

Decision Making for Animal Health and Welfare: Integrating Risk-Benefit Analysis with Prospect Theory

Helena Hansson* and Carl Johan Lagerkvist

This study integrated risk-benefit analysis with prospect theory with the overall objective of identifying the type of management behavior represented by farmers' choices of mastitis control options (MCOs). Two exploratory factor analyses, based on 163 and 175 Swedish farmers, respectively, highlighted attitudes to MCOs related to: (1) grouping cows and applying milking order to prevent spread of existing infection and (2) working in a precautionary way to prevent mastitis occurring. This was interpreted as being based on (1) reactive management behavior on detection of udder-health problems in individual cows and (2) proactive management behavior to prevent mastitis developing. Farmers' assessments of these MCOs were found to be based on asymmetrical evaluations of risks and benefits, suggesting that farmers' management behavior depends on their individual reference point. In particular, attitudes to MCOs related to grouping cows and applying milking order to prevent the spread of mastitis once infected cows were detected were stronger in the risk domain than in the benefit domain, in accordance with loss aversion. In contrast, attitudes to MCOs related to working in a precautionary way to prevent cows from becoming infected in the first place were stronger in the benefit domain than in the risk domain, in accordance with reverse loss aversion. These findings are of practical importance for farmers and agribusiness and in public health protection work to reduce the current extensive use of antibiotics in dairy herds.

KEY WORDS: Animal health and welfare; managerial behavior; risk-benefit analysis; prospect theory; psychometrics

1. INTRODUCTION

Mastitis, an inflammatory response of the cow's udder, is one of the most problematic diseases in dairy herds. It can be caused by bacteria of contagious or environmental origin and can be either clinical (with visible symptoms) or subclinical (without visible symptoms), with clinical mastitis (CM) being the more severe and costly form. It has been estimated that the annual cost of CM to the U.S. dairy

industry is about \$1.7–2 billion, which represents 11% of the total value of U.S. milk production.⁽¹⁾ In Sweden, it has been estimated that the cost of mastitis (clinical and subclinical) is about 5% of total gross margin in a 150-cow dairy herd.⁽²⁾ The economic arguments for reducing the incidence of mastitis are significant in today's dairy industry, where farmers face increasingly volatile input and output prices, meaning that economic returns are also more volatile. The upside of higher riskiness in economic outcomes is generally valued in positive terms, but the downsides are more problematic and can lead to liquidity problems and eventual bankruptcy. One way of coping with the downsides of riskiness in economic outcomes would be to reduce the incidence of mastitis.

Department of Economics, Swedish University of Agricultural Sciences, P.O. Box 7013, SE-75007, Uppsala, Sweden.

*Address correspondence to Helena Hansson, Department of Economics, Swedish University of Agricultural Sciences, P.O. Box 7013, SE-75007 Uppsala, Sweden; tel: +46-18-671714; Helena.Hansson@slu.se.

Apart from the economic imperative, there are animal welfare considerations for reducing the incidence of mastitis, as it is painful for the cow. From the farmer's perspective, knowing that production animals are suffering may significantly compromise personal happiness and the legitimacy of farming, thus bringing consequences beyond the pure economic effects.⁽³⁾ In addition, CM is associated with undesirable use of antibiotics, which is a public health concern. In the United States, it is accepted practice to use antibiotics in dairy herds for preventative purposes,⁽⁴⁾ while Swedish legislation stipulates that antibiotic therapy may only be initiated after a diagnosis has been made by a veterinarian. The concern about overuse of antibiotics is based on the risk of resistance developing in bacteria, which would further elevate the adverse economic consequences and the concerns about public health.

Farmers can control mastitis and thereby reduce its incidence by applying various mastitis control options (MCO). However, the current understanding of farmers' management behavior in relation to mastitis management is limited, although knowledge of this would be of significant benefit in developing advisory tools for use in the agricultural industry and in policy design. MCO are risky to the farmer in the sense that the actual outcome in terms of reduction in mastitis incidence from actions taken cannot be guaranteed, and such options are therefore typically associated with a tradeoff between the benefit they provide and their riskiness. Earlier findings suggest that the benefit perception of individuals concerns all features that make a situation attractive, and that this is based on heuristics and experience.⁽⁵⁾ The risk perception of individuals, however, is related to cognitive information processing⁽⁵⁾ and/or affective evaluations.^(6,7) Furthermore, evidence suggests that there is a negative correlation between perceptions of risk and benefits associated with a certain situation.⁽⁸⁾ This suggests that the preference of individuals for risky options is a function of this tradeoff.⁽⁹⁾

Prospect theory^(10,11) states that the utility individuals associate with risky options depends on the reference point taken. Integrating risk-benefit analysis with prospect theory would allow an analysis of how individuals differ in their evaluation and integration of the risks and benefits, while taking reference point into explicit consideration.

