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Abstract

Analysis of a survey of Scottish farmers (162) confirmed that they do not perceive all types of risk to be equal. Choices with potential negative ethical or health & safety consequences were perceived to be riskier than those that might have negative financial and social outcomes. A negative relationship was found between perceived riskiness and stated likelihood of taking a risky course of action with one exception - where a health & safety harm might arise. The findings could assist the development of behavioural models with greater predictive powers. In addition, the study suggests that risk awareness is not the most limiting factor for improving health & safety in the Scottish farming industry.

Key words: decision, choice, risk preferences, risk perceptions, ordinal mixed-effects model.

1. Introduction

Risk and uncertainty are well known and widely researched characteristics of agricultural activity that are fundamental to the choice made in many farm management decisions. Despite the considerable wealth of literature much is still to be learnt and there remain calls for researchers to undertake more studies to gain a better understanding of the decisions made by farmers (OECD, 2009; Ohlmer et al., 1998; Webster, 2003). The development of better farm level decision support and dedicated risk management tools are among the leading study areas. However, these commonly promote a risk management process that considers each risk independently such as described by Theuvsen (2013), or focus on a single

objective function such as a socially desirable outcome, farm output or farm profit maximisation (for examples see Paulson et al. (2016), Arribas et al. (2017), Jones et al. (2017), Mosnier et al. (2017) and Liu et al. (2017). Thus they do not address the common situations where farm management decisions must balance competing sets of, or multiple, risks. An alternative approach has been the study of farmer behaviour and their previous decision choices to identify factors associated with particular actions see for example Mase et al. (2017) and Hamilton-Webb et al. (2017). Such studies however largely overlook the available alternatives at the decision point and therefore also miss the influence of preferences for options with different risk profiles and expected values. (The term 'risk' is used here to encompass all situations where there is potential for negative consequences.) Cases where farmers must rely largely on their own judgement and subjective assessment of the risks are currently poorly understood and rarely studied (Hardaker and Lien, 2010). Yet there is a long standing recognition that risk perceptions have important impacts on the choices people make and their likely response to policy interventions (Slovic, 1987; Tversky and Kahneman, 1974). As noted 30 years ago by Slovic (1987) there is a need to understand how people think about and respond to risk or 'well intended policies may be ineffective'. The purpose of this study is to investigate the knowledge gap that exists about the subjective risk preferences of farmers. The aim is to provide some new insights that can contribute to the development of better predictive models of farmer decision choices and thereby enable better policy design. The two main objectives are to determine the relative preferences of farmers to different types of risk and to investigate the relationship between the perceived riskiness of an action and the likelihood that they would engage in the action i.e. take the risk.

The study follows a novel approach in the context of farm management and builds on the approaches of Weber et al. (2002) and Blais and Weber (2006) by exploring the risk perceptions of and likelihood of risk taking by Scottish farmers. The statistical methodology used differs from previous studies in that the Likert scale response data is treated as ordinal rather than numeric, thus importantly for the statistical analysis it assumes a flexible distance between scale points (Agresti, 2002; Allen and Seaman, 2007). It involved the development, administration and analysis of data from a survey of Scottish farmers, though the method could be used with other groups and the findings provide insights that are not bounded by geographic region.

2. Study methods

The study consisted of primary data collection using a paper questionnaire from a sample of farmers followed by the development of statistical models to determine whether or not farmers differentiated between different types (or 'domains') of risk; their relative order; and any associations with potential explanatory variables.

Domains of risk and risky choices

Many different domains of risk have been identified as affecting agricultural production and farm households. Among these are the five defined by Weber et al.'s (2002) in their study of the general population: financial; health & safety; ethical; recreational; and social. In the business context there are also 'production' risks to be considered and for this study this gave a total of six risk domains to be explored (see Table 1). The study of farmer risk preferences Hansson and Lagerkvist (2012) also builds on the work of Weber et al. (2002) explores four risk domains (financial, production, environmental and social), thus this study considers a wider range of the risk types known to affect agricultural activity. For each risk domain an extensive set of risky choices that farmers could encounter were identified then refined by testing their relevance to a wide range of farming situations and likely level of choice farmers were likely have. Thus for examples decisions about actions required by law even if risky were excluded from the study. The final 69 risky choices are given in Appendix 1. As some have the potential for multiple negative consequences they could be allocated to more than one risk domain and arguably have not been allocated to the correct risk domain. Completely avoiding misallocation of questions to domains is difficult, given the nature of decision making by humans (Weber et al., 2002). Mis-allocation of questions to domains is likely to reduce the strength of separation between domains, and therefore to reduce the statistical power to detect differences between domains (and so will reduce power to confirm the existence of distinct domains). It is therefore reasonable to assume that any significant differences between domains that are detected by the analysis are likely to be genuine.

