ELICITATION OF RISK PREFERENCES FOR IRRIGATION FARMERS IN THE WINTERTON AREA: WEALTH RISK VERSUS ANNUAL INCOME RISK

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The purpose of this article is to measure the absolute risk aversion coefficients (RACs) of irrigation farmers in the Winterton area if annual income and wealth are at stake. Decision makers became more risk averse when wealth instead of annual income is at stake. RACs measured at low, medium and high annual income and wealth levels, showed no change when annual income or wealth levels increased. The majority of irrigation farmers have risk neutral annual income and wealth risk preferences.

Meting van die risiko-voorkeure van besproeiingsboere in die Wintertongebied: Inkomste- versus welvaartrisiko

Die doel van hierdie artikel is om besproeiingsboere se absolute risiko-vermydingskoëffisiënte (ARVK) te meet indien enersyds jaarlikse inkomste en andersyds welvaart op die spel is. Daar is gevind dat besluitnemers meer risiko-vermydend word indien welvaart in stede van jaarlikse inkomste op die spel is. ARVK wat by lae, gemiddelde en hoë jaarlikse inkomste- en welvaartsvlakke gemeet is, toon geen betekenisvolle verandering soos inkomste of welvaart toeneem nie. Die meerderheid besproeiingsboere in die Wintertongebied se risiko-voorkeure is as risiko-neutraal gemeet.

1. Introduction

Irrigation farmers in Western Natal are facing risky decisions, such as the use and/or implementation of more sophisticated irrigation scheduling strategies, the building of water storage facilities and investing in new irrigation equipment, which will significantly affect their prosperity. Analyses of such decisions must first account for the risk preference of the farmer or his willingness to assume risk. Second, analysis dealing with wealth risks such as irrigation investment, should examine the effects of uncertainty on the dispersion of wealth, rather than on annual income (McCarl and Musser, 1985). Stochastic dominance with respect to a function (SDWRF) has become a very popular method for the analysis of risky decisions, as it accounts for preferences by placing lower and upper bounds on the Arrow-Pratt absolute risk aversion function (King and Robison, 1981b). Appropriate Arrow-Pratt coefficients can either be generated or obtained from coefficients elicited in other studies.

The problem is that risk preference towards wealth risk (potential income generated by an investment over several years) has not yet been locally elicited. In addition, risk elicitation studies (e.g., Wilson and Eidman, 1983; Cochran, et al., 1985; Tauer, 1986; Lombard and Kassier, 1990; Meiring and Oosthuizen, 1993) have only elicited risk preferences on an annual income basis. As a result, there is little known about how risk attitudes change when wealth instead of annual income is at risk. There is also a lack of empirical evidence to guide the selection of risk intervals for eliciting risk preferences when long-term instead of annual income is at stake. This has led to uncertainty concerning the rescaling of secondary data elicited at annual farm income levels, and consequent ambiguity in classifying risk attitudes by risk aversion coefficients (Cochran and Raskin, 1987).

The main objective of this study was to determine whether attitudes toward wealth risk are significantly different from attitudes towards annual income risk. In relation to this objective the following null hypothesis was tested, Ho: $r(w) = cr(x)$, that attitudes towards wealth risk, $r(w)$, are not significantly different from risk attitudes towards annual income risk, $cr(x)$, where c is a rescaling factor that accounts for the differences in the wealth and income scales (Cochran and Raskin, 1987).

Other objectives are:

1) To obtain risk aversion coefficients (RACs) for use in farm level analyses concerning annual income and wealth risk.

2) To determine if decision makers will have decreasing absolute risk aversion as the level of annual income and wealth increases. In relation to this objective the following null hypothesis was tested: decision makers will have a constant absolute risk aversion function as the level of annual income/wealth increases.

3) To test if decision makers have consistent risk preferences as the annual income and wealth levels increase.

2. Conceptual model

The specification of a measurement scale is the first step to implement the interval approach. Special attention needs to be given to the definition of the preference interval and the scaling of the outcome variables.

A large number of different preference intervals (risk intervals) have been used (see Cochran, 1986) to represent risk preferences. Clearly the measurement scales used in the USA for the elicitation of attitudes toward annual income risk have improved in terms of the trade-offs between the probabilities of Type I and Type II errors (King and Robison, 1981a). The risk intervals used by Tauer (1986) can be further improved by including an extremely risk seeking interval, as done by Meiring and Oosthuizen (1993).

