AAEA Meeting Invited Paper Sessions

Attitudes and Values: Determinants of Decision Making
(Ellen Goddard, University of Alberta, and Carola Grebitus, University of Arizona, Organizers)

Risk Aversion, Subjective Beliefs, and Farmer Risk Management Strategies

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Building upon early theoretical work that established the underlying principles of decision making in settings involving risk (e.g. Arrow 1965; Pratt 1964; Von Neumann and Morgenstern 1944), a substantial body of experimental literature has developed investigating the theory of risk in laboratory and field settings in order to better understand agent behavior and market outcomes. These experimental explorations are motivated by the ubiquity of risk across the spectrum of decisions that agents make on a daily basis. In agricultural production, where farmers' yields and revenue are dependent upon numerous largely exogenous factors such as weather conditions and price fluctuations, risk and uncertainty is omnipresent in farming decisions. Ultimately, risk and uncertainty influence crop-selection and crop-rotation schemes (El-Nazer and McCarl 1986), technology adoption (Purvis et al. 1995), environmental degradation and policy compliance (Ozanne, Hogan, and Colman 2001), and crop insurance markets.

Early experimental studies focusing on decision making under uncertainty revealed that the predominance of individuals are risk averse (Binswanger 1980). Recent experimental evidence has provided a deeper understanding of the individual-specific characteristics related to differing degrees of observed levels of risk aversion and the relationship with economic outcomes. Examples include an assessment of the link between individual-level risk preferences and socio-demographic characteristics (Harrison, Lau, and Rutström 2007), cognitive abilities (Dohmen et al. 2010) and personality attributes (Eckel and Grossman 2008).

In this study we build upon this experimental evidence and explore the linkage between risk attitudes and subjective beliefs of an uncertain outcome occurring with a specific focus on agricultural losses due to weather events. Under subjective expected utility theory (Savage 1954), an agent's optimal decision in a risky setting is determined not only by their attitude towards risk, but also their subjective belief regarding the probability of an uncertain outcome occurring. This framework recognizes that in many risky settings individuals do not know the probability of uncertain events occurring, and thus make decisions based upon subjective beliefs which may not necessarily correspond with true probabilities. The underlying cognitive processes, heuristics, and individual-specific factors that shape how agents formulate their subjective beliefs, particularly in complex settings with limited information, is an open question (Gilboa, Postlewaite, and Schmeidler 2008). In particular, as we focus upon in this study, it is unclear if and how risk attitudes are

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related to the subjective probabilities agents perceive of uncertain outcomes occurring. That is, does an agent's degree of risk aversion influence their perception of the probability of uncertain events occurring?

We assess whether there is a relationship between risk aversion and subjective probabilities by using an experimental approach with a random sample of relatively homogenous (in terms of agricultural operations) farmers facing weather risks. As detailed in the following section, lottery-choice tasks (Eckel and Grossman 2008) were used to elicit each farmer's risk attitudes, and a simple structured smoothing method (Norris and Kramer 1990) was used to elicit each farmer's subjective belief of the probability of crop losses due to weather events. Using the experimental outcomes and controlling for a number of factors that would be hypothesized to influence subjective probabilities (e.g. past experiences with crop losses, information, and communication with other farmers), regression analysis is used to assess the relationship between risk attitudes and subjective beliefs.

Experiment Design and Data Summary

In the spring of 2011, a sample of 313 apple farmers in the Province of Trento, Northern Italy, was recruited via the local extension service to participate in a series of experiments exploring risk attitudes among agricultural producers. With an annual production value of over 200 million Euros, apple production in the Province of Trento is the region's largest crop sector, representing 30% of its gross marketable agricultural production (Servizio Statistica 2007). Due to the unique microclimate in the region, apples from the Province of Trento that meet exacting grading standards set by local cooperatives receive a substantial price premium in the market. Two key weather-related risks–hail and spring frosts–affect both the quality premium and quantity of output for apple farmers in the region, and represent the two key weather risks to producers' annual profits. Historically, hail has been the most significant source of revenue losses for apple farmers, and there is an emerging concern among climatologists that the gravity of hailstorms in the Province of Trento will increase. Similarly, given the location and altitude of the region and the proximity to the Alps, spring frosts, although a relatively rare phenomenon, also represent a major concern for farmers in the region.

