranging from innovation adoption, crop-choice, input selection through to marketing strategies, will, I suggest, focus on how farmers combine information. Bayes' theorem is said to provide *the* appropriate method for handling new information but it should be realised that hypothesis testing and uncertainty (weight of evidence) based theories, which are both intelligible from the perspective of classical statistics, will lead to different predictions about how new information is combined with prior beliefs and how it subsequently affects behaviour. Where standard data sources are used, even n, the number of observations available, may be a good proxy for the weight a decision-maker attaches to her estimate of r/n, the relative frequency of that event.

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Appendix

Question 1 (Q)

Would you prefer to choose a ball from the marked container or one of the unmarked ones?
Response: (1a)
Why: (1b)
What is the probability that you would get a black ball if you choose from an unmarked container?
Response: (1c)

Question 4 (Q_4)

Imagine that a fertiliser company offers you a fertiliser which is the same as the one you are using except for a special additive which, if it works at all, will give you a net benefit of £100 (DM400 to S_3 subjects).

The additive is free because it is being tested for foreign markets but you are guaranteed that it will not harm your crops in any way.

There are two versions which you can choose from: brand 'a' stands a 50% chance of success and brand 'b' stands a 30–70% chance. Which would you choose?
Response:

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