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Routine inertia and reactionary response in animal health best practice

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Abstract Animal health is a key factor affecting the economic efficiency of the dairy industry. Improvements in animal health are also of relevance to society more broadly, given important implications for animal welfare, food safety and quality. Although the economic gains of best practice with regard to animal health have been well documented, many farmers are not adopting optimal herd management techniques. This paper utilises nationally representative farm-level data from Ireland for 2013 to identify drivers and barriers to the adoption of best practice with regard to on-farm mastitis management. Exploratory factor analysis is used to derive measures of farmers' attitudes towards animal health and mastitis and econometric techniques are employed to empirically assess the influence of these on the uptake of beneficial herd health management practices. A number of focus groups were also undertaken to complement the analysis. This paper concludes that farmers' attitudes towards animal health are not a key driver in the uptake of best practice, although perceived disease risk is of relevance. A number of interesting issues arise in identifying barriers to the uptake of best practice, these include the possibility of routine inertia, i.e., farmers do not deviate from the routine developed around mastitis prevention until there is an indication of infection, as well as constraints around the availability of labour and time. Farmer behaviour with respect to mastitis management can thus be considered as reactionary as opposed to precautionary. This research highlights the valuable role of the extension agent but concludes that engagement around knowledge transfer and technology adoption is particularly complex.

Keywords Animal health · Technology adoption · Attitudes · Behaviour · Mixed methods

Introduction

Improvements in animal health and milk quality are essential in an increasingly competitive dairy industry, particularly given important implications for animal welfare and food safety. Somatic cell count (SCC) is a key indicator of milk quality with elevated cell count levels (above 200,000 cells/ml) generally accepted as an indicator of the

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presence of intra-mammary infection (Dohoo and Leslie 1991; International Dairy Federation 1997).[1] Mastitis is the inflammation of the mammary gland caused by bacterial infection (Huijps 2009) and remains a particular and costly challenge for the dairy industry as despite recognised best practice many farmers are still not adopting optimal herd health management techniques (Dillon et al. 2016; Huijps et al. 2010a). The economic losses of animal diseases such as mastitis are often underestimated by farmers due to the mostly hidden effects such as reduced milk quality and processability (Klerkx and Jansen 2010; van Asseldonk et al. 2010).

This paper identifies the drivers and barriers to optimum herd health management and specifically explores the role of farmers' attitudes towards animal health in influencing their uptake of mastitis management best practice. Previous international research has highlighted the effectiveness of particular practices such as milk recording and improved hygiene in enhancing herd-health and reducing mastitis incidence (Barkema et al. 1998, 1999; Huijps et al. 2010a and Dufour et al. 2011) and as such the utilisation of these practices are generally described here as "best practice". Exploratory factor analysis is used to derive measures of farmers' attitudes towards animal health and mastitis and econometric techniques are then employed to empirically assess the influence of these on the uptake of "best practice". The effect of farm-level structural factors and other pertinent characteristics of the farmer are also considered with the overall objective of identifying the drivers and barriers to the adoption of a range of mastitis management techniques. The data utilised in the analysis are Irish nationally representative farm-level data from 2013. These data are complemented by qualitative data garnered through a number of focus groups with farmers which provides further insights on technology adoption and practice implementation.

Social psychology methodology has been widely used in the literature to gain insights into peoples' attitudes, decision-making processes and managerial behaviour and to identify particular influences on behaviour that could be targeted for change (Barkema et al. 1999; Beedell and Rehman 1999; Sutton 2002; Jansen et al. 2009). According to Jansen et al. (2009) farmers' attitudes are a better measure than their self-reported behaviour to explain and predict differences in mastitis incidence between farms. The conceptual framework linking attitudes to behaviour is guided in large part by the theories of reasoned action and planned behaviour (Ajzen 1991; Ajzen and Fishbein 1980) the latter of which describes three predictors of behavioural intention (and thus behaviour), as attitude, subjective norm and perceived behavioural control. For our purposes, the health belief model developed by Hochbaum, Kegeles, Leventhal and Rosenstock (Rosenstock 1974) is of interest. The model suggests that a person's belief in a personal threat of a disease or illness together with their belief in the effectiveness of the recommended health behaviour or action will predict the likelihood the person will in turn adopt a particular behaviour. This paper, in its exploration of the role of farmers' attitudes in influencing their uptake of mastitis management best practice concludes that attitudes are not a key driver in this instance. According to the analysis, farmers' perceptions around disease risk are of more relevance and the hypothesis that farmer behaviour is reactionary as opposed to precautionary is supported by both quantitative and qualitative evidence. Potential barriers to the uptake of best practice include routine inertia as well as constraints around the availability of labour and time. In the context of these research findings relevant cues in modifying farmer behaviour with regard to animal health management are thus identified. As with previous research undertaken in this area the valuable role of the extension agent in influencing farmer uptake of recommended herd health management practices is validated. However, it is concluded that such engagement around knowledge transfer and technology adoption is particularly complex.