Table 1: Risk domains and examples of risky choices.

Domain	Number of risky choice questions	Examples of risky choice questions
Financial	18	Borrowing a large sum of money to invest in an existing enterprise. Buying land to increase scale if it was available. Selecting to receive subsidy payments in Euros.
Production	12	Not adjusting crop protection plans in response to weather conditions. Changing your production method significantly.
Health & safety	11	Undertaking potentially dangerous farm activities without someone knowing where you are. Entering a pen with a bull or recently calved cow without a stick or taking other protective measures.
Ethical	12	Knowingly undertake an action that could damage a valuable/protected habitat. Not always notify households neighbouring your fields when you are going to spray crops.
Recreational	4	Pilot your own small plane, if you could. Try out bungee jumping at least once.
Social	12	Disagree with your family peers about how the farm is run. Lend a friend/neighbour valuable equipment.

The two questions posed to study participants with respect to these risky choices were:

- How risky do you consider the following, given your current situation and assuming they are possible?
- How likely are you to do any of the following, assuming they are possible?

Question one directly investigates respondent's subjective perceptions of the risk and the second their behaviour given the risk, both give an indication of attitudes to each risk. The strength of a respondent's view is captured using rating (Likert) scales, five point scales were used in this study: 1=not at all risky to 5 = very risky and 1=very unlikely to 5=very likely respectively. In this study we therefore ask respondents directly about their perceptions of risk whereas the questions posed by Hansson & Lagerkvist (2012) are directed to the importance of an action that might reduce or increase the level of risk.

Questionnaire design and survey administration

The questionnaire was developed in three sections: The first section asked about the respondents background, including factors relevant to risk preferences (Burton, 2006;

104 Edwards-Jones, 2006; Rehman et al., 2008; The Royal Society, 1992; Wilson, 2011; Wilson et
105 al., 2013). These included farm type; farm size; land tenure; age; education; income
106 dependency on the farm business; capital security of the farm business and attitudes to the
107 importance of farming to societal goals such as environmental care and food security. The
108 second and third sections respectively posed the two questions about perceived risk and
109 likelihood of engaging in a risky action. Questions in these sections were separately
110 randomised and the risk domains were not explicitly referred to at any point in the
111 questionnaire, which was piloted with three farmers prior to final release.

112 *Data collection*

113 A convenience sampling method was selected due to the size of the questionnaire and
114 sensitivity of some of the questions. Trusted brokers from SAC Consultancy (16 regional
115 offices) distributed questionnaire according to the following framework: any farmer who
116 they direct contact with during the following 2-3 weeks should be invited to participate in
117 the study – no farm or farmer attributes should be used in the recruitment process. All
118 questionnaires were in paper format and completed anonymously.

119 *Model development*

120 The statistical methodology used in this paper is closely related to Weber et al. (2002) and
121 Blais and Weber (2006), but differs in one crucial respect: we treat the two risk related
122 response variables (five-point Likert scale) as ordinal categorical data, rather than as
123 continuous data. This is an important difference, because it means that in this paper we
124 make no assumption that the gaps between points on the Likert scale are equal. The scores
125 allocated to categories of the Likert scale provide a ranking but the values themselves (1, 2,
126 3, 4 and 5) are labels rather than measured values and so are essentially arbitrary, as there is
127 no reason to believe that the gaps between consecutive scores will necessarily be equal on
128 an absolute scale. The treatment of the response variables as ordinal, rather than numeric,
129 therefore improves the defensibility of the methodological approach.
130 To establish whether or not farmers differentiated between different risk domains with
131 respect to both their risk perceptions and likelihood of engaging in a risky choice an ordinal
132 mixed-effects model was developed. This model also provided estimated values on the
133 relative perceived riskiness of each domain and how likely respondents were to engage in
134 those activities. Finally the model was developed further to test for associations with

contextual factors (farm or farmer background characteristics). All statistical models were implemented by using the lcmm function in the R 'ordinal' package, which fits mixed-effects models with one or more random effects for ordinal data. The test of the overall domain effect and other explanatory variables were carried out by the likelihood ratio test, and paired Wald tests were then use to further test for differences between specific pairs of domains.

