American Journal of Agricultural Economics Advance Access published October 27, 2011

AAEA Meeting Invited Paper Session

Experiments with Farmers: Risk, Ambiguity, and Discounting (David H. Herberich, University of Chicago, Organizer)

A Generalized Measure of Marginal Risk Aversion: Experimental Evidence from India and Morocco

David R. Just and Travis J. Lybbert

Since Binswanger's (1980) early risk experiments with Indian farmers, a long tradition has developed that uses simple experiments to elicit risk preferences. Recent research in this tradition has sought to test expected utility and prospect theories of decision making under risk and to explore the implications of differences in risk preferences on production and consumption outcomes. While a high degree of correspondence can be found between these experimental results and real world response to risk (see e.g., Pennings and Garcia 2001), framing risk as static gambles in isolation may be too restrictive a frame.

Recent experiments with farmers in India suggest that farmers may respond not only to the standard risk characteristics of isolated gambles, but also to marginal changes in risk that occur between two gambles (Just and Lybbert 2009). Thus, a farmer may evaluate the risk characteristics of a new seed variety based on how these characteristics differ from a familiar variety rather than assessing the new seed in isolation. The responses to these changes, dubbed *marginal risk behavior*, display a systematic relationship to standard measures of risk aversion, called *average risk behavior*. Despite this systematic relationship, however, marginal risk behavior is often inconsistent with average risk behavior: while most farmers are risk averse according to average measures, their marginal behavior reveals a desire for more risk on the margin. Whether economists should focus on average risk aversion, marginal risk aversion, or both likely depends on the context, but it clearly matters whether we frame risk decisions as isolated gambles or as changes from a reference gamble.

This paper contributes to the literature by creating a feasible method to measure and describe marginal risk aversion using field generated data. This method may open new opportunities to explore the relationship between changes in risk and risk behavior in natural field settings. Such an extension is necessary if policy and welfare implications are to be drawn, Further, this work confirms and elaborates on several behavioral regularities discovered in our previous work.

Background and Theory

In Just and Lybbert (2009) we explore the possibility that individuals respond to changes in risk more so than risk itself. Thus, a farmer may make some marginal changes to his production decisions based on the anticipated impact of changes in weather patterns on yield rather than recalculating all production

David R. Just drj3@cornell.edu is Associate Professor in the Dyson School of Applied Economics & Management, Cornell University, Travis J. Lybbert tlybbert@ucdavis.edu is Associate Professor in the Department of Agricultural & Resource Economics, University of California, Davis. This article was presented in an invited paper session at the 2011 AAEA annual meeting in Pittsburgh, PA. The articles in these sessions are not subjected to the journal's standard refereeing process.

Amer. J. Agr. Econ. 1–7; doi: 10.1093/ajae/aar072

decisions based upon the new anticipated yield distribution. We refer to such re-evaluation of changes in risk as *marginal* risk behavior and show that individuals are often risk averse in isolation (valuing risky gambles at less than their expected value) but risk loving on the margin (increasing their valuation of gambles that are more risky). Using the difference between an individual's willingness to pay (WTP) for a baseline gamble and an alternative gamble (ΔWTP), we proposed the following two crude measures of marginal risk aversion:

$$(1)\qquad MR_{E(x)} = \begin{cases} 1 - \dfrac{\Delta WTP}{\Delta E(x)} & \text{if } \Delta E(x) > 0 \text{ and } \Delta\sigma = 0 \\ \dfrac{\Delta WTP}{\Delta E(x)} - 1 & \text{if } \Delta E(x) < 0 \text{ and } \Delta\sigma = 0 \end{cases}$$

and

$$(2)\quad MR_\sigma = -\frac{\Delta WTP}{\Delta\sigma} \text{ if } \Delta E(x) = 0 \text{ and } \Delta\sigma \neq 0$$