Background

Mastitis is a costly disease, due to losses (a reduction of output) and expenditure (additional inputs required to treat the disease). Jansen et al. (2009) contend that when mastitis incidence increases, either infection pressure has increased or cows' resistance has decreased, usually indicating that farm management is not optimal. It is important therefore to demonstrate herd health best practice with regard to mastitis to farmers, and to describe the disease in monetary terms. Previous research by Dillon et al. (2015) illustrated the potential productivity and profitability gains associated with the improved control of subclinical mastitis and has in line with prior international research, highlighted the relative importance of farmer behaviour in

[1] Somatic cell count is the number of cells present in milk (body cells as distinguished from invading bacterial cells) and is used as one indicator of udder infection. Somatic cells are made up of a combination of white blood cells and epithelial cells. White blood cells enter milk in response to inflammation, which may occur due to disease, or occasionally to injury. Epithelial cells are shed from the lining of the udder tissue. White blood cells make up the majority of the somatic cells, especially when the cell count is raised (Blowey and Edmondson 2010). Sub-clinical cases occur when the cell count level is elevated although the cow is not showing any clinical signs of the disease. As any indicator, it should be acknowledged that is not a perfect measure of milk quality, i.e., bulk tank readings can be influenced by factors such as the exclusion of milk from cows with high SCC or stage of lactation etc.

the optimum management of herd health. Furthermore, the effectiveness of management practices such as milk recording and improved hygiene methods in reducing mastitis incidence have been confirmed by amongst others Barkema et al. (1998) and Dufour et al. (2011). However, despite this, according to the literature, the adoption and implementation of management practices to control mastitis is an action of behavioural change which in general can be difficult to achieve and sustain. Difficulties in modifying actual behaviour are not unique to agriculture; for example, Kennedy et al. (2009) found that although international research has shown increases in environmental values and beliefs over the past four decades, a parallel increase in environmentally-supportive behaviour has not been observed. Similarly, Auger and Devinney (2007) found that despite their ethical intentions, ethically minded consumers rarely purchase ethical products. That is to say, despite stated preferences with regard to intention to purchase and willingness to pay, the level of influence of ethical issues may vary across consumers depending on the specific situation and context (e.g., the type of product, the specific type of issue, the nature of the purchase situation, etc.). The well documented phenomenon of the 'intention-behaviour gap' is of relevance here, i.e., although some people may develop an intention to change their behaviour with regard to their health for example, they might not take any action. To this end, the adoption and maintenance of physical exercise to improve health has been examined by many including Falko et al. (2005); Amireault et al. (2008) and Schwarzer (2008) who conclude that planning, perceived self-efficacy and perceived behavioural control may be important post-intentional factors or volitional variables. Equally, there is now wide recognition within the agricultural literature (Fairweather and Campbell 2003; Rehman et al. 2007; Wauters et al. 2010; Howley et al. 2015; Toma et al. 2013) that in addition to economic factors, farmer behaviour may be influenced by farmers' attitudes and indeed previous research by Valeeva et al. (2007) and Huijps et al. (2010b), amongst others, have cited their influence in explaining within-herd mastitis incidence.

Attitudes have been defined by Willock et al. (1999) as 'a positive or negative response towards an attitude object' (where an attitude object may be a person, idea, concept or physical object) and are formed by what an individual perceives to be true about the attitude-object. This perception may or may not be based upon information and knowledge and/or an emotional reaction towards the object. According to Hansson and Lagervist (2014) attitudes are driven by the references people make to the world and are therefore influenced by 'framing effects and context effects' (Kahneman and Sugden 2005). Equally, previous research by Edwards-Jones (2006) has shown a potential relationship between farmers' attitudes and other aspects of their personal characteristics (i.e., education). It is therefore generally accepted that the influence of attitudes, norms, habits and expectations can accurately predict behaviour. In examining the particular role of attitudes in explaining farmer behaviour, previous research by van Huik and Bock (2007) and Hansson and Lagervist (2014) has found that identifying farmers' attitudes to farm animal welfare is an important step in determining their behaviour in this regard. Similarly, Bruijnis et al. (2013) found that attitude and intention were important in examining the drivers and barriers of dairy farmers in taking action to improve dairy cow foot health. In the same way, the exploration of farmers' attitudes towards animal health and mastitis (themselves welfare issues), is undertaken here to investigate their potential influence on farmer uptake of recommended herd health management practices. It should be acknowledged here that animal health is a component of welfare but does not equal welfare, i.e., an animal in good health can suffer poor welfare (although in the long-term, poor welfare will contribute to health problems) and animals with poor welfare are highly susceptible to infectious diseases such as mastitis.