Computer assisted face-to-face interviews were conducted with each farmer to elicit their degree of risk aversion, their subjective beliefs on the risk of crop damage from adverse weather events, and a number of characteristics pertaining to them and their farming operation. Due to the infeasibility of conducting experiments involving stakes on the level of annual farm income losses, several measures were undertaken to mitigate potential biases due to the hypothetical nature of the experiments. In addition to receiving a gift for participation (a hacksaw or a pruning shear valued at approximately 30 Euro), farmers were promised feedback regarding their risk attitudes as a non-monetary incentive, as in Reynaud and Couture (2012). Further, a cheap-talk script was used with each participant.

Subjective Probability Experiment

Prior to implementing the experiments, three different pre-tests were conducted to develop and refine the elicitation mechanisms. In particular, for eliciting subjective beliefs it was critical to identify a natural framing context for subjects to express weather risks and the likelihood of risky prospects. Pre-tests indicated that for farmers in the region, the natural way of expressing risk outcomes was in terms of the percentage of their crop value lost due to adverse weather. Further, focus groups identified six primary damage intervals as natural ranges of potential crop value losses due to inclement weather during the growing season. Using these intervals, each farmer in the computerized experiment completed two tasks that were designed to reduce the cognitive burden involved in eliciting subjective beliefs and to ensure that measures reflecting true beliefs on loss probabilities were captured. In the first task, based upon their direct and indirect recollection of previous growing seasons, each farmer identified the number of growing seasons falling into each of the six crop value loss intervals. These responses were then transformed into probabilities by the computer and explained to the farmer. Then, in the second task each farmer was invited to consider and adjust the displayed probabilities to best reflect, based on his current knowledge and expectations, his belief of the probability of incurring crop losses for the upcoming growing season. Table 1 presents the damage intervals and a summary of the responses by the experiment participants. Averaging across all participants, farmers believed that the most likely outcome for the 2011 growing season would be a crop value loss between 0-30%, with an average probability of 56.9% assigned to this damage interval. Fitting with expert opinions, farmers on average assigned a small but positive probability to catastrophic losses of more than 80% of their crop value. Instilling confidence in the elicitation mechanism, the average distribution of perceived loss probabilities for the 2011 growing season strongly correspond with historical losses. However, the correlation coefficient between 2011 risk perceptions and historical losses is 0.73, indicating that at the individual level, farmers have perceptions for the 2011 growing season that do not perfectly correspond with past experiences.

Risk Aversion Experiment

The second major component of the experiments elicited a measure of each farmer's degree of risk aversion using a lottery-choice task. We adopted a procedure developed by Eckel and Grossman (2008) in which subjects are confronted with a set of 50-50 gambles, including a sure outcome and several risky outcomes with linearly increasing expected payoffs and risk (measured as the standard deviation of expected payoffs). The gamble tasks were framed in terms of gambles over each farmer's 2011 farm income, with the sure payoff being 100% of the value of the annual farm ordinary gross income. The 11 gambles shown to participants in the lottery-choice task are presented in table 2. The first four columns, which contain the choice events, the probability of each outcome (50%), and the payoff of each gamble in terms of farm income, was displayed on a computer screen for each participant to select from. The next three columns of table 2 are calculations (not presented to participants) describing the expected payoff, standard deviation of the expected payoff, and the range of values of a constant relative risk aversion utility function that would correspond to an individual choosing that particular gamble. Finally, the last column of table 2 presents the percentage of respondents that choose each gamble task. As expected, farmers in the sample displayed significant levels of risk aversion, with 87.5% of respondents choosing either gamble 1, 2, or 3. Less than 2% of respondents choose gambles 8-11, which would represent very low levels of risk aversion. Overall, while there was heterogeneity in terms of preferred gambles, the experiments indicated that the farmers were not willing to risk significant portions of their farm income. This observed level of risk aversion is stronger than that found in other experiments (e.g. Eckel and Grossman

Table 1. Crop Damage Ranges and Responses

% of Crop Value Lost	Mean Historical Probability Across Respondents	Mean 2011 Growing Season Probability Across Respondents
<30%	55.8	56.9
30-39%	17.1	17.2
40-59%	11.5	12.0
60-79%	7.2	7.0
80-89%	4.2	3.8
90-100%	4.3	3.1

Table 2. Summary of Gamble Task Experiment Design and Share of Farmers Who Chose Each Gamble