where $\Delta E(x)$ is the change in expected value and $\Delta\sigma$ is the change in variance between the baseline and alternative gamble. While the intuition behind these two measures is clear, their empirical usefulness is clearly limited for two primary reasons. First, they can be applied only where either the expected value of the gamble or the standard deviation of the outcomes of the gamble remain constant. Most naturally occurring changes in risk will not conform to either of these conditions. Even within the experimental gambles considered in Just and Lybbert (2009), there was one gamble that could not be evaluated because it had a different mean and variance from all other considered gambles. Secondly, equations (1) and (2) are merely ordinal measures. They are not comparable to other, more familiar measures of risk aversion nor are they comparable to each other, It would be difficult to examine values of equation (1) and know what they might imply for values of equation (2).

In order to address these two issues, it is necessary to devise a more robust measure of marginal risk aversion, Suppose that an individual was considering the change from gamble h to gamble g. Let $x \in \mathbb{R}_+$ be one potential outcome of a gamble. We extend the notion of marginal risk aversion by introducing the delta-utility of wealth function, which we defined as

$$(3)\qquad V_{h,g}(x) = U_g(x) - U_h(x).$$

Marginal absolute risk aversion can be measured as

$$(4)\qquad R_{AM} = -\frac{\left(\frac{\partial^2 U_h(x)}{\partial x^2}\frac{\partial V_{h,g}(x)}{\partial x} - \frac{\partial^2 V_{h,g}(x)}{\partial x^2}\frac{\partial U_h(x)}{\partial x}\right)}{\left(\frac{\partial U_h(x)}{\partial x} + \frac{\partial V_{h,g}(x)}{\partial x}\right)\frac{\partial U_h(x)}{\partial x}}$$

having a form similar to familiar Arrow–Pratt coefficients of risk aversion. Note that if an individual's behavior is consistent with expected utility behavior, then the same utility of wealth function can represent behavior with respect to all gambles. In this case, $U_i(x) = U_j(x)$ for all i, j and for all values of x, implying that $V_{i,j}(x) = 0$ for all x, and R_{AM} is thus 0, To show how this relates to our previous notion of marginal risk aversion, suppose gamble g and h have mean payout μ_i and variance σ_i^2, where $i = \{g, h\}$. Willingness to pay for a gamble is defined as

$$(5)\qquad E(U_i(x - WTP_i)) = \int_{-\infty}^{\infty} U_i(x - WTP_i)f_i(x)dx = U_i(0)$$

where current wealth is represented by 0, and $f_i(x)$ is the probability density of gamble i. Using a standard Taylor series approximation of the utility function evaluated around the mean of the gamble, we can rewrite equation (5) in the familiar form

$$(6)\qquad WTP_i \approx \mu_i - \tfrac{1}{2}R_A\sigma_i^2$$

where R_A is the standard coefficient of absolute risk aversion. If we instead consider moving from gamble g to gamble h and write equation (5) in terms of the delta-utility function, we obtain

$$(7)\qquad E(U_h(x - WTP_h)) = \int_{-\infty}^{\infty} [U_g(x - WTP_h) + V(x - WTP_h)]f_h(x)dx = U_g(0) + V(0).$$

Using a similar approximation, we obtain

$$(8)\qquad WTP_h + \Delta WTP \approx \mu_h + \Delta\mu - \tfrac{1}{2}(R_A^g + R_{AM})(\sigma_h^2 + \Delta\sigma^2)$$

or

$$\Delta WTP \approx \Delta\mu - \tfrac{1}{2}R_A^g \Delta\sigma^2 - \tfrac{1}{2}R_{AM}(\sigma_h^2 + \Delta\sigma^2) \quad (9)$$

where R_A^g is the coefficient of absolute risk aversion for the utility function U_g. Thus, our measure of R_{AM} relates very closely to measures of risk aversion in using standard expected utility theory. Increasing WTP for an increase in variance, holding mean constant, would result from a negative R_{AM}. This approximation suggests that an increase in the mean, holding variance constant, will increase WTP by a corresponding amount. This, of course, is only an approximation and will not hold in general. In any case, our generalized measure is closely related to the previous measure in equation (1), but it is unclear from this initial analysis how it relates to equation (2). Estimating the delta-utility of wealth function independently of the absolute risk aversion estimates should, in principle, allow us to identify marginal and average risk aversion independently, which we demonstrate using data from India and Morocco.