Accordingly, the overall aim of this study was to identify the type of management behavior farmers exhibit when choosing MCO to reduce the incidence of CM. In an initial step, farmers' attitudes

to risky MCO in the risk-benefit framework were identified.⁽⁹⁾ This allowed the identification of farmers' preferred groups of MCO to cope with risk associated with CM. In a second step, evaluations of risks and benefits were compared in order to determine how farmers differ in their evaluation of MCO when their individual reference point (their current CM incidence) is taken into explicit consideration. The novel contribution of this study lies in its approach of integrating managerial decision making based on domain-specific risk attitudes with the behavioral insights from prospect theory.

While farmers' general risk perceptions have been widely studied from various theoretical standpoints,⁽¹²⁻¹⁹⁾ farmers' risk attitudes in relation to MCO have not previously been analyzed. Therefore, this study sought to help agricultural advisory services by providing insights into the management behavior of farmers that determines their work to reduce mastitis, farmers' evaluations of MCO, and how they make choices among different types of MCO. This would allow advice that fitted the needs of the individual farmer to be developed. The findings were also intended for use by policymakers in devising schemes to reduce the incidence of mastitis and thereby improve farm animal welfare and reduce the use of antibiotics by focusing on effective mastitis control.

2. CONCEPTUAL FRAMEWORK

This study is based on a behavioral framework for identifying farmers' attitudes to MCO. Attitudes represent the individual's idea of objects and thus exist in the mind of the individual.⁽²⁰⁾ Attitudes are viewed as summary evaluations of psychological objects, i.e., a feeling of liking, disliking, or indifference to a particular object.^(20,21) There is strong consensus in the extant literature that behavioral intentions and behaviors, when mediated by motivation, are guided by people's attitudes.⁽²¹⁻²⁴⁾ Farmers' management behavior in relation to MCO is perceived to be based on their attitudes; these are assumed to be composed of the farmers' beliefs about MCO, which are formed from their perceptions. There is hence a causal relationship from perceptions to beliefs, which compose the attitudes, and finally to behavioral intentions and behaviors, with the last link mediated by motivation. This is in line with behavioral approaches to studying farmers' risk attitudes in general.^(13,19)

People's attitudes to options with risky outcomes can be described in a risk-return framework, where individuals face an affective tradeoff between the benefit they believe will accrue from an option and the riskiness of that option.⁽⁹⁾ Importantly, it is not comparisons between alternative states of the world that are modeled, but instead the hedonistic range between benefit and risk in the mind of the decision-maker. This framework is appealing in the present case because it recognizes that options may have both positive and negative affective outcomes. Furthermore, the risk-benefit framework⁽⁹⁾ allows analysis of where individuals differ in their integration of the benefits and riskiness of the options. In particular, people's attitudes, or in the terminology of Weber *et al.*,⁽⁹⁾ preferences, for options with risky outcomes can be defined as:⁽⁹⁾

$$\begin{aligned} & \text{Attitude to risky option } X \\ & = a (\text{Expected benefit } (X)) \\ & + b(\text{Perceived risk } (X)), \end{aligned} \quad (1)$$

where X refers to an option with a risky outcome. Hence, defining farmers' attitudes to risky MCO according to the model in Equation (1) involves viewing the attitudes to each option as a composite variable consisting of the sum of the expected benefit and perceived risk. Attitudes to risky options may differ across risky domains or areas, which means that individuals may hold different attitudes to risky options depending on the type of risk involved.⁽⁹⁾ Hence, individuals may be risk averse when considering risk in one domain, while they are risk taking in other domains. Risky options can be grouped according to the domains they belong to. Attitudes to risky options can then be evaluated at domain level.

Insights from prospect theory^(10,11) state that individuals represent choices in terms of losses or gains relative to a reference point and that there is an asymmetry in the decision utility⁽²⁵⁾ derived from a gain compared with the corresponding disutility derived from a loss relative to a reference point. In terms of the risk-benefit framework,⁽⁹⁾ this implies that individuals' evaluations of the benefits and risks associated with risky options are likely to depend on whether the evaluation is made in the benefit or risk domain.

In the original version of prospect theory,^(10,11) the asymmetry in the evaluation relative to a loss or a gain is due to loss aversion. It appears as though choices framed as gains compared with a reference point receive less impact in terms of change

in utility compared with choices framed as losses relative to the same reference point. This means that the disutility from a loss is larger than the utility from a corresponding gain. In terms of the risk-benefit framework,⁽⁹⁾ prospect theory suggests that an option evaluated in the benefit domain will be attributed less impact than the same option evaluated in the risk domain. However, loss aversion has been proven to be dependent on the size of stakes; in particular, loss aversion has been found to be reversed in cases where the stakes are small.⁽²⁶⁾ This implies that when a decision concerns a relatively small amount of money or a relatively small sacrifice in other terms, the utility obtained from a gain in relation to the reference point is larger than the disutility derived from a corresponding loss compared with the reference point.