To make interpretation of the result from the models easier a data transformation was applied prior to analysis. This involved reversing the direction of the five-point Likert scale relating to the likelihood that respondents would take a risky choice, thus a score of 1 equated to 'very likely' and a score of 5 represented 'very unlikely' and represent the likelihood of respondents not taking a risky choice. Thus the signs of the coefficients (see below) from the models would be aligned. (During the piloting phase of the survey it was established that the scale direction used in the analysis was difficult for respondents and therefore inappropriate.)

Ordinal mixed-effects models were estimated, with unstructured thresholds, using the clmm function in the Ordinal package for R (Christensen, 2015). This type of model is an extension of linear models, such as ANOVA (Agresti, 2002; McCullagh, 1980; Tutz and Hennevogl, 1996) and it has two key characteristics:

1) Response variables are treated as being an ordinal, rather than a numeric, variable. This is done by assuming that the values of the ordinal variable *y* represent intervals on a latent continuous variable *z* (which can be thought of as representing the underlying variable that the Likert scale is trying to quantify), and assuming that this latent variable *z* - rather than the observed score *y* - that is related to the explanatory variable. The values of *y* can be computed deterministically from the values of *z* through the equation

$$y = I(z<\alpha_2) + 2\, I(\alpha_2 < z<\alpha_3) + 3\, I(\alpha_3 < z<\alpha_4) + 4\, I(\alpha_4 < z<\alpha_5) + 5\, I(z>\alpha_5)\ , \quad (1)$$

where $I(x)$ is the indicator function (so that $I(x) = 1$ if x is true, and $I(x) = 0$ otherwise). The unknown cut-points α_2, α_3, α_4 and α_5 are estimated as part of the model fitting algorithm.

2) Random effects as well as explanatory variables (or "fixed effects") are included in the model to capture unexplained sources of variation within the model, including that which could arise from a lack of variable independence.

Thus the final form of the model was

$$Z_{ij} = \beta_{D(i)} + U_i + V_j + W_{jD(i)} + \varepsilon_{ij}, \quad (2)$$

where z_{ij} denotes the response to question *i* by farmer *j* and $\beta_{D(i)}$ denotes the domain effect (fixed-effect) associated with question *i*. Three random effects are included here to deal with the multilevel structure in the design of this study. 1) U_i is the question-specific random effect; 2) V_j is the farmer-specific random effect; 3) $W_{jD(i)}$ is the random effect capturing the interaction between domain and farmer. Finally, ε_{ij} is the unexplained random error associated with question *i* and farmer *j*. All these three random effects and the random error are assumed to be normally distributed with a mean of zero and an unknown variance (estimated from the data as part of the model fitting).

To confirm whether farmers do (or do not) differentiate between the risk domains the model was run twice, first for 'risk perception' and second for 'the likelihood of not taking a risky choice'. A likelihood ratio test, using a single *p*-value (Equation 2) then determines whether the model that allows for differences between risk domains is better supported by the data than the simpler 'base' model which does not (and hence assumes all risk domains are equivalent). If a statistically significant association is found, it is then meaningful to further test for differences (paired Wald test) between pairs of risk domains and establish their relative ordering. This is achieved by comparing the $\beta_{D(i)}$ coefficients of a 'base' and a 'comparator', testing whether $\beta_{comparator} - \beta_{base}$ is significantly different from zero, and, if so, the magnitude and sign of this difference. A positive coefficient indicates that scores for the comparator group are higher than those for the base group; a negative value indicates that scores for the comparator group are lower than those for the base group.

Contextual factors such as age, education, farm size as well as general attitudes may provide some explanation of either risk perception or the likelihood of not taking risks. To test for any associations the model was developed by replacing the domain variable by each of the contextual factors in sequence and including domain as a random effect. The model was run for associations with both risk perception and the likelihood of not taking a risk. As respondents' opinions about the importance of agriculture to societal goals were ordinal in nature (on a 5-point Likert scale: score 1-not at all important to score 5-very important) it would be possible to treat these contextual factors as either continuous or categorical. Both were tested and models which treat them as continuous were found to have a better empirical goodness of fit - as determined by the Akaike Information Criterion (AIC; (Akaike,

198 1973)) and the Bayesian Information Criterion (BIC; (Schwarz, 1978)) – and we therefore
199 treated these variables as continuous within all analyses.
200 The coefficients (estimated mean score difference) generated by these models are
201 interpreted in the same way as other regression analysis: a positive coefficient indicates a
202 positive relationship between the two variables and a negative coefficient indicates that as
203 one increases the other decreases.