Gamble Number	Prob.	Payoff: % of Farm Income	Expected Payoff[a]	Risk[a,b]	CRRA Ranges[c]	% of Farmers
1	50 vs. 50	100 vs. 100	1.00x	0.00x	$r > 4.92$	42.8%
2	50 vs. 50	90 vs. 120	1.05x	0.15x	$1.64 < r < 4.92$	23.6%
3	50 vs. 50	80 vs. 140	1.10x	0.30x	$1.00 < r < 1.64$	21.1%
4	50 vs. 50	70 vs. 160	1.15x	0.45x	$0.72 < r < 1.00$	5.1%
5	50 vs. 50	60 vs. 180	1.20x	0.60x	$0.56 < r < 0.72$	2.9%
6	50 vs. 50	50 vs. 200	1.25x	0.75x	$0.45 < r < 0.56$	3.2%
7	50 vs. 50	40 vs. 220	1.30x	0.90x	$0.38 < r < 0.45$	0.0%
8	50 vs. 50	30 vs. 240	1.35x	1.05x	$0.30 < r < 0.38$	1.0%
9	50 vs. 50	20 vs. 260	1.40x	1.20x	$0.24 < r < 0.30$	0.0%
10	50 vs. 50	10 vs. 280	1.45x	1.35x	$0.16 < r < 0.24$	0.0%
11	50 vs. 50	0 vs. 300	1.50x	1.50x	$r < 0.16$	0.3%

(a) $x = 100\%$ of ordinary farm income. (b) Measured as standard deviation of expected payoff. (c) Calculated as the range of values of r in the constant relative risk aversion function, $U(w) = \frac{w^{1-r}}{1-r}$, for which a subject would choose a given gamble.

Table 3. Farm and Farmer Characteristics

Variable Name	Variable Definition	Mean	Stdev
Farm and Farmer Characteristics			
Age		45.54	11.82
Education	Years	10.44	2.85
Farming Experience	Years	24.53	12.74
Full Time	1 if a full time farmer	0.90	0.30
Household Size		3.43	1.18
Farm Size	Hectare	5.17	2.65
Cultivated/Owned	% of cultivated land that is owned	72.43	28.49
Income	1000 Euro/month	2.52	1.36
Level of Concern	Average stated concern (10 point scale) over 10 risk factors	5.98	1.54
Probability Test Score	# of probability questions correctly answered	3.31	1.16
Past Damage and Risk Relevance			
Past Crop Damage	Farmer assessment of historical losses (% of crop value)	13.44	6.11
Crop Value at Risk	Crop value potentially affected by the elicited weather risk (1000 Euro)	62.25	46.16
Land Size at Risk	Land covered by crop exposed to the elicited weather risk	2.99	2.05
Information and Interaction with Other Farmers			
Coop Member	1 if a member of a farmer cooperative	0.91	0.28
Coop Representative	1 if involved in Co-op management as farmer representative	0.30	0.46
Co.Di.Pr.A	1 if attended an information session by Co.Di.Pr.A in 2011	0.45	0.50
Sessions & Articles	# of recently attended information sessions and articles read	4.82	2.27

2008; Reynaud and Couture 2012) and may reflect the order of magnitude (i.e. shares of farm income vs. units of dollars) of the gamble payoff.

Other Experiment Questions

In addition to the subjective probability and risk aversion experiments, each participant provided responses to questions pertaining to their farming background and farm characteristics that could be hypothesized to influence risk perceptions. Table 3 presents a summary of responses. In terms of farmer characteristics, the average age is 45.54, with 24.53 years of farming experience, education is 10.44 years of schooling, and 90% are full-time farmers. For the farming operations, the average size is 5.17 hectares, with the majority of cultivated land being owned by the operators (72.43%). These characteristics closely match the farming population in the region (Servizio Statistica 2007).

In the survey, questions were included to capture the level of information on farming risks that farmers sought or were exposed to, in addition to their interactions with other farmers. About 45% of farmers reported they attended the annual information session by Co.Di.Pr.A., the farmer association in charge of crop insurance. On average, farmers read booklets or participated in 4.82 information sessions by the extension services during the last year. Most are members of a cooperative (91%), with 30% being a farmer representative involved in the management of a cooperative.

We also included two additional tasks. A set of 7 probability tasks, adapted from Fischbein and Schnarch (1997), was used to assess farmers' ability to process probabilistic information. On average, farmers correctly answered 3.13 questions with a standard deviation of 1.16. To capture farmers' general level of concern/optimism, ten different risk factors on a ten point scale were used to construct a composite score of each farmer's general level of concern. The average level of concern is 5.98, with a standard deviation of 1.54.