In addition to attitudes, previous research (Pannell et al. 2006; Fraser et al. 2010; Garforth et al. 2013) has found that farmer uptake of new management practices is influenced by perceptions around adoption costs, general distrust in their economic advantage, lack of knowledge and difficulties around implementation. Insights into these factors and their impact on farmers' management behaviour were garnered in this analysis through a number of focus groups with farmers. This component of the research helped to identify key drivers and barriers to the uptake of best practice with regard to mastitis management to gain a better understanding of how best to engage with those farmers whose behaviour remains sub-optimal in this regard.

Methods

Despite the accepted value of particular herd health management practices, general farmer uptake is not always optimal. An indication as to why this is the case is vital if behavioural change is desired. As such, a clearer understanding of the relationship between relevant attitudes and on-farm decision making is important. To this end, it is hypothesised here that attitudinal data relating to animal health and mastitis prevention can help inform the drivers of and barriers to particular mastitis management techniques. That is to say that positive attitudes towards same would be influential in the uptake of "best practice" by farmers. Teagasc National Farm Survey (NFS) data are utilised here in moving from a conceptual framework to an empirical investigation at the farm-level. The NFS is operated as part of the Farm Accountancy Data Network (FADN) of the EU and fulfils Ireland's statutory obligation to provide data on farm output, costs and income to the European Commission. A random, nationally representative sample is selected annually in conjunction with the Central Statistics Office (CSO). Each farm is assigned a weighting factor so that the results of the survey are representative of the national population of farms.[2] Farms are assigned into six farm systems on the basis of farm gross output, as calculated on a standard output basis. Standard output measures are applied to each animal and crop output on the farm and only farms with a standard output of €8000 or more are included in the sample (Hanrahan et al. 2014). For the purposes of this paper, the data utilised relate to that collected on specialist and mixed dairy farms in 2013 ($N=283$). In order to elicit farmers' attitudes to animal health generally and mastitis more specifically, survey respondents were presented with a series of statements and asked to state how much they agreed or disagreed with these on a Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*). The statements were based on similar statements drawn from the literature (Jansen et al. 2009, 2010a, b; Huijps et al. 2010b). Exploratory factor analysis was first used to reduce the attitudinal data collected to a number of latent constructs with the objective of deriving measures of farmers' attitudes towards animal health and mastitis. Econometric techniques were then utilised to empirically assess the influence of the latent constructs identified on the uptake of a range of mastitis management practices. The econometric models used also considered the effect of particular farm-level structural factors and other pertinent characteristics of the farmer, with the overall objective of identifying the drivers of and barriers to farmer adoption of animal health "best practice". This resulted in the design of two separate logistic regression models with dependent variables relating to practices around (1) milking hygiene and (2) herd management. The decision to examine the uptake of best practice in this way was because of the broad range of practices in question and the need to gain a deeper understanding of farmer behaviour relating to these more specifically than generally.

Logistic regression models imply a non-linear relationship between the explanatory variable and a dichotomous dependent variable (Greene 2011). Under this specification the coefficients cannot be directly interpreted with any substantive meaning. However, logistic regression allows for the calculation of odds ratios (the ratio of the odds of an event occurring to it not occurring) by taking the exponential of both sides of the equation. Coefficients are derived that make observed values most 'likely' to occur for a given set of independent variables. In this instance, the influence of farmers' attitudes towards animal health and mastitis as well as a range of other relevant characteristics relating to both the farmer and the farm on the probability of farmers' optimum management of herd health is of interest. In addition, the efficacy of particular mastitis management practices is also explored using ordinary least squares (OLS) regression methods.