A measurement scale for the elicitation of SA farmers' attitudes toward annual income risk can be obtained by rescaling the measurement scales used in the USA. Raskin and Cochran (1986) described a procedure to approximate risk intervals, maintaining similar attitudes, when the outcome variable has changed. When the currency value associated with absolute risk aversion coefficient (RAC) is changed from dollar ($) to rand (R), the R/$ exchange rate can be used as a rescaling factor. Meiring and Oosthuizen (1993) used a R/$ exchange rate of R3-to-$1.

3. Material and methods

3.1 Irrigation farms in the Winterton area

A test of attitudes toward wealth versus attitudes toward annual income risk was carried out with 52 farmers in the Winterton area. Sources of risk as well as the way farmers adjust farming practices to account for variabilities, were obtained. In addition, socioeconomic information was obtained. This included information concerning the farmer's financial situation, biographical data, the type of farming arrangement, and information about the farming operation itself.

The age of the 52 respondents in the Winterton area varies between 24 and 71 years. The average farm size is 764 ha, of which 631 ha is owned by the farmer himself and 133 ha is leased. The number of hectares under irrigation varies between 10 ha and 320 ha. Farmers have a variety of crop and livestock enterprises. Land used for dry land crop production varies between 0 ha and 730 ha, while land used for grazing varies between 0 ha and 1500 ha. Irrigation is used on about 47 per cent of the cultivated land. This amounts to 16 per cent of the total farm size.

Forty-four percent of the irrigation farmers supplemented farm income with non-farm income. Gross annual income varied from R20 000 to R3 000 000. However, 78 per cent of the farmers received a gross annual income of less that R999 999, 55 per cent of which receive less than R500 000 annually. Thirty-one (60 per cent) of the 52 farmers had a total net worth of less that R999 999. However, there also were total net worth values in excess of R2 000 000.

3.2 Annual income measurement scale

The first step was to adjust the measurement scale used by Tauer (1986). The coefficients at the risk seeking end of the measurement scale were widened. The measurement scale was then rescaled to elicit annual income risk preferences for SA farmers. This was done by dividing the annual income (USA) measurement scale by the exchange rate. The exchange rate ratio used by Meiring and Oosthuizen, (1993) was kept unchanged. The annual income and wealth measurement scales, respectively, used to elicit risk preferences towards annual income and wealth risk, are presented in Table 1.

3.3 Annual income and wealth performance measures

To evaluate annual income versus wealth risk, it is important to define annual income and wealth for the decision makers correctly. The emphasis therefore was on selecting performance measures that were well defined and familiar to irrigation farmers in Winterton.

The performance measure selected for the elicitation of annual income risk preferences is before tax net farm income (BTNI). BTNI is calculated by subtracting from the total annual gross income all fixed and variable costs incurred over that year. In other words, the outcome values presented in the distributions were money available, over the next year for paying principal instalments on all loans (short-term, intermediate, and long-term loans), family living expenses, expansion of the farm, new machinery and income tax.

From the farmers' financial data and with the experience of a local chartered accountant low, medium and high BTNI levels of R0 (4500), R60 000 (9000) and R120 000 (18400) were identified for farmers in the area. The values in parentheses are the standard deviations (STDs) used in the INTID elicitation program that generates choice distributions (King and Robison, 1981b). The STDs were calculated as 15 per cent of the selected BTNI values because they were big enough to reflect some variations in BTNI levels experienced by irrigation farmers, while still close enough to the 10 per cent STD used by Tauer (1986). The standard deviation should not be too large, because the elicitation procedure assumes that absolute risk aversion remains constant over the range of outcomes reflected within a distribution that is compared to other distributions by the respondent (King and Robison, 1981b).