Data

This paper uses experimental data collected in India and Morocco. In both locations, we conducted risk experiments that offered farmers different gambles framed as different seed varieties. Although the experiments were not designed to be identical—the specific features of the gambles and the framing of the experiment differed—they both elicited open-ended WTP for the gambles offered. We exploit this similarity in our empirical analysis.

The Indian field experiment was conducted in 2003–2004 in Salem and Perambalur districts of Tamil Nadu, India, and involved 290 rural households. The experiment consisted of a series of hypothetical farming seasons. At the beginning of each season, farmers were offered a "seed" with a known rupee-payoff distribution. This distribution was explained simply and repeatedly and shown graphically in order to facilitate farmers' understanding of the payoff distribution implied by a given "seed." The distribution of a particular seed was represented by ten chips in a small black bag. There were three colors of chips, each representing a "harvest" payoff: blue (high), white (average), and red (low). The distribution was modified by changing the proportion of blue, white, and red chips in the bag. Farmers' valuation of the seed was elicited using an open-ended question and the well-known Becker–DeGroot–Marschak (BDM) mechanism. As shown in figure 1, the experiment involved five payoff distributions: a benchmark baseline gamble (*Base*); a high gamble with a higher mean payoff (*High*); a low gamble with a lower mean payoff (*Low*); a stabilized gamble with lower variance (*Stable*); and a truncated gamble with positive skewness (*Truncated*). Every farmer valued each of these payoff distributions several times, first during practice rounds, then in a final high stakes round. To control for learning and ordering effects, all farmers started and ended with the benchmark gamble B, and each farmer's valuation of B was computed as his average valuation of B over these two rounds. Between these two B rounds, gambles H, L, S, and T were randomly ordered (see Lybbert 2004 for details about the experiment).

We conducted the Moroccan experiment among 259 farmers in 2007 as part of a

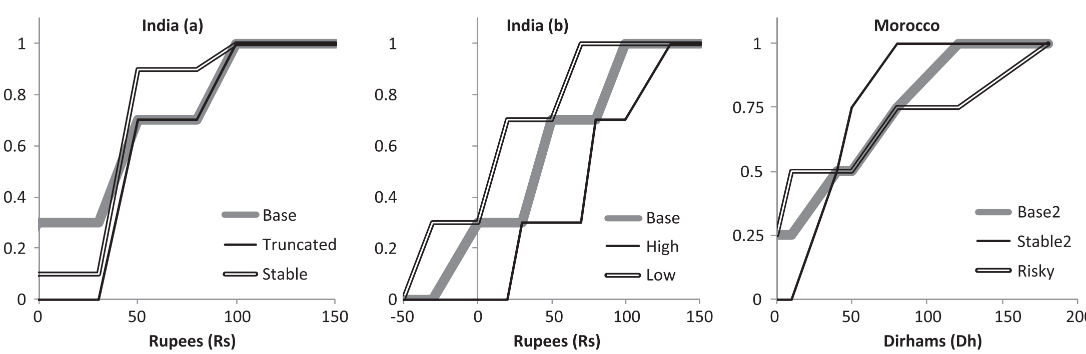

Figure 1. Cumulative distribution functions for gambles offered to subjects in Indian and Moroccan risk experiments

multiyear project aimed at characterizing drought risk and better understanding household drought coping strategies. This framed field experiment involved rainfed cereal farmers in the Meknes region. The goal of these experiments was to assess farmers' valuation of drought tolerance as a seed trait. In these experiments, farmers were offered three distinct payoff distributions—each representing a crop return distribution associated with a "seed." The payoff distributions presented payoffs as a function of "rainfall." A "rainfall" chip was drawn at the end of each round to determine the crop return for that round. As shown in figure 1, these distributions include a baseline gamble (*Base2*), a stabilized "drought tolerant" gamble (*Stable2*) that was less sensitive to low "rainfall" draws, and a risky, high return gamble (*Risky*) that was much more responsive to the "rainfall" draw. As with the Indian experiment, we are able to use these gambles in isolation to estimate absolute risk aversion or in comparison to estimate marginal risk aversion.