Viewing attitudes to risky options in the risk-benefit framework and describing them in terms of prospect theory, especially as regards the loss aversion and reversed loss aversion notation, mean that information on decisionmakers' management behavior can be derived from the evaluations they make of options with risky outcomes. In particular, we propose that the relative strength of attitudes in benefit domains compared with attitudes in risk domains can be used to evaluate whether decisionmakers think of options as being relatively large or small sacrifices. Based on an examination of the strengths of attitudes in the benefit domain and of those in the risk domain in relation to MCOs available to farmers, the following hypotheses were formulated:

- (1) If attitudes¹ to a risky option framed in the benefit domain are weaker than attitudes to the same option framed in the risk domain, farmers are loss averse and act according to original prospect theory in their decision making about MCO. Mastitis control in this case is evaluated by farmers as being about relatively large sacrifices.
- (2) If attitudes to a risky option framed in the benefit domain are stronger than attitudes to the same option framed in the risk domain, farmers are reverse loss averse. Mastitis control in this case is evaluated by farmers as being about relatively small sacrifices.

For the purposes of the present study, attitudes were considered latent constructs and tapped

¹In this study, stronger attitudes refer to more favorable evaluations of MCO.

via psychometric measurement variables.⁽²⁷⁾ The psychometric approach is well anchored within cognitive psychology, since it can be expected that contextual, social, and cultural variables influence perceptions of risks and benefits.⁽²⁸⁾ Farmers' beliefs about the benefits and risks associated with a number of MCO were used as measurement variables in this study. A central question in the measurement of latent constructs is the direction of causality between the measurement variables and the underlying latent construct, which governs the technique used to elicit the latent construct.^(29–31) In this study, causality was assumed to go from the latent attitude construct to the measurement variables. This is in line with previous research on farmers' risk attitudes.^(13–15,19) Farmers' beliefs about the benefits and risks associated with various MCO were thus considered to be guided by the underlying attitude construct.

3. DATA AND METHODS FOR ASSESSING ATTITUDES

Data for this study were collected through an extensive self-administered postal questionnaire sent in May 2011 to a sample of 898 Swedish dairy farmers. The sample was drawn from the database of the Swedish official milk recording scheme, which was run by the Swedish Dairy Association. Data were stratified according to housing and milking system: all herds with free-stalls and an automatic milking system (AMS) ($n = 298$) were included in the study, and a sample of 300 herds with tie-stalls and pipeline milking and 300 herds with free-stalls and parlor milking was identified by randomization from all farms in the respective populations. The sample was not representative of the population of Swedish dairy farmers, as most still house their cows in tie-stalls. However, stratifying the sample according to housing system allowed us to capture possible differences in perceptions of MCO associated with different housing systems. The questionnaire was part of a larger research project and comprised a total of nine pages and 23 questions, several of which were designed with subquestions. Completion of the questionnaire was estimated to take approximately 30 minutes. Dispatch and collection were managed by Statistics Sweden. The questionnaire was pretested on two researchers, one with experience of designing questionnaires and one with experience of mastitis research. The questionnaire was also reviewed for clarity by Statistics Sweden. Each questionnaire was distributed together with a

lottery ticket to increase the respondents' willingness to reply. The instructions provided with the questionnaire specifically requested that the person responsible for udder health in the herd should answer the questionnaire.

A total of 428 answers were received, after one reminder, which corresponded to a response rate of 48%. This is comparable to the 47% response rate obtained in another recent study of Swedish farmers.⁽¹⁹⁾ However, several respondents did not correctly answer all questions, meaning that several questionnaires suffered from missing values in some of the questions, possibly because the farmers found them difficult to answer. This meant that the statistical procedures were based on considerably smaller samples (163 and 175 observations, respectively). An analysis of differences between the respondents whose answers appeared in the final analyses and those for whom data had to be omitted revealed that the former were younger and considered the incidence of CM in their herds to be a smaller problem. Furthermore, compared with the original data set, there was an underrepresentation of farmers with AMS among those retained in the final analyses, possibly because these farmers felt less motivated to answer questions about the suggested MCOs. The results need to be interpreted in light of this. Table I shows descriptive statistics for the study sample at the stage when there was an even distribution of farms with pipeline milking, parlor milking, and automatic milking. The respondents evaluated their own incidence of CM to be quite low, with an average figure of 2.55.

3.1. Scale Design

In order to assess farmers' attitudes to MCO under the premise that decisions about MCO are risky and using the risk-benefit framework,⁽⁹⁾ two classes of questions were devised. The first class (the benefit version) assessed farmers' beliefs about how important the suggested MCO can be to reduce the incidence of CM in their herds, on a 1–5 Likert scale, and the second class (the risk version) assessed their beliefs about the risk of increased CM incidence associated with not implementing the MCO, also on a 1–5 Likert scale. It was assumed that reduction in the incidence of mastitis was a benefit to the farmer and hence the first class of questions was used to assess the benefit part of the risk-benefit framework.⁽⁹⁾ The second class of questions was used to assess the farmers' beliefs about risks. In total, a set of 21 MCO

Table I. Descriptive Statistics on the Study Sample

	Mean Value	Standard Deviation
Type of production (1 if conventional; 0 if organic)	0.86	n.a.
Pipeline milking (1 if yes; 0 if no)	0.33 ^a	n.a.
Milking parlor (1 if yes; 0 if no)	0.36 ^a	n.a.
Automatic milking system (1 if yes; 0 if no)	0.37 ^a	n.a.
Size of herd	107.3	75.94
Self-assessment of incidence of clinical mastitis in the herd 2010 (5 = very high; 1 = very low)	2.55	0.788

^aFarms may have several milking systems, hence the total exceeds 1.00.

selected to reflect Swedish farming practices and recommendations from advisory services about feasible ways to reduce the incidence of mastitis were studied.