To facilitate the wealth risk elicitation, wealth is expressed as the returns received over 15 years from investing in irrigation equipment. In other words, the performance measure selected is the 15-year net present value (NPV) from making irrigation investment decisions. The NPV is calculated by discounting and summing the annual net returns generated over 15 years and expressing it in current rand terms. Put more simply, this is the total amount of money received over the next 15 years, after paying the costs associated with both production and the irrigation system. Production cost included fixed costs like depreciation and insurance on the irrigation system and machinery; as well as variable cost like seed, fertilizer, labour and fuel. Irrigation cost included electricity, water and repair costs. From this money, however, the following still had to be paid; existing loans on machinery and land, living expenses for the next 15 years and expansion of the farming operation.

The 15-year NPV calculated by Meiring and Oosthuizen (1991) for irrigation investment decisions was used as a benchmark for selecting realistic levels of return on irrigation investment decisions. Low, medium and high wealth levels of R250 000 (37500), R600 000 (90000) and R950 000 (142500) were selected. The STD in parentheses, were also calculated as 15 per cent of the 15-year NPV levels selected.

3.4 Wealth measurement scale

The annual income measurement scale could now be rescaled to a wealth-based measurement scale according to the theorems presented by Raskin and Cochran (1986:206).

Table 1: Annual income and wealth measurement scales used in the Winterton area to elicit risk preferences towards annual income and wealth risk, 1993

Risk group	Annual income scale			Wealth Scale		
	Reference level	Lower	Upper	Reference level	Lower	Upper
1	-0.00030	-∞	-0.00017	-0.00003	-∞	-0.000017
2	-0.00017	-0.00030	-0.00003	-0.000017	-0.000030	-0.000003
3	-0.00003	-0.00017	0.00000	-0.000003	-0.000017	0.000000
4	0.00000	-0.00003	0.00003	0.000000	-0.000003	0.000003
5	0.00003	0.00000	0.00010	0.000003	0.000000	0.000010
6	0.00010	0.00003	0.00030	0.000010	0.000003	0.000030
7	0.00030	0.00010	0.00170	0.000030	0.000010	0.000170
8	0.00170	0.00030	+∞	0.000170	0.000030	+∞

A rescaling factor of 10 was used for the rescaling, because the medium annual income and wealth levels differ by a factor of 10 (i.e., R60 000 BTNI versus R600 000 NPV). The absolute RACs for eliciting wealth risk preferences were obtained by dividing the annual income RACs by 10. This resulted, like in the case of the annual income measurement scale, in only one wealth measurement scale for all three outcome levels. The wealth measurement scale is also presented in Table 1.

3.5 Questionnaire

Twenty distributions with six values each, rounded off to the nearest R100 were generated for each of the selected income/wealth levels according to the specified measurement scales. Pairs of distributions were generated with the INTID program, with the specified standard deviation, to which someone with the specified RAC would be indifferent. By asking the decision makers to select from such pairs of distributions, it was possible to determine the upper and lower bounds of the decision maker's absolute risk aversion function. Risk preferences for each of the selected income levels were obtained by repeating this process.

The same procedure used by Meiring and Oosthuizen (1993) was used to test if decision makers were consistent in their choices. Annual income risk preferences around each of the three BTNI levels were elicited by constructing two separate questionnaires. The two questionnaires were then linked so that risk preferences around the low BTNI level could be elicited twice before going on to medium BTNI level. With the three levels of income, and the duplication at each level, the annual income elicitation questionnaire consisted of 42 questions of which decision makers answered only 18. The same procedure was followed in constructing a wealth elicitation questionnaire. Finally the income and wealth questionnaires were combined in one questionnaire. However, the annual income and wealth questionnaires were still separate units with their own introductions and practice example, as well as question numbers from 1 to 42.

The questionnaire consists of two main parts. Each part was preceded by an introduction. The introduction was developed to cover the main points of the Stanford/SRI assessment protocol (Morgan and Henrion, 1990) which was developed for elicitation of subjective probabilities, but which was also appropriate for risk elicitation. The decision makers were first informed about the purpose of the risk elicitation and how the results would be used. Care was taken not to give rise to any motivational bias by stressing that the study would be used for research purposes only and that there were no right or wrong answers. The structure of the questionnaire was then explained along with the uncertainties associated with the BTNI and NPV variables. This was done by defining the properties of the two outcome variables. The introduction was followed by a short exercise. Similarly, the wealth elicitation part of the questionnaire consisted of the introduction, a short practice and the elicitation section of the questionnaire.