Estimation and Results

We estimate R_A and R_{AM} assuming a quadratic utility function. By independence of affine transformations, we can arbitrarily define the quadratic utility function as $U(x) = x - \gamma x^2$. For each decision, $E(U(x - WTP)) = U(0) = 0$, by the definition for WTP and the utility functional form we have assumed. For each individual gamble, we thus minimize $E(U(x - WTP))^2$ in order to estimate the utility function parameter values that rationalize that particular decision. The coefficient of absolute risk aversion, R_A, is thus given by $R_A = \gamma$. This method produces a single estimate for each gamble, for each participant. In the case of the baseline gamble, which was always offered first and last in the sequence of gambles offered to farmers, we use the average WTP for both times the gamble was offered to net out order effects. We used a similar technique to estimate marginal absolute risk aversion—namely, we find $V(x) = x - \delta x^2$ that minimizes $[E(V(x - WTP_x) - V(y - WTP_y))]^2$, where y represents the baseline gamble and x represents the alternative gamble. Then our measure of marginal absolute risk aversion is given by $R_{AM} = \gamma_g - \delta$. This yields one estimated coefficient for each participant and for each gamble paired with the baseline gamble. To net out order effects, we use the average WTP for the baseline gamble, which was played first and last in each session. Summary statistics for marginal and absolute risk aversion are found in table 1. In the case of two gambles, marginal risk aversion is significantly different from zero and thus could not be explained by standard expected utility alone. In all other cases, marginal risk aversion is relatively close to zero. This is not surprising given the relationships we found previously that suggested heterogeneous marginal risk aversion/loving behavior dependent upon the level of absolute risk aversion.

Next, we test the relationship between absolute risk aversion for the baseline gambles and marginal risk aversion based on the changes from the baseline to other gambles. We first test this relationship for each gamble change in

Table 1. Descriptive Statistics for Estimated Absolute and Marginal Risk Aversion

	INDIA			MOROCCO	
	Mean	Std. Error		Mean	Std. Error
Absolute risk aversion					
R_A (*Base*)	0.0030*	0.0004	R_A (*Base2*)	0.00114*	0.0004
R_A (*S*)	0.0130*	0.0008	R_A (*S2*)	−0.00096	0.0014
R_A (*T*)	0.0077*	0.0008	R_A (*Risky*)	0.00240*	0.0001
R_A (*H*)	0.0086*	0.0003			
R_A (*L*)	−0.0044*	0.0003			
Marginal risk aversion: From base (Base2) to new gamble…					
R_{AM} (*S*)	0.0183*	0.005	R_{AM} (*S2*)	0.00079	0.0014
R_{AM} (*T*)	−0.0005	0.004	R_{AM} (*Risky*)	0.00185	0.0015
R_{AM} (*H*)	−0.0103	0.010			
R_{AM} (*L*)	−0.0649*	0.019			

* denotes significantly different than zero at the 10% level.

Table 2. Results for Gamble-Specific Regressions with Baseline CARA as Regressor and Including Village Fixed Effects (not shown)