204 **3. Results**

205 A total of 162 completed questionnaires were returned from across Scotland of which three
206 were excluded from the analysis due to large amounts of missing data.

207 ***Descriptive statistics***
208 The respondents (159), while not a statistically representative sample of Scottish farms,
209 encompassed a wide range of situations as shown from the descriptive summary below.

210 • Farm type: Upland livestock (36%) farms were the commonest type and hill farms the
211 least common (11%). Dairy, lowground livestock and predominantly arable farms
212 each represented approximately 15% of the sample.

213 • Farm size: the majority (62%) of farms had 81-120 hectares, 4% (6 farms) were less
214 than 40ha, and 12% had 41-80ha.

215 • Land tenure: almost half (47%) of participants owned all the land they farmed, about
216 one quarter (25%) owned 50 -100% of the land, 11% of them owned 1-50% and 17%
217 seasonally rented or were tenants on all the land farmed.

218 • Age: 72% of participants were over 40 (52% aged between 41-60 and 20% were over
219 61). Six respondents (4%) were under the age of 25 and the remaining 24% were
220 aged 25-40.

221 • Qualifications: Overall just over half (51%) of the total sample had post-school
222 qualifications in agricultural related subject. 40% had either school or college (e.g.)
223 qualifications, 12% had gained a university undergraduate qualification, and a further
224 7% had a post-graduate award.

- Income dependency on the farm business: around half (51%) of respondents were entirely dependent on the farm business for family income. Most of the remainder (43%) were partly dependent, and nine (6%) of respondents did not draw any income from the farm business.

- Capital security of the farm business: 30% of respondents were in a very secure capital position (they held savings in the bank or equivalent) and a similar proportion were in a secure capital position (little/no savings but has no long term borrowings). One quarter had a small amount of long term borrowed capital and about 13% had a large amount of long term borrowed capital (i.e. were capitally insecure).

- The importance of farming to societal goals: over 80% of the study sample felt that farming had an 'important' or 'very important' role to play with respect to all the societal goals investigated bar one. For this, 'Providing the public with space for recreation', only 23% of respondents felt it was important.

Model results

Confirmation of presence of domains

Likelihood ratio tests comparing a model that allows for differences between risk domains against one that does not confirmed that study participants did not perceive all domains of risks as equal ($p<0.01$) (perceived riskiness) and their likelihood of not engaging in risky activities varied with domain ($p < 0.01$).

Relative ordering of domains

Following this confirmation pairwise comparisons of risk domains tests are appropriate and the results are shown in Table 2. For ease of interpretation the estimates of the mean score differences are sorted in ascending order by their perceived riskiness within each domain. Significant differences between a number of the domains are found. Specifically, ethical risks were perceived to be a significantly greater risk than production-related risks (coef 1.51, and p-value < 0.01), financial risks (coef = 2.08, and p-value < 0.01) and social risks (coef = 2.18, and p-value < 0.01). Health & safety risks were similarly perceived to be a greater risk than production risks (1.56, and p-value = 0.01), financial (coef = 2.14, and p-value < 0.01) and social risks (coef = 2.24, and p-value < 0.01).

Overall, the perceived 'riskiness' of actions with potential negative ethical, health & safety, and recreational consequences were similar, as coefficients estimated by the model are small and non-significant (see table 2 the final three rows). Similarly, the perceived 'riskiness' of the production, financial and social domains are on a par. Thus the model indicates that perceptions of the risk domains form two clusters.

With regards to the stated likelihood of not following a risky course of action, the model found differences between domains broadly similar to those for perceived riskiness (above). Respondents indicated that they were significantly more likely to avoid ethical risks than those associated with financial (coef = 2.68, and p-value < 0.01), social risks (coef = 1.86, and p-value < 0.01), or production (coef = 1.94, and p-value < 0.01). The stated likelihood of not taking a risky choice for decisions within the ethical and recreational domains were similar, with only a small and non-significant estimate for the differences between these domains (0.25, and p-value > 0.05). One interesting result is that respondents indicated that they were significantly more likely to avoid ethical risks than to avoid those associated with health and safety (coef = 1.42, and p-value = 0.01), even though the perceived levels of risk for these two domains were very similar. The results from Table 2 are illustrated in Figure 1.