Finally, two focus groups with dairy farmers were carried out in November 2014, the findings of which enriched the quantitative analysis undertaken. To allow for some degree of regional variation, the focus groups were held in two distinct areas of the country. Recruits to both focus groups were from discussion groups active in the respective areas. Letters of consent to participate in the focus groups were signed by all farmers. Both focus groups lasted approximately 50 min. The focus groups concentrated on gathering data on the strategies farmers follow and their implementation of, attitudes towards, and opinions on, a range of mastitis prevention, diagnosis and treatment technologies and practices, and breeding technologies and practices. The discussion was recorded and subsequently transcribed. Analysis of the transcripts was done manually, proceeding from coding to categories to themes (Lichtman 2013). This qualitative approach helped gain a more in-depth understanding around technology adoption and practice implementation and thus the potential drivers and barriers around best practice adoption by farmers. The contribution of mixed methods for complex research questions has been well documented in the literature by Creswell and Plano-Clark (2007), Creswell (2012) and Mertens (2015) amongst others.

Results

Factor analysis

Survey responses (contained in Appendix 1) indicate that farmers' attitudes towards animal health are generally positive and suggest that the economic gain from improved animal health and mastitis management is overwhelmingly recognised even when there is a cost involved, e.g., 98% of farmers agreed with the statement: "Improving animal health will increase profit on the farm." Results further indicate that farmers recognise the importance of seeking

[2] Data on over 1000 farms representing a farm population of over 105,000 farms were collected up to 2012 when sampling changes were made, i.e., in 2012 data were collected on 922 farms representing a farming population of 79,292. The 2010 census of agriculture as conducted by the Central Statistics Office recorder the population of farms at 139,829. As pigs, poultry and farms with a standard output of less than €8000 are excluded within the NFS, 79,292 were represented in 2012.

advice and information from others i.e., although 75% report adequate knowledge around mastitis control, 60% would like to learn more about the disease from their peers and (59%) by attending CellCheck workshops (farmer workshops facilitated by a team of trained service providers including veterinary advisors, farm advisors, milking machine technicians and co-op milk quality advisors).[3] Interestingly it would appear (in line with the literature) that the stick is better than the carrot in incentivising farmers to reduce SCC within the herd, i.e., a penalty imposed on milk with a high cell count is more effective than a bonus offered for milk with a lower cell count with 87% of survey respondents agreeing with the statement "The penalty imposed on milk with a high SCC encouraged me to lower SCC in the herd" as opposed to only 42% who disagreed with the statement: "The bonus on offer for milk with a lower SCC is not enough for me to make efforts to reduce SCC in the herd."

With regard to general animal health management the majority of respondents contend that new methods should first be proven on other farms. One could hypothesise that this somewhat removes the risk in undertaking novel methodologies at farm-level. Indeed there is much empirical evidence (Marra et al. 2003 and Yesuf and Bluffstone 2007) to suggest that risk aversion can act as a barrier to farmers in adopting efficiency-enhancing technologies. Furthermore, previous research has proven the effectiveness of benchmarking (the process used to identify, learn from and adapt better practices from other farmers) in improving farm performance, efficiency, sustainability and profitability (Kahan 2013; Kragten and de Snoo 2003). Such feedback to farmers motivates them to compete, provides an incentive system and demonstrates the economic return possible if certain performance criteria are met. As with previous research undertaken in the area of technology adoption by Baumgart-Getz et al. (2012) the importance of access to information and the valuable role of participatory extension in influencing farmer uptake of recommended best practice is validated here. The qualitative data in particular identified farmer discussion groups as critical sources of independent advice with trust and confidentiality amongst farmers developed over time. According to one focus group participant "It's all about helping each other." Despite this, it is clear that challenges remain around effective knowledge transfer and exchange in order to engage with more diverse farmers who are currently not engaged in such groupings. When this very issue was discussed at the focus group participants maintained that those 'hard to reach' farmers were set in their ways or don't want to change. Farmer age and lack of time were also put forward as reasons why they may not attend a discussion group or CellCheck meeting.

For the most part, respondents acknowledge the need to innovate in farming i.e., 87% agree with the statement "To survive farmers need to adapt to new ways of farming" however, conversely, 34% would prefer to use current practices at the expense of economic gain. Similarly, 24% of respondents acknowledge that there is more to farming than making money. To this end some interesting work previously undertaken by Howley (2015) and Howley et al. (2014) cites the role of non-pecuniary benefits in explaining why some farmers act in a non-profit maximising manner. In other words, while costs and returns are clearly important, non-pecuniary benefits may make some choices more attractive than alternatives which may be more rewarding financially. Almost three quarters of respondents report that previous experience of mastitis influenced their management behaviour: "After having mastitis in the herd I started managing things differently," a finding which is also reflected in the qualitative analysis undertaken here where one focus group participant stated: "if I had a few high [cell count cows]….I'd pre spray [disinfect] them as well before I wipe them down." Similarly, Toma et al. (2013) in their study of biosecurity on British farms found that farmers' who experienced disease outbreaks in the past were more likely to apply more biosecurity measures and utilise relevant biosecurity information sources. Interestingly, the survey data here indicate that although the majority of respondents don't generally cite a lack of time as a potential barrier to the uptake of best practice, 29% were in agreement with the statement "I do not have time to carry out all of the measures needed to prevent mastitis." Similarly, time constraints did emerge as an obstacle to the uptake of certain management practices during discussions at the focus groups. Finally, although the qualitative data did not indicate that cost constraints were a particular barrier to optimum mastitis management within the herd 36% of the survey respondents cited it as such agreeing with the statement that "Carrying out all of the measures needed to prevent mastitis costs too much."