3.6 Selection criteria

Different selection criteria were used to select the risk preferences used in the analyses. Only decision makers that were consistent in their risk preferences were included in the analyses. A decision maker was regarded as consistent if his second round elicitation was within two intervals, on either side, of his original choice at the different outcome levels. The two-interval-on-each-side decision rule was used because risk preferences can be separated by one complete risk interval and still be consistent (Tauer, 1986).

Only decision makers that were consistent on all three the annual income levels or on all three the wealth levels were included in the analyses to determine if RACs remain constant over increasing/decreasing levels of income/wealth. As a result, decision makers were dropped from the annual income elicitations if they failed one or more consistency tests in the annual income elicitations. However, the decision maker could still be included in the wealth elicitations if he was consistent in all three wealth risk elicitations. The probability of passing this decision criterion for all three the income or wealth levels by randomly selecting answers are only 0,15.

Thirty out of the 52 farmers (58 per cent) interviewed, were consistent on three annual income elicitations. Similarly, 33 farmers (63 per cent) were consistent on all three wealth elicitations. The number of consistent decision makers on both the annual income and wealth elicitation was in accord with results obtained by Tauer (1986) and Meiring and Oosthuizen (1993).

Where the differences between RACs elicited on an annual income basis are compared to RACs elicited on a wealth basis, only decision makers that were consistent

on all six the annual income and wealth levels were included. The probability of passing all 6 consistency tests by randomly selected answers is 0,02. Only 20 of the farmers (38 per cent) were consistent on all six annual income and wealth levels.

Risk preferences were first tested to determine if the obtained consistency results could not be the result of selecting the correct distributions randomly. The test statistic used, assumes normal approximation of the binomial distribution (Tauer, 1986). Values of 8,62 and 9,79 are calculated by using the annual income and wealth pass rates, respectively. A value of 17,62 is obtained when only the 20 consistent decision makers were used. All three the calculated values are highly significant when compared to critical z-values of -2,575 and 2,575 that were obtained from a two-tailed standard normal (z) distribution at a 99 per cent confidence level (α = 0,01). Risk preferences obtained in this study could therefore be used in further analyses because preferences were not obtained from randomly selected preference distributions.

3.8 Testing of the hypotheses

Risk preferences as elicited in the second elicitation (replication of the questionnaire) were taken as the best representation of the actual risk attitudes of farmers in the Winterton area. However, the Wilcoxon test statistics, using the first round risk elicitations, were also calculated and used as supportive statistics. Test statistics calculated for the first and second round elicitations identify the two outer perimeters of the interval over which RACs varied. As a result, if test statistics obtained from both the first and second round elicitation's results in the rejection of the hypothesis, all other RACs between the first and second round elicitations will result in the rejection of the hypotheses.

The Wilcoxon rank-sum test for two matched samples was used to test the null hypothesis, that attitudes towards wealth risk are not different from risk attitudes towards annual income. Tauer (1986) also used the Wilcoxon test because it uses the magnitudes of the differences as well as the sign in testing for equality between two populations (Hays and Winkler 1970; Zar, 1984).

The hypothesis that decision makers will have decreasing absolute risk aversion over increasing levels of income/-wealth was also tested by the Wilcoxon test. The problem with nonparametric tests is that it lacks the sensitivity of parametric tests, with the result that the null hypothesis is not rejected as often as it is in similar parametric tests (Triola, 1980). Because of the higher probability of a Type II error (i.e., to conclude that there is no difference between income and wealth risk attitudes when in fact there is) it was decided to test the null hypothesis at a 95 per cent (α = 0,05) confidence level. In other words, there would be sufficient ground for rejecting the null hypothesis if the probability for obtaining the z-value, calculated by the Wilcoxon test, is less than 0,05. If the probability (p) of obtaining the z-value is less that 0,002 there is a highly significant difference.

4. Results and discussion of the results

4.1 Annual income versus wealth risk preferences

The total number of consistent second round elicitations at each of the identified absolute risk aversion interval groups, for both the BTNI and NPV outcome variables is presented in Table 2. The frequency data presented in Table 2 were used to test if risk preferences towards wealth risk are significantly different from attitudes towards annual income.