Data Analysis

To assess the relationship between farmers' degree of risk aversion and their subjective beliefs of the probability of crop value losses due to adverse weather, for brevity we report just the results of a standard linear regression model (alternative constructions with similar quantitative and qualitative results are available from the authors). The dependent variable in the regression model is the expected crop loss perceived by each farmer, which was constructed by weighting the midpoint of the crop value loss interval identified in table 1 by the

Table 4. Farmers' Expected Crop Value Loss: OLS Regression Estimates

Variable	Coefficient	Standard Error
Risk Aversion (CRRA lower bound)	0.435**	(0.198)
Age	0.496**	(0.231)
Age- Squared	−0.005**	(0.002)
Education	0.031	(0.146)
Farming Experience	0.009	(0.059)
Full Time	0.270	(1.147)
Household Size	−0.211	(0.397)
Farm Size	0.128	(0.169)
Cultivated/Owned	−0.016	(0.014)
Income	−0.083	(0.293)
Level of Concern	0.134	(0.301)
Probability Test Score	0.393	(0.313)
Past Crop Damage	0.723***	(0.047)
Crop Value at Risk	−0.033**	(0.016)
Land Size at Risk	0.565	(0.387)
Co-op Member	−1.798	(1.733)
Co-op Representative	−1.715*	(0.971)
Co.Di.Pr.A	1.253	(0.902)
Sessions & Articles	0.355*	(0.178)
Constant	−5.115	(5.682)
R-Squared	0.569	

Note: *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

respective perceived probabilities. In addition to the outcomes of the gamble-lottery tasks assessing each farmer's degree of risk aversion, additional factors are included in the regression that could be hypothesized to influence subjective probabilities. These variables, which are described in table 3, include general farm and farmer characteristics, external information sources, and past damage experiences.

As can be seen in table 4, the regression analysis indicates a positive and significant relationship between a farmer's level of risk aversion and his subjective belief of the probability of crop losses. This indicates that farmers who are more risk averse are also more likely to perceive a greater probability of suffering damages and, conversely, farmers that have risk attitudes approaching risk neutrality perceive a lower probability of losses. This result has a number of implications. First, it indicates that risk aversion and subjective beliefs, which are traditionally considered as two independent features constituting an agent's internal optimization problem in settings of risk, are instead significantly correlated. Taking the presence of such a statistical relationship into account is important in the interpretation of risk aversion estimates obtained from revealed preference data in the presence of risk. It is possible that the degree of heterogeneity in risk attitudes is overestimated and that, once subjective beliefs are accounted for, risk aversion plays a lesser role (Armantier and Treich 2009). Second, the presence of this positive relationship might help explain why broad participation in crop insurance markets is difficult to achieve even with the high subsidization of insurance premia. Also, this positive relationship might influence the scope of farmers' perceptions de-biasing measures aimed at increasing crop insurance participation.

In addition to the estimated positive relationship between risk aversion and subjective beliefs, several other farm and farmer characteristics are also found to influence risk perceptions. As expected, past experiences with crop losses have a significant impact on current perceptions. Farmers that have experienced more substantial past losses have a significantly higher perception of current growing season risk probabilities. Similarly, farmers who are older, have smaller crop values at risk, or have been exposed to more outreach materials tend to also have higher perceived probabilities. However, those farmers who serve as a farmer representative in a cooperative, and are therefore more frequently confronted with a variety of management and marketing problems, tend to perceive a lower weather risk. Few other farm and farmer factors are found to have a significant impact on risk perceptions. This fits well, as the farmers constituting the sample are relatively homogenous in terms of their farming operations and socio-economic backgrounds.

Conclusion

Better understanding how farmers perceive farm-related risks and behave in settings of uncertainty is critical for interpreting agricultural outcomes and designing policies, outreach programs, and insurance instruments that effectively assist farmers. In this paper, two sets of experiments were conducted with farmers to investigate their perceptions of weather risks to apple production, and their degree of risk aversion. Our findings confirm previous research suggesting that agricultural producers are risk averse. Also, our experiments provide new evidence on the relationship between subjective beliefs and risk attitudes. In particular, our findings indicate that farmers who are more (less) risk averse tend to perceive greater (smaller) probabilities of farm losses occurring. The existence of a positive relationship between subjective beliefs and risk attitudes raises a number of questions for future research, for example, what are the effects of a relationship between subjective beliefs and risk aversion on farmers' decisions to purchase crop insurance, and the need for government subsidies of insurance premiums to achieve high levels of participation in insurance markets?

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