Farmers were asked to evaluate the MCO identified in the (benefit and risk versions) of questions. The questions in the risk version were phrased as the negative of the questions in the benefit version. For example, in the benefit version the MCO “All cows prestripped” was suggested to reduce the incidence of CM in the herd and the farmer was asked to indicate his/her opinion of this on the Likert scale. In the risk version, this MCO was negatively worded into “Not all cows prestripped” (can increase the risk of CM in the herd), and the farmer was again asked to indicate his/her opinion of this. Response options on a 1–5 Likert scale were anchored to facilitate interpretation of the results. Hence each response option was given an interpretation: “not at all,” “somewhat,” “neutral,” “quite,” and “very,” where “not at all” referred to end point 1 and “very” to end point 5. The opt-out alternative “not relevant” was provided as a response option for respondents who had housing and milking systems they believed did not comply with implementation of a certain MCO. The respondents were specifically asked to rate MCO that they had not implemented, but that could have been implemented in their herds, and were in these cases asked to evaluate the effect they anticipated the option would have. Descriptive statistics on the farmers’ evaluations of the MCO are presented in the Appendix.

3.2. Assessing Attitudes

Farmers’ attitudes to MCO were assessed with exploratory common factor analysis (ECFA). This method allows assessment of latent constructs, where a reflective relationship between the constructs and

their measurement indicators can be assumed⁽³⁰⁾ in a situation where no previously established measurement scale exists. The factorability of the matrices of measurement items was evaluated with Kaiser’s overall measure of sampling adequacy (KMO). A factorable matrix has an overall KMO and individual KMO of each measurement item above 0.5.⁽³²⁾ Both matrices met these requirements.

ECFA groups measurement items to factors based on the correlations between each measurement item and the underlying attitude construct and the correlations between the measurement items. The factors are taken to represent the underlying latent constructs, in this case the farmers’ attitudes to MCO. The decision on the number of factors to retain was guided by the eigenvalues of the factors and by the desire to obtain a comprehensive solution that could be interpreted in a meaningful way.

Measurement items with insignificant factor loadings were removed one at a time, starting with the measurement items with the lowest communalities, until only items with significant loadings were retained. Measurement items loading significantly on two or more factors were also deleted.

The final factor solutions were rotated before being interpreted. Rotation was based on the oblique (oblimin) technique because it allows factors to be correlated. Attitudes to MCO are likely to be correlated across domains and hence the oblique rotation technique was expected to provide a factor solution with theoretically more valid factors. The final factor solutions were also evaluated with respect to reliability. To this end, measures of item-to-item correlation, item-to-total correlation, and Cronbach’s alpha were used.⁽³²⁾ Recommended cut-off values of these measures (0.3, 0.5, and 0.6, respectively⁽³²⁾) were used as reference points for the evaluation of reliability.

Table II. Rotated Factor Structure for Benefit Factors ($n = 163$)

Actions to Reduce the Incidence of Clinical Mastitis (Perceived Benefit) ^a	Factor 1 <i>Grouping Cows and Applying Milking Order to Prevent Spread of Existing Infection</i>	Factor 2 <i>Working in a Precautionary Way to Prevent Mastitis Occurring</i>
Yards cleaned at least twice a day		0.530
Cows in milk grouped according to udder-health status	0.675	
Dry cows grouped according to udder-health status	0.453	
Gloves worn by milking staff during every milking		0.512
Cows with CM milked last	0.763	
Cows with high SCC milked last	0.828	
Teat-cup liners replaced according to manufacturer's recommendations		0.509
Dry cows fed a mineral feed that covers their needs		0.598
Calving in single pens cleaned between calvings		0.535
Feeding plans continuously reviewed and revised when needed		0.632
Cronbach's alpha	0.779	0.719
Range, item-to-item correlation	0.255–0.701	0.204–0.445
Range, item-to-total correlation	0.725–0.859	0.558–0.698

^aUnderlying scale: 1–5.

Note: Only significant loadings displayed.

4. RESULTS

4.1. Exploratory Common Factor Analysis

Farmers' evaluations of the MCO were factor analyzed with the ECFA. One factor analysis was applied on the benefit version of the measurement items and one on the risk version. In this way, decomposed measures of farmers' attitudes to MCO were obtained, explicitly taking the benefit and risk domains into consideration.

In the factor analysis of the benefit domain, as many as 11 of the 21 items had to be removed on the grounds that they did not load significantly on any factor or that they loaded highly on two factors. In the risk domain, seven measurement items were removed on these grounds. The overall KMO of the final factor matrices was 0.716 and 0.825 for the benefit and risk domain, respectively, with individual KMO ranges of 0.615–0.826 and 0.701–0.942, respectively. This shows that the final matrices were suitable for factor analysis.