The Wilcoxon test using the total number of consistent second round elicitations, produced a z-value of 3,96 (p = 0,00007). The test was repeated on the frequency distributions obtained from the first round elicitations. The first choice preferences produced a z-value of 4,70 (p = 0,00). In both cases a positive sign was obtained, indicating that RACs moved towards the positive (risk averse) end of the measurement scale.

The risk attitude of decision makers towards wealth risk differs significantly from their attitudes towards annual income. Given the fact that RACs were rescaled from the annual income measurement scale, decision makers became more risk averse if wealth instead of annual income is at stake. In their minds' wealth risk is much greater than and different from annual income risk. Wealth losses may take years to recoup whereas annual income losses may be recouped in the following years(s). In the decision maker's mind annual earnings are not perfectly positively correlated. In other words, they do not realise that a bad year could very well be followed by a good year.

A decision maker can be categorized in different income and wealth intervals, first, because of differences in his attitude towards annual income and wealth risk, and second because of changes in the measurement scale (rescaling factor), and finally, because of an incorrect interpretation of wealth.

4.2 Absolute risk aversion as income/wealth increases

The nature of risk preferences towards annual income and wealth risk for irrigation farmers in the Winterton area is presented in Table 3. Table 3 is a frequency table with the number of decision makers categorized, according to their second round choices, in each of the risk aversion intervals for the three selected annual income and wealth levels. For example, 17 decision makers were categorized in risk group 3 (RACs between - 0.00017 and 0.0) around the BTNI level 1.

The highest frequency (40 per cent) of decision makers has RACs between -0.0017 and 0.0 (risk group 3). Risk groups 4 and 5 were also well represented with respectively 19 per cent and 13 per cent of the preferences. In total there was only one preference that could not be bounded by the most risk averse interval (0.003 to $+\infty$) used. At the other end of the scale there were 5 preferences in total that could not be bounded by the most risk seeking interval ($-\infty$ to -0.00017) used.

The frequency distribution of risk preferences towards wealth risk is also presented in Table 3. The largest number of decision makers was categorized in the middle section of the risk aversion scale (risk groups 3, 4, 5 and 6). In total, only 3 wealth risk preferences could not be bounded by the most risk seeking interval used, and 4 preferences by the most risk averse interval used.

It is apparent that both the annual income and wealth risk preferences were concentrated in risk groups 3, 4 and 5 where 72 per cent of the annual income preferences and 69 per cent of the wealth risk preferences were located.

Table 2: Total number of consistent second round elicitations (n=60) at each of the identified risk groups for both the BTNI and NPV performance measures, 1993

Performance Measures	Absolute risk aversion interval groups							
	1	2	3	4	5	6	7	8
BTNI	0	3	23	13	11	5	5	0
NPV	1	3	12	15	16	6	4	3

Table 3: Number of irrigation farmers in the Winterton area categorized according to their RACs elicited in the second round at the three selected annual income and wealth levels, 1993

Performance Measure	Absolute risk aversion interval groups							
	1	2	3	4	5	6	7	8
Annual income (R)								
0	2	1	17	4	2	4	0	0
60 000	2	2	11	4	4	2	5	0
120 000	1	2	8	9	6	1	2	1
Total	5	5	36	17	12	7	7	1
%	5,5	5,5	40	19	13	8	8	1
Wealth (R)								
250 000	2	3	3	7	9	5	2	2
600 000	1	2	7	2	15	5	1	0
950 000	0	5	9	12	5	4	1	2
Total	3	5	19	21	29	14	4	4
%	3	5	19	21	29	14	4	4

The income and wealth risk preferences were tested in pairs to determine if RACs remain constant over increasing/decreasing levels of income and wealth. Income/-wealth level 1 versus 2 were first compared, followed by income/wealth levels 1 versus 3 and 2 versus 3. The results from these tests are presented in Table 4.

It is clear from the positive signs that decision makers became more risk averse as the BTNI level increased. This increase in risk aversion is highly significant when comparing risk preferences elicited around BTNI levels 1 (R0) and 2 (R60 000), as well as between BTNI levels 1 and 3 (R120 000). However, risk attitudes remained fairly unchanged when BTNI increased from R60 000 to R120 000, producing an insignificant z-value ($p = 0,81$). Similar results were obtained from testing risk attitudes obtained in the first round elicitations. First round elicitations, between the three BTNI levels, produced z-values at significant levels of respectively 0,00009, 0,00006 and 0,53. Because there was no significant change in RACs between all three BTNI levels, the null hypothesis that decision makers will have constant RACs over increasing levels of annual income, was accepted.