Table 2: Risk domain coefficients (estimated mean scores difference) and standard errors

Base domain	Comparator domain	Perceived risk Coefficient (SE)	Stated likelihood of not taking a risky choice. Coefficient (SE)
Financial	Social	-0.10 (0.51)	0.81 (0.50)
	Production	0.57 (0.51)	0.74 (0.50)
	Recreation	**1.71*** (0.74)	**2.42*** (0.73)
	Ethical	**2.08**** (0.51)	**2.68**** (0.50)
	Health & Safety	**2.14**** (0.52)	**1.25*** (0.51)
Social	Production	0.67 (0.55)	-0.07 (0.55)
	Recreation	**1.81*** (0.77)	**1.61*** (0.76)
	Ethical	**2.18**** (0.55)	**1.86**** (0.55)
	Health & Safety	**2.24**** (0.56)	0.44 (0.56)
Production	Recreation	1.14 (0.77)	**1.69*** (0.76)
	Ethical	**1.51**** (0.55)	**1.94**** (0.55)
	Health & Safety	**1.56**** (0.56)	0.51 (0.56)
Recreation	Ethical	0.37 (0.77)	0.25 (0.76)
	Health & Safety	0.43 (0.78)	-1.17 (0.77)
Health & Safety	Ethical	-0.06 (0.56)	**1.42*** (0.56)

* Significant at 0.05; **significant at 0.01 level.

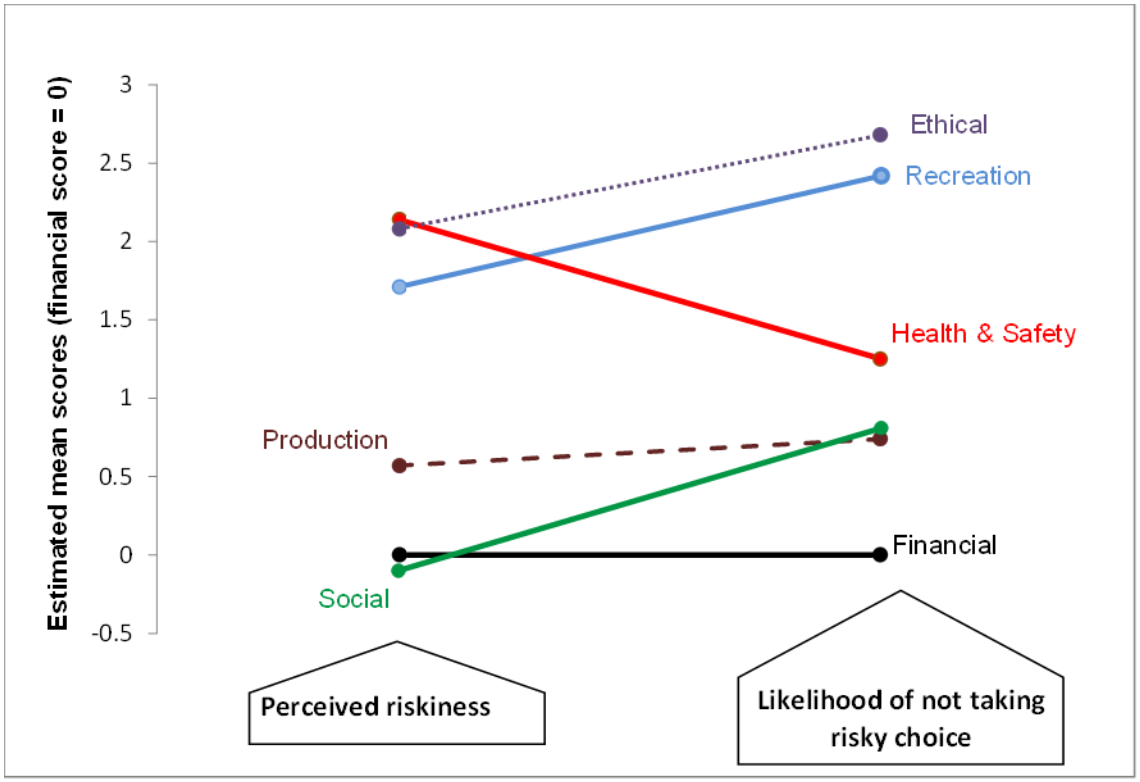
To investigate potential relationships between risk perceptions and the likelihood of not taking a risky choice the model estimates can be compared graphically. The Financial domain was selected as the reference domain for this comparison, which can be seen in figure 1. On the x axis are the two response variable – perceived riskiness and likelihood of not taking a risky choice. The y axis represents the estimated mean score coefficients for each domain as given in Table 2 (first five rows). The positive slopes indicate domains where risk aversion is relatively high, and negative slopes indicate domains where risk aversion is relatively low. (As separate models were constructed for risk perception and risk not taking, the significance of the slopes of the lines shown in Figure 1 have not been formally tested, so these results should be interpreted cautiously.) As can be seen from the drawn relationships the highest levels of risk aversion are for the social, recreational and ethical domains, and the lowest levels of risk aversion are for the health and safety domain. The level of risk aversion appears to be substantially lower for health and safety than for any other domain, suggesting three difference types of domain are present:

1) domains with low risk perception and a low likelihood of risk avoidance (production, social, financial)

2) domains with high risk perception and a high likelihood of risk avoidance (ethical, recreational)

3) domains with high risk perception but a low likelihood of risk avoidance (health & safety).

Figure 1: Model estimated mean scores by domains relative to the financial domain (as given in the first five rows of Table 2).



Contextual effects

Although none of the farm and farmer context variables were found to have a significant relationship with risk perceptions two farmer related variables (age and agriculture-related education) were found to have an association with the likelihood of not taking a risk choice (see Table 3). On further examination (see Table 4) respondents over 40 years of age were found to be significantly less likely to take risks than those in younger age categories (p-values < 0.05) and respondents with agriculturally related qualifications were more willing to take a risky choice than respondents with other educational backgrounds (coef = 0.55 and p-value = 0.01).

303 **Table 3:** Categorical farm-related variables significance using likelihood ratio tests.

Variable	Number of categories	Risk perception (p-value)	Stated likelihood of not taking a risky choice (p-value)
Farm business related factors			
Farm type	5	0.08	0.35
Farm size	4	0.26	0.48
Proportion of farmed land owned	4	0.89	0.35
Income dependency on farm business	3	0.81	0.76
Capital security of farm business	4	0.18	0.15
Farm household related factors			
Age	4	0.13	**0.01****
Education level	4	0.52	0.58
Agriculture-related education	2	0.07	**0.01****

* Significant at 0.05; **significant at 0.01 level.

304

305 **Table 4:** Details of significant farm household relationships.

	Stated likelihood of not taking a risky choice		
	Base group	**Comparator group**	**Coefficient (SE)**
Age group	<25	26 to 40	0.36 (0.43)
		41 to 60	**0.82*** (0.42)
		61 over	**1.10*** (0.44)
	26-40	41 to 60	**0.46*** (0.19)
		61 over	**0.73**** (0.24)
	41-60	61 over	0.27 (0.21)
Qualification in agriculture related subjects	Yes	No	**0.55**** (0.19)

* Significant at 0.05; **at 0.01 significant level.

306

307 A significant positive relationship was found between risk perceptions and the importance of
308 farming to all six societal goals (Table 5). In addition, for three of the societal goals a positive
309 relationship was found with the stated likelihood of not taking risky choices. Thus the more
310 important respondents felt farming was to the achievement of societal goals the higher their
311 perceived riskiness scores and lower their stated likelihood of taking risky choices.

312 **Table 5:** Effect on opinions about the role of farming

How important is farming to: (1= not at all important; 5= very important)	Risk perception	Stated likelihood of not taking a risky choice
	Coef. (SE)	Coef. (SE)
Looking after the environment	**0.47**** (0.09)	**0.42**** (0.09)
Keeping a rural community alive	**0.26**** (0.08)	**0.26**** (0.08)
Maintaining the local landscape	**0.51**** (0.09)	**0.47**** (0.10)
Food security	**0.30**** (0.10)	0.10 (0.11)
Maintaining the land for future generations	**0.26*** (0.11)	0.08 (0.11)
Providing the public with space for recreation	**0.14*** (0.07)	0.09 (0.07)

* Significant at 0.05; **at 0.01 significant level.