The rotated factor structure of farmers' attitudes to MCO in the benefit domain is shown in Table II and for MCO in the risk domain in Table III. In both domains, factor structures with two retained factors were obtained. This implies that in both domains the attitude construct can be interpreted as being two-dimensional. In the benefit domain, the first factor comprised measurement items related to grouping of

cows and applying milking order, while the second factor comprised measurement items related to the use of hygiene routines and fodder regimes. From a managerial behavior point of view, the first factor was interpreted as reflecting a benefit domain about a more reactive strategy to group cows and apply milking order so as to prevent the spread of infection on detection of individual cows with udder-health problems. The second factor was interpreted as reflecting a benefit domain about a more proactive and precautionary strategy to prevent mastitis occurring. These factors were named "grouping cows and applying milking order to prevent spread of existing infection" and "working in a precautionary way to prevent mastitis occurring." The factor structure obtained in the risk domain closely resembled the structure obtained in the benefit domain, but the order of the factors was reversed. Accordingly, the first factor in the risk domain was interpreted as relating to "not working in a precautionary way to prevent mastitis occurring" and the second factor as relating to "not grouping cows and applying milking order to prevent spread of existing infection." Hence, from a managerial behavior point of view the factors differed, especially with respect to the reactive or proactive strategy they involved.

In terms of reliability, all factors were associated with high Cronbach's alpha values, in the range 0.719–0.846. Furthermore, item-to-total correlations

Table III. Rotated Factor Structure for Risk Factors ($n = 175$)

Actions That Can Increase the Risk of CM (Perceived Risk) ^a	Factor 1 <i>Not Working in a Precautionary Way to Prevent Mastitis Occurring</i>	Factor 2 <i>Not Grouping Cows and Applying Milking Order to Prevent Spread of Existing Infection</i>
Cows in milk not grouped according to their udder-health status		0.561
Gloves not worn by milking staff during every milking	0.613	
Dirty udders are not washed with water or dried before attaching the cluster	0.489	
All cows not treated with postmilking teat disinfectant	0.517	
Clusters not rinsed with warm water after milking cows with CM ^b	0.464	
Cows with CM not milked last		0.909
Cows with high SCC ^c not milked last		0.851
Cows not kept standing at least 30 minutes after milking	0.470	
Teat-cup liners not replaced according to manufacturer's recommendations	0.609	
Dry cow therapy not administered in consultation with veterinarian	0.609	
Udder-health status of the herd not regularly discussed with veterinarian	0.682	
Dry cows not fed a mineral feed that covers their needs	0.576	
Calving not in single pens cleaned between calvings	0.656	
Feeding plans not continuously reviewed and revised when needed	0.595	
Cronbach's alpha	0.846	0.834
Range, item-to-item correlation	0.157–0.568	0.516–0.809
Range, item-to-total correlation	0.565–0.703	0.826–0.918

^aUnderlying scale: 1–5.

^bClinical mastitis.

^cSomatic cell count.

Note: Only significant loadings displayed.

were all above the cut-off value of 0.5⁽³²⁾ whereas the item-to-item correlations in some cases were below the cut-off value of 0.3.⁽³²⁾ However, this was not considered a major problem, since all individual measurement items correlated above, or close to, this cut-off value with at least some other measurement items. Overall, the reliability of all factors obtained was considered satisfactory.

4.2. Comparing Benefit Domains to Risk Domains

Summed scales reflecting attitudes to MCO evaluated in the benefit domain and the risk domain were calculated by adding the responses to all measurement items loading highly to the same factor and dividing by the number of measurement items. This gave four summed scales, two reflecting the attitudes in the benefit domain and two reflecting the attitudes in the risk domain. The strength of attitudes in the benefit domain was compared with that of attitudes in the risk domain by dividing the corresponding summed scales in both domains by each other. This gave two benefit/risk ratios, which were used to evaluate whether or not farmers are influenced by loss aversion in their management behavior related to MCO. The benefit/risk ratio associated

with “grouping cows and applying milking order to prevent spread of existing infection” had an average value of 0.979 and was significantly less than 1 (p -value 0.015, one-tailed t -test), implying that farmers generally had weaker attitudes to MCO evaluated in the benefit domain than for MCO evaluated in the risk domain. Thus the farmers were influenced by loss aversion. In contrast, the benefit/risk ratio associated with “working in a precautionary way to prevent mastitis occurring” had an average value of 1.077 and was significantly greater than 1 (p -value 0.000, one-tailed t -test), implying that farmers generally had stronger attitudes to MCO evaluated in the benefit domain than for MCO evaluated in the risk domains. Thus, with respect to this group of MCO, farmers made decisions based on reverse loss aversion.