Decision makers were inclined to place more emphasis on positive (higher) ends of the distributions when BTNI values were very low (BTNI level 1), compared to BTNI distributions at higher BTNI levels. This resulted in the relatively strong risk seeking behaviour expressed around BTNI level 1, compared to the BTNI levels 2 and 3. Decision makers were thus inclined, at such a low BTNI level, to take more risk than they normally would at higher monetary outcomes. There were, for example, 18 risk seeking decision makers (risk groups 1 and 2) around BTNI level 1. The number of risk seeking decision makers declined to respectively 4 and 3 at BTNI levels 2 and 3.

With respect to changes in risk aversion with wealth, the Wilcoxon test produced very small z-values that were all statistically insignificant at 95 per cent significance level, except for risk attitudes elicited in the first round elicitation between NPV levels 1 and 3 where a significant z-value of 2,13 ($p = 0,03$) was obtained. Little evidence was found that decision makers displayed decreasing absolute risk aversion as the level of wealth increased. Because only one of the test results was statistically significant, the null hypothesis that decision makers will have constant RACs over increasing levels of wealth, was accepted.

This study supplied very little additional support for Arrow's (1971) hypothesis that decision makers will have decreasing absolute risk aversion over an increasing level of wealth. Both the studies of Tauer (1986) and Wilson and Eidman (1983) came to similar conclusions, although their tests were only a "rough" approximation because they used income instead of wealth as the argument in the utility function.

Table 4: Determination of increasing, constant or decreasing absolute risk aversion, using second round elicitation as annual income/wealth increase, 1993

Performance measures	Income/Wealth levels					
	Income 1 : Wealth 2		Income 1 : Wealth 3		Income 2 : Wealth 3	
	Z	P	Z	P	Z	P
BTNI (Second)	+3,15	(0,002)	+3,62	(0,0003)	+0,24	(0,81)
NPV (Second)	-0,66	(0,51)	-0,57	(0,57)	-0,003	(1)

4.3 Consistency of annual income and wealth risk preferences

The number of decision makers that passed the consistency test on each of the BTNI levels increased from about 77 per cent at the first income level to 81 per cent and 90 per cent at income levels around R60 000 and R120 000. The same pattern was observed at the wealth risk elicitations where 71 per cent of the decision makers were consistent on the first wealth level. The passing rate increased to 85 per cent and 98 per cent at wealth levels of R600 000 and R950 000.

The consistency levels obtained in the elicitation of both annual income and wealth were acceptable. In both annual income and wealth elicitations consistency increased as the level of BTNI or NPV increased. The increase in consistency as the level of annual income increased was also observed by Wilson and Eidman (1983), Tauer (1986) and Meiring and Oosthuizen (1993). The reason for the increase in consistency at higher level of income can be contributed to clearer (bigger) differences among the distributions at higher outcome levels (Meiring and Oosthuizen, 1993).

Possible reasons why the increasing trend in consistency observed on a wealth basis begin at a lower level than the consistency level obtained at the highest BTNI level, may be the result of rescaling annual income RACs to wealth RACs, or the differences in attitudes towards annual income and wealth risk.

5. Conclusions

It was determined that decision makers' risk attitudes towards wealth risk are significantly different from their attitudes towards annual income risk. The differences in attitudes between income and wealth and the drop in consistency between BTNI level 3 and NPV level 1 should be further investigated by determining the role scale adjustments played in attaining these results.

No evidence could be found that the RACs continually changed as the level of income/wealth changed from the low to the high levels. The magnitude and direction of change in the RACs depended on the outcome variable used (income or wealth) and the outcome levels selected.

Risk preferences of most irrigation farmers in the Winterton area were located around risk neutrality. However, there were some decision makers with strong risk seeking and risk averse preferences, especially among the decision makers that were not consistent. It is, therefore, important to obtain credible risk seeking and risk averse RACs for use in risk analyses.

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