313

314 **4. Discussion and conclusions**

315 This study confirms what is a commonly accepted but largely disregarded assumption in
316 models of farmer decision choice - that not all risks are equal. While a larger and stratified
317 sample would provide greater confidence that the results of the statistical analyses are
318 robust, particularly the relative ordering, the background information on respondents
319 indicates that they are not an atypical sample. The strength of difference between the
320 domains may be greater than that detected here, since the effect may have been reduced as
321 a consequence of the inclusion of risky choices that were not exclusive to a single risk
322 domain.
323 Decision choices with an ethical component were perceived to be particularly risky and
324 participants were more averse to taking these as compared to other risks. Many of the
325 ethical decision choices investigated were subject to regulations, with the potential for
326 prosecution and fines if an unacceptable outcome arose. Damage to a site of special
327 scientific interest (SSI) or a scheduled ancient monuments for instance can incur fines of up
328 to £40,000 or £50,000 respectively in Scotland (Scottish Parliament, 2011, 2004). It was not
329 possible in this study to distinguishing the extent to which legislation or true ethical values
330 drove respondents' views, but the relatively high level of risk aversion to taking these risks
331 should be reassuring to interested parties whether government, Non-Governmental
332 Organisation or individual member of society.
333 The financial risk domain was perceived to be one of the least risky and contained choices
334 that participants were least likely to avoid. This finding is consistent with previous studies

335 flowing from the sentinel work of Gasson (1973) highlighting that profit generation is not the
336 only and is often not the primary goal of farmers. Furthermore, it accentuates the call made
337 by OECD (2009) for holistic studies of farmer behaviour that go beyond financial
338 optimisation if better models are to be developed.
339 With most respondents considering that farming has an important role to play in wider
340 societal goals and their preference to particularly avoid ethical and health & safety risks the
341 results indicate a positive attitude to issues that in other business environments might be
342 termed 'corporate social responsibility'. However, there is anecdotal evidence that this does
343 not translate into practice in all cases. The study findings therefore suggest that barriers
344 may be preventing farmers acting in line with their risk preferences in many situations. For
345 instance where legislation or markets require farmers to engage in hazardous activities such
346 as tagging calves and clipping cattle which resulted in injuries to 24% of respondents in a
347 survey of Scottish farmers (Lindsay et al., 2004). This supports the viewpoint that there has
348 been too great a focus on farmer attitudes, behaviour and choice in recent years (Burton,
349 2004; Shove, 2010). Defining these barriers and finding solutions that are effective in
350 commercial conditions could lead to greater consistency between attitudes and behaviours
351 as well as greater progress towards the desired goals of both farmers and society. One
352 hypothesis worthy of investigation would be that the level of perceived or actual control
353 plays a key role. This might also explain why the three types of risk domain emerged from
354 the statistical model as there can be greater opportunities to implement mitigating actions
355 with respect to production, financial and social risks as compared to the ethical and
356 recreational risks explored in the study (domain types 1 and 2). Furthermore, anecdotal
357 evidence suggests that farmers feel they are unable to avoid some health & safety risks. For
358 example, many farmers are sole workers and consequently it was difficult for them to ensure
359 they were not 'Undertaking potentially dangerous farm activities without someone knowing
360 where you are'. Similarly farmers commonly must operate in close vicinity of recently calved
361 cows in order to comply with regulations requiring calves to be tagged within a few days of
362 birth. The apparent acceptance of such risks (type 3 domains of risk) is a concern but since
363 decisions that presented health & safety risks were perceived amongst the riskiest choices
364 the results indicate there is a good level of health & safety awareness. Consequently, while
365 education remains essential, this study suggests that other approaches are likely to be
366 required if the annual level of agriculture related fatalities, which has changed little in more

than ten years, is to be improved (the average rate of fatality per 100,000 workers was 9.2 for the five years to 2002/3 and averaged 9.9 for the five year period to 2012/13 (HSC, 2001; HSE, 2014, 2004, 2003, 2002).

A mixture modelling approach of the data collected is currently being undertaken to explore the domains and associated risky choices in greater depth, including issues associated with the fact that many risky choices cannot readily be assigned to a single domain. A key question in this work is whether the assumed domain structure accurately describes that perceived by farmers. In addition, further investigation of relationships between farm-farm household factors and risk preferences is planned since, arguably, more may have been expected than were found in this analysis.