Figs. 1 and 2 show kernel density estimates of the distributions of the benefit/risk ratios. From these it is evident that the benefit/risk ratios were distributed around 1, implying that for both types of MCO there were farmers who acted according to loss aversion and reverse loss aversion. Furthermore, a visual inspection of Fig. 1 suggests that a larger part of the sample is situated below 1, again suggesting weaker attitudes for MCO evaluated in the benefit domain

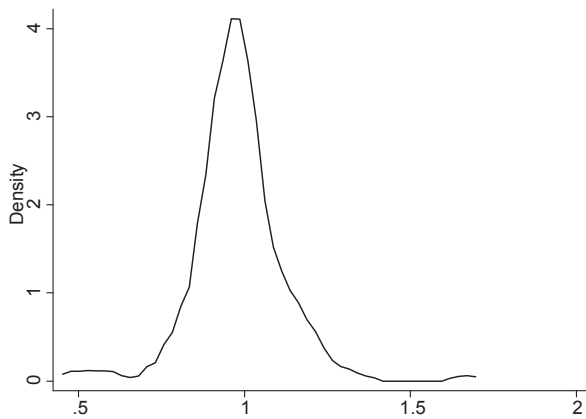


Fig. 1. Kernel density estimate of benefit/risk ratio associated with “Grouping cows and applying milking order to prevent spread of existing infection.”

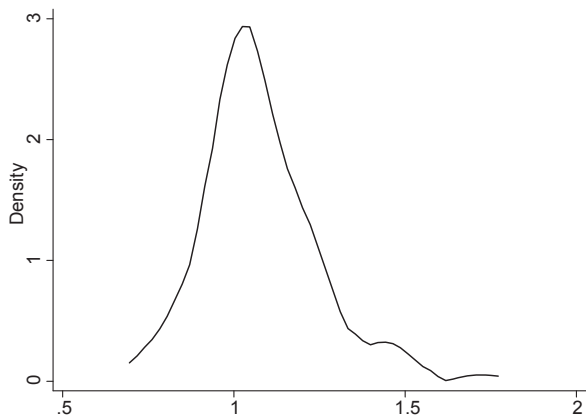


Fig. 2. Kernel density estimate of benefit/risk ratio associated with “Working in a precautionary way to prevent mastitis occurring.”

compared with those evaluated in the risk domain. A visual inspection of Fig. 2 suggests that a larger part of that sample is situated above 1, suggesting stronger attitudes for MCO evaluated in the benefit domain compared with those evaluated in the risk domain. A Friedman test statistic of 11.557 (p -value: 0.001) significantly rejected the null hypothesis that the two benefit/risk ratios follow the same distribution, lending further support to the conclusion that the two benefit/risk ratios represent different evaluations.

5. DISCUSSION AND CONCLUSIONS

This study integrated managerial decision-making analysis based on domain-specific risk attitudes⁽⁹⁾ with insights from prospect theory,^(10,11) with the aim of identifying the type of management

behavior displayed by farmers in their work to control mastitis. The inclusion of prospect theory, which holds that evaluations of risky options may depend on the reference point taken, is a novel approach compared with that taken in previous studies assessing attitudes to risky options in a risk-return framework.

Farmers' attitudes to MCO to cope with the risk associated with CM were identified as being related to: (1) grouping cows and applying milking order to prevent spread of existing infection; and (2) working in a precautionary way to prevent mastitis occurring. From a managerial behavioral point of view, the factor analyses indicated that farmers' attitudes to MCO are based on reactive management behavior to limit the negative impact of udder-health problems once detected and proactive management behavior to prevent problems with mastitis to develop to begin with.

Our approach allowed explicit assessment of responses to MCO depending on the individual farmer's reference point in terms of self-evaluation of perceived incidence of CM in the herd. The findings clearly showed that farmers' assessments of the two groups of MCO were based on asymmetrical evaluations of risk and benefits and suggested that farmers' management behavior depended on their individual reference point. An interesting finding in this respect is that the order of asymmetry in the evaluations differed in the two groups of MCO identified. The benefit/risk ratio associated with “grouping cows and applying milking order to prevent spread of existing infection” was evaluated in accordance with original prospect theory, with stronger evaluations in the risk domain, whereas the benefit/risk ratio associated with “working in a precautionary way to prevent mastitis occurring” had stronger evaluations in the benefit domain. These findings suggest that farmers' management behavior is influenced by loss aversion^(10,11) when they make the arguably more reactive decisions about MCO aimed at preventing the spread of existing infection between cows, while they are influenced by reverse loss aversion⁽²⁶⁾ when they make the arguably more proactive decisions about how to prevent new cases of mastitis developing in the herd.

The farmers surveyed appeared to perceive mastitis control to be generally about a relatively large sacrifice once, at the stage when more reactive MCO are necessary, but otherwise to be about a smaller sacrifice. This suggests that the decision-making process is orientated toward problem solving. When the

more reactive MCO are implemented, the farmer is already facing problems with infected cows and may therefore consider it necessary to implement more powerful actions that are associated with feelings of larger sacrifice. In contrast, application of the more proactive MCO is likely to be associated with situations where mastitis is not perceived as an overwhelming problem, but where handling routines can be used to maintain, or improve, an acceptable incidence.

It was also found that the benefit/risk ratios displayed pronounced heterogeneity. For both types of benefit/risk ratios studied, some farmers displayed management behavior in accordance with original prospect theory but other farmers did not. Further research about individual differences is needed to better understand the antecedents of the apparent heterogeneity in managerial behavior.