LHS Var: Marginal Risk Aversion	India			Morocco		
From baseline gamble to:	*Truncated*	*Stable1*	*High*	*Low*	*Stable2*	*Risky*
% change EV:	30%	0%	60%	−40%	−13%	13%
% change SD:	−41%	−42%	0%	0%	−63%	61%
CARA(baseline)	−0.806	0.727	−0.38	−5.417**	1.593***	1.427*
	(0.51)	(0.36)	(0.82)	(0.02)	(<0.001)	(0.11)
Wealth index	0.00446	0.00151	−0.00386	0.0191	0.00132	0.000587
	(0.65)	(0.82)	(0.83)	(0.48)	(0.47)	(0.70)
CARA(baseline)*Wealth	−2.36	0.45	3.021*	−2.87	0.19	0.52
	(0.19)	(0.62)	(0.13)	(0.41)	(0.67)	(0.32)
Constant	0.0186*	−0.0281	0.0179	0.0448	−0.00445	0.00129
	(0.14)	(0.24)	(0.53)	(0.21)	(0.23)	(0.66)
Observations	290	290	290	290	259	259
R-squared	0.046	0.036	0.024	0.022	0.27	0.14

Robust *p*-values in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.15$.
Notes: LHS = left-hand side; EV = expected value.

Table 3. Results for Gamble-Specific Regressions with CARA in the New Gamble as Regressor and Including Village Fixed Effects (not shown)

LHS Var: Marginal Risk Aversion	India			Morocco		
From baseline gamble to:	*Truncated*	*Stable1*	*High*	*Low*	*Stable2*	*Risky*
% change EV:	30%	0%	60%	−40%	−13%	13%
% change SD:	−41%	−42%	0%	0%	−63%	61%
CARA(new)	0.945	0.958**	−6.794***	−8.505***	0.0869	3.149***
	(0.24)	(0.04)	(0.01)	(0.00)	(0.16)	(0.01)
Wealth index	0.0142	−0.000757	0.000658	0.0202	0.00163	−0.00023
	(0.51)	(0.89)	(0.99)	(0.56)	(0.42)	(0.92)
CARA(new)*Wealth	−1.14	0.49	−0.27	2.27	−0.01	0.50
	(0.36)	(0.19)	(0.94)	(0.48)	(0.87)	(0.53)
Constant	0.0107	−0.0313	0.0775**	−0.0254	−0.00259	−0.00409
	(0.43)	(0.17)	(0.04)	(0.57)	(0.37)	(0.21)
Observations	290	290	290	290	259	259
R-squared	0.069	0.068	0.059	0.032	0.123	0.104

Robust *p*-values in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.15$.
Notes: LHS = left-hand side; EV = expected value.

the Indian and Moroccan experiments, respectively. We then test the relationship with data from both locations with a pooled specification. The separate specifications and results are shown in tables 2 and 3. Results from the pooled specifications are shown in table 4.

As shown in table 2, higher absolute baseline risk aversion is associated with higher marginal risk aversion for the gambles that become substantially more or less risky (with mean shifting less than 20%), though this relationship is significant for only the *Stable2* and *Risky* gambles conducted in Morocco. This is consistent with the relationship found by Just and Lybbert (2009). Absolute baseline risk aversion is associated with a decrease in marginal risk aversion when large (>20%) shifts in mean occur (*Truncated*, *High,* and *Low*), though this effect is significant in only the case of *Low* conducted in India. Household wealth does not appear to shape marginal risk aversion.

We also estimate the same specification with the constant absolute risk aversion (CARA) estimate from the new gamble, CARA(new), instead of that of the baseline gamble as a regressor. These results (table 3) differ in

Table 4. Results From Pooled Regression of Moroccan and Indian Experiments Including Village Fixed Effects (not shown)

	Baseline CARA on RHS			New CARA on RHS		
	(1)	(2)	(3)	(1)	(2)	(3)
CARA(baseline)	1.553**	1.668**	1.514*			
	(0.04)	(0.02)	(0.14)			
CARA(new)				0.05	0.0815*	0.07
				(0.40)	(0.12)	(0.88)
Change EV (%)		−0.0684***	−0.0708***		−0.0685***	−0.0793***
		(0.00)	(0.00)		(0.00)	(0.00)
Change SD (%)		0.0162*	0.0174		0.0149*	0.0164
		(0.09)	(0.17)		(0.13)	(0.21)
Change EV * CARA(base)			0.83			
			(0.71)			
Change SD * CARA(base)			−0.67			
			(0.77)			
Change EV * CARA(new)						2.759**
						(0.03)
Change SD * CARA(new)						−0.56
						(0.46)
Constant	0.0107**	0.0185***	0.0187***	0.0141***	0.0218***	0.0178**
	(0.04)	(0.01)	(0.01)	(0.00)	(0.00)	(0.03)
Observations	1720	1720	1720	1720	1720	1720
R-squared	0.003	0.018	0.018	0.0001	0.015	0.017