Confirmation that farmers hold heterogeneous, as compared to constant, risk preferences opens new research pathways for those interested in improving policy effectiveness and potential responses of farmer managers to changes in their operating environment. Specifically, where decision choices are holistically being examined the inclusion of heterogeneous risk preferences may improve the explanatory and/or predictive power of models, particularly in cases where balancing multiple and competing goals strongly feature.

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492

493 **Appendix 1 Risky choices investigated in the study**

Risk domain	Risky choice
Financial	Continuing to employ someone you don't have enough work for
	Using an overdraft rather than a loan to fund a capital purchase
	Selling livestock at auction
	Continuing to employ someone that you can't really afford
	Investing a large amount of your own capital in a new enterprise
	Investing a large amount of your own capital in an existing enterprise
	Buying land to increase scale if it was available
	Selecting to receive subsidy payments in Euros
	Renting land to increase scale if it was available
	Forward selling produce
	Borrowing a large sum of money to invest in a new enterprise
	Borrowing a small sum of money to invest in a new enterprise
	Investing in a significant new farm building
	Borrowing a large sum of money to invest in an existing enterprise
	Trading Single Farm Payment entitlements
	Forward buying inputs
	Not having spare capacity in machinery/equipment in case working windows are shorter than average
	Borrowing a small sum of money to invest in an existing enterprise
Ethical	Disposing of a chemical/chemical container in a way that is not recommended
	Not calling the vet immediately to treat a sick animal when you cannot identify the cause
	Not always notifying households neighbouring your fields when you are going to spray crops
	Not acting to make safe an animal straying on the road that belongs to neighbour who is out
	Spraying crops or grassland when there is a risk of wind drift
	Applying fertiliser including FYM/slurry at a time that could lead to pollution
	Leaving a lambing/calving/farrowing animal unsupervised to attend a family event
	Not checking breeding animals regularly during lambing/calving/farrowing
	Knowingly undertake an action that could harm a protected species
	Not treating an injured animal immediately it was identified
	Knowingly undertake an action that could damage a scheduled monument
	Knowingly undertake an action that could damage a valuable/protected habitat
Production	Buying inputs from a known new supplier
	Buying inputs from an unknown supplier.
	Not adjusting crop protection plans in response to weather conditions
	Buying replacement females at auction from an known source
	Buying replacement stock at auction from an UNKNOWN source
	Employing someone who you are not entirely comfortable can do the job/fit in to your business
	Not responding immediately to an unusual livestock health problem
	Starting an entirely new enterprise on the farm
	Selling produce into a new market
	Changing your production method significantly e.g. finishing cattle off grass instead of a housed system.
	Significantly changing the scale of one or more enterprise on your farm
	Not adjusting stocking & grazing fertiliser rates from year to year
Health & safety	Not wearing full protective clothing whilst working with chemicals
	Working with machinery that does not have all its safety guards
	Driving when you know or think you might be over the legal alcohol limit
	Not wearing a seat belt when being a passenger in the front seat and on a public road
	Undertaking potentially dangerous farm activities without someone knowing where

	you are
	Enter a pen with a bull or recently calved cow without a stick or taking other protective measures
	Not providing workers with the full protective clothing recommended for a task
	Consuming five or more alcoholic drinks in a single evening
	Not wearing a helmet when riding the farm quad bike
	Not wearing a helmet when riding a motorcycle
	Driving a quad bike or tractor over terrain which has a slope which might be dangerous
Recreational	Occasionally engaging in dangerous sports e.g. sky diving
	Going down a ski run that is beyond your ability or closed
	Trying out bungee jumping at least once
	Piloting your own small plane, if you could
Social	Arguing with family peers about a major issue not relating to the farm
	Disagreeing with your family peers about how the farm is run
	Telling a friend that you don't agree with their behaviour
	Defending an unpopular issue that you believe in at a social event
	Admitting that your tastes are different from those of your friends
	Not assisting a farming friend/neighbour when they ask for help
	Taking time off during harvest to go to a family event
	Arguing with a friend
	Not informing a neighbour immediately if his/her animals were straying
	Selling something to a friend/neighbour without accurately stating any quality problems it might have/has
	Selling something to an unknown person without accurately stating any quality problems it might have/has
	Lending a friend/neighbour valuable equipment

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