Insights about management behavior in relation to mastitis control, as well as the MCO attitude scales developed here, can be used by advisors to map management profiles of their clients and thereby provide advice that is better targeted at the individual farmer's perceptions and attitudes. For instance, the risk and benefit versions of the MCO attitude scales can be used by advisors to evaluate whether individ-

ual farmers think of mastitis control as a relatively large or small problem and thereby adjust advice accordingly. The findings may also be of value to farmers by providing insights into their decision making and how problems may be perceived and approached depending on the perceptions about the sacrifice associated with the problem. This can make the farmers more aware of how evaluation of reference point influences their decision making and thereby help them to view their decision making in a new light and to be more critical of how their reference point influences their management behavior. Furthermore, the approach devised in this study can be used to profile farmers' management behavior in different regions and countries. From a policy point of view, this would allow for better targeting of policy measures to individual farmers to achieve higher quality milk, improved animal welfare, and public health protection through reducing the current use of antibiotics in dairy herds.

ACKNOWLEDGMENTS

This study was financed by the Swedish Research Council Formas, Grants no. 2011-254 and 2009-1673, which is gratefully acknowledged.

APPENDIX: DESCRIPTIVE STATISTICS ON MEASUREMENT ITEMS

Actions to reduce the incidence of clinical mastitis (perceived benefit) ^a	Mean (std)	Actions that can increase the risk of increased incidence of clinical mastitis (perceived risk) ^a	Mean (std)
Houses cleaned and fresh bedding material provided at least twice a day	4.71 (0.584)	Houses not cleaned and fresh bedding material not provided at least twice a day	4.52 (0.714)
Yards cleaned at least twice a day	4.00 (1.133)	Yards not cleaned at least twice a day	3.63 (1.216)
Cows in milk grouped according to udder-health status	4.29 (0.894)	Cows in milk not grouped according to udder-health status	4.05 (0.952)
Dry cows grouped according to udder-health status	3.37 (1.047)	Dry cows not grouped according to udder-health status	3.24 (1.063)
Gloves worn by milking staff during every milking	3.46 (1.167)	Gloves not worn by milking staff during every milking	3.18 (1.150)
Dirty udders washed with water and dried before attaching the cluster	4.02 (1.000)	Dirty udders not washed with water or dried before attaching the cluster	3.84 (1.012)
Teats cleaned before attaching the cluster, one cloth per cow	4.79 (0.551)	Teats not cleaned before attaching the cluster, cloth shared by cows	4.51 (0.705)
All cows prestripped	4.47 (0.864)	Not all cows prestripped	4.06 (0.958)
Hard-milking cows stimulated manually at milking	3.83 (1.035)	Hard-milking cows not stimulated manually at milking	3.62 (0.993)
All cows treated with postmilking teat disinfectant	4.58 (0.823)	All cows not treated with postmilking teat disinfectant	4.21 (0.944)
Clusters rinsed with warm water after milking cows with CM ^b	4.60 (0.766)	Clusters not rinsed with warm water after milking cows with CM	4.33 (0.874)
Clusters rinsed with warm water after milking cows with high SCC ^c	4.20 (0.931)	Clusters not rinsed with warm water after milking cows with high SCC	4.00 (0.944)
Cows with CM ^b milked last	4.64 (0.778)	Cows with CM not milked last	4.47 (0.830)
Cows with high SCC ^c milked last	4.34 (0.957)	Cows with high SCC not milked last	4.25 (0.903)
Cows kept standing at least 30 minutes after milking	3.58 (1.12)	Cows not kept standing at least 30 minutes after milking	3.41 (0.980)
Teat-cup liners replaced according to manufacturer's recommendations	4.52 (0.677)	Teat-cup liners not replaced according to manufacturer's recommendations	4.19 (0.878)
Dry cow therapy administered in consultation with veterinarian	4.28 (0.880)	Dry cow therapy not administered in consultation with veterinarian	3.970 (0.920)
Udder-health status of the herd regularly discussed with veterinarian	3.86 (0.919)	Udder-health status of the herd not regularly discussed with veterinarian	3.63 (0.949)
Dry cows fed a mineral feed that covers their needs	4.22 (0.822)	Dry cows not fed a mineral feed that covers their needs	3.77 (0.923)
Calving in single pens cleaned between calvings	4.07 (0.962)	Calving not in single pens cleaned between calvings	3.78 (1.047)
Feeding plans continuously reviewed and revised when needed	4.31 (0.859)	Feeding plans not continuously reviewed and revised when needed	3.74 (1.037)

^aUnderlying scale: 1–5.

^bClinical mastitis.

^cSomatic cell count.