Robust *p*-values in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.15$.
Notes: LHS = left-hand side; EV = expected value.

magnitude and significance. We find significant negative coefficients on CARA(new) for two of the three gambles that involve a substantial mean shift (*High* and *Low*). Further, we find significant and positive coefficients on CARA(new) in two gambles with shifts in the riskiness of the gamble (*Stable1*, *Risky*). In each case other than *Truncated*, those gambles for which there was little significance before now display a high degree of significance and vice versa. We are in the process of refining our approach, but note that the differences between tables 2 and 3 may be due to anchoring on a reference gamble, as explored by Just and Lybbert (2009).

Tables 2 and 3 provide the percent change in expected value and standard deviation that creates the new gamble from the baseline gamble, but in order to explicitly test how these moment changes affect marginal risk aversion and its relationship with absolute risk aversion, we must pool data across gambles and locations while making adjustments for currency values (as is required in order to compare absolute risk aversion). The statistically strong positive relationship between marginal and absolute risk aversion is clear in the estimates in table 4. Larger percent increases in expected value are associated with lower levels of marginal risk aversion. The opposite is true of percent changes in variance, though this relationship is only marginally significant. In each case, CARA(baseline) is associated with a greater marginal risk aversion, while CARA(new) has almost no relationship to marginal risk aversion. Only the interaction term showing that larger changes in expected value lead to a more positive association between CARA(new) and marginal risk aversion is significant.

Overall, these pooled results suggest that marginal risk aversion may indeed change in systematic ways in response to specific types of changes in risk and may systematically relate to standard measures of risk aversion. Interestingly, we find evidence that absolute and marginal risk aversion are negatively related when the estimations use each gamble separately (paired with the baseline gamble) but positively related when all the gambles are pooled together. Thus cross-sectional relationships are very different from longitudinal relationships.

Conclusions

This article develops a new general measure of marginal risk aversion and confirms that it is closely (though often negatively) related to measures of absolute risk aversion. Thus we again confirm that individuals who are risk averse often desire to take on additional risk on the margin. Just and Lybbert (2009) argued that standard decision theories suggest that marginal risk aversion should be a relatively stable and robust measure, though empirically it did not appear to be so. The measure we have derived for this paper is somewhat more stable and robust for changes in standard deviation, though very sensitive to changes in expected value. Moreover, increases in expected value tend to make individuals much more tolerant of marginal risk. This appears to be contrary to the predictions of more static models of risky decisions with respect to a reference point, such as prospect theory, which predict risk-averse responses to gains. This work establishes the need to further derive measures of marginal risk aversion that are appropriate for all moment changes and to determine the predictable relationships between changes in risk and marginal risk behavior.

References

Binswanger, H. P. 1980. Attitudes Toward Risk: Experimental Measurement in Rural India. *American Journal of Agricultural Economics* 62:395–407.

Just, D. R., and T. Lybbert. 2009. Risk Averters that Love Risk? Marginal Risk Aversion in Comparison to a Reference Gamble. *American Journal of Agricultural Economics* 91:612.

Lybbert, T. J. 2004. Technology and Economic Development: Three Essays on Innovation, Pricing, and Technology Adoption. PhD dissertation, Cornell University.

Pennings, J. M. E., and P. Garcia. 2001. Measuring Producers' Risk Preferences: A Global Risk-Attitude Construct. *American Journal of Agricultural Economics* 83:993–1009.