REFERENCES

1. Jones GM, Bailey TL. Understanding the basics of mastitis. u.o.: Virginia Cooperative Extension. Publication 404–233, 2009.
2. Nielsen C, Ostergaard S, Emanuelson U, Andersson H, Berglund B, Strandberg E. Economic consequences of mastitis and withdrawal of milk with high somatic cell count in Swedish dairy herds. *Animal*, 2010; 4(10):1758–1770.
3. McNerney J. *Animal Welfare, Economics and Policy. Report on a Study Undertaken for the Farm & Animal Health Economics Division of Defra.* Exeter, UK: Defra, 2004.
4. Tonsor GT, Wolf CA. On mandatory labeling of animal welfare attributes. *Food Policy*, 2011; 36(3):430–437.
5. Ueland O, Gunnlaugsdottir H, Holm F, Kalogeras N, Leino O, Luteijn JM, Magnússon SH, Odekerken G, Pohjola MV, Tjihuis MJ, Toumisto JT, White BC, Verhagen H. State of the art in benefit-risk analysis: Consumer perception. *Food and Chemical Toxicology*, 2012; 50:67–76.
6. Finuance ML, Alhakami A, Slovic P, Johnson SM. The affect heuristic in judgements of risks and benefits. *Journal of Behavioral Decision Making*, 2000; 13:1–17.
7. Slovic P, Finuance ML, Peters E, MacGregor DG. Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis*, 2004; 24(2):311–322.
8. Alhakami AS, Slovic P. A psychological study of the inverse relationship between perceived risk and the perceived benefit. *Risk Analysis*, 1994; 14:1085–1096.
9. Weber EU, Blais AR, Betz N. A domain-specific risk-attitude scale: Measuring risk perceptions and risk behaviors. *Journal of Behavioural Decision Making*, 2002; 15:263–290.
10. Kahneman D, Tversky A. Prospect theory: An analysis of decision under Risk. *Econometrica*, 1979; 47(2):263–292.
11. Tversky A, Kahneman D. Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, 1992; 5:297–323.
12. Mishra AK, Goodwin BK. Farm income variability and the supply of off-farm labor. *American Journal of Agricultural Economics*, 1997; 79:880–887.
13. Pennings JME, Leuthold R. The role of farmers' behavioral attitudes and heterogeneity in futures contracts usage. *American Journal of Agricultural Economics*, 2000; 83(4): 993–1009.
14. Pennings JME, Smidts A. Assessing construct validity of risk attitude. *Management Science*, 2000; 46:1337–1348.
15. Pennings JME, Garcia P. Measuring producers' risk preferences: A global risk-attitude construct. *American Journal of Agricultural Economics*, 2001; 83(4): 993–1009.
16. McNamara KT, Weiss C. Farm household income and on- and off-farm diversification. *Journal of Agricultural and Applied Economics*, 2005; 37:37–48.
17. Lien G, Hardaker JB, Flaten O. Risk and economic sustainability of crop farming systems. *Agricultural Systems*, 2000; 94(2):541–552.
18. Franken JRV, Pennings JME, Garcia P. Do transaction costs and risk preferences influence marketing arrangements in the Illinois hog industry? *Journal of Agricultural and Resource Economics*, 2009; 34(2):297–315.
19. Hansson H, Lagerkvist CJ. Measuring farmers' preferences for risk: A domain-specific risk preference scale. *Journal of Risk Research*, 2012; 15(7):737–753.
20. Kahneman R, Sugden D. Experienced utility as a standard of policy evaluation. *Environmental & Resource Economics*, 32:161–181.
21. Ajzen I. The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 1991; 50:179–211.
22. Conner M, Abraham C. Conscientiousness and the theory of planned behavior: Toward a more complete model of the antecedents of intentions and behavior. *Personality and Social Psychology Bulletin*, 2001; 27(11):1547–1561.
23. Kaiser FG, Scheuthle H. Two challenges to moral extension of the theory of planned behaviour: Moral norms and just world beliefs in conservationism. *Personality and Individual Differences*, 2003; 35(5):1033–1048.
24. Siegel Levine D, Strube MJ. Environmental attitudes, knowledge, intentions and behaviors among college students. *Journal of Social Psychology*, 2012; 152(3):308–326.
25. Kahneman D. New challenges to the rationality assumption. *Journal of Institutional and Theoretical Economics*, 1994; 150:18–36.
26. Harinck F, Van Dijk E, Van Beest I, Mersmann P. When gains loom larger than losses: Reversed loss aversion for small amounts of money. *Psychological Science*, 2007; 18(12):1099–1105.
27. DeVellis RF. *Scale Development—Theory and Applications.* Thousand Oaks, CA: Sage Publications Inc, 2003.
28. Cardello AV. Consumer concerns and expectations about novel food processing technologies: Effects on product liking. *Appetite*, 2003; 40:217–233.
29. Rositter JR. The C-OAR-SE procedure for scale development in marketing. *International Journal of Research in Marketing*, 2002; 19:305–335.
30. Podsakoff PM, MacKenzie SB, Podsakoff NP, Yeon LJ. The mismeasure of man(agement) and its implications for leadership research. *Leadership Quarterly*, 2003; 14(6):615–656.
31. Jarvis CB, Mackenzie SB, Podsakoff PM. A critical review of construct indicators and measurement model misspecification in marketing and consumer research. *Journal of Consumer Research*, 2003; 30:199–218.
32. Hair JF, Black WC, Babin BJ, Anderson RE. *Multivariate Data Analysis—A Global Perspective.* Upper Saddle River, NJ: Pearson, 2010.