Exploratory factor analysis was used to reduce the attitudinal statements to a number of latent constructs. This resulted in three factors with an eigenvalue greater than one which were then retained for further analysis. A number of tests were applied to determine the suitability of respondents' answers to these attitudinal statements for factor analysis and they were as such deemed adequate. The three factors combined explained 53% of the variation in respondents' response patterns. These three derived latent constructs reflect farmers' attitudes towards animal health and mastitis management.

[3] Further information on the CellCheck programme can be found at: http://www.animalhealthireland.ie/page.php?id=29.

Table 1 Factor analysis of animal health related attitudinal statements

	Animal health	Reluctant	Knowledge	Mean scores
Improving animal health will increase profit on the farm	**0.72**	−0.08	0.11	6.5
It is important to learn from other farmers about new ways of farming and improving animal health	**0.56**	0.23	−0.09	5.9
Looking after animal health is important even if it costs money (e.g., bringing a sick animal to the vet)	**0.48**	−0.15	0.09	6.3
It is important to seek advice before making decisions about animal health	**0.40**	−0.15	0.24	5.8
I know enough about mastitis to control the disease in my herd	0.03	0.00	**0.59**	5.2
The most annoying thing about mastitis is the financial loss	0.06	0.11	**0.51**	5.5
I do not have time to carry out all the measures needed to prevent mastitis	−0.06	**0.65**	−0.08	3.0
The bonus on offer for milk with a lower SCC is not enough for me to make efforts to reduce SCC in the herd	−0.05	**0.41**	0.06	3.8
Carrying out all the measures needed to prevent mastitis costs too much	−0.07	**0.54**	0.27	3.6
Reducing SCC will increase farm profit	0.26	0.17	**0.43**	6.4

Bold values relate to the highest loading statements on each factor

Extraction method principal axis factoring, *rotation method* varimax with Kaiser Normalization

Factor loadings are contained in Table 1 these are the weights and correlations between each attitudinal statement and the derived latent constructs. The higher the loading the more relevant the statement is in defining the factor's dimensionality. The statements that had high loadings for factor 1 were mainly associated with attitudes towards animal health. Examples of such statements include "Improving animal health will increase profit on the farm" and "It is important to learn from other farmers about new ways of farming and improving animal health" and as such this factor variable was labelled as 'animal health'. The statements that had high loadings for factor 2 were primarily related to barriers to undertaking particular management practices such as "I do not have time to carry out all the measures needed to prevent mastitis" and "Carrying out all the measures needed to prevent mastitis costs too much" and therefore this factor variable was labelled as 'reluctant'. The third factor comprised of statements relating to mastitis control and was thus labelled 'knowledge' with statements such as "I know enough about mastitis to control the disease in my herd" and "The most annoying thing about mastitis is the financial loss." The higher a farm operator's score on each of these factor variables, then the higher their overall level of agreement with the statements that make up that factor. Factor scores were subsequently utilised in the regression models to examine the influence of these factor variables on the uptake of best practice with regard to herd health management.

Uptake of herd management best practice

Information on farmers' uptake of a range of herd management practices which have previously proven effective in reducing mastitis within the herd was captured within the survey. As expected, the vast majority of respondents (98%) reported that they generally monitored SCC within the herd. To this end a number of different practices were utilised with almost half (45%) measuring SCC through milk recording. The advantage to farmers of monitoring milk quality and managing diseases like mastitis through milk recording is that it provides detailed information on milk composition on a per cow basis, allowing for the further investigation of cows with elevated cell counts that may not have visible signs of infection, but could spread infection within the herd and raise overall herd-level (milk bulk-tank) SCC. Previous research by Dillon et al. (2016) found that both agricultural education and extension are positively related to the uptake of milk recording by farmers therefore it is positive that 74% of survey respondents had undertaken some form of agricultural training and 80% were in contact with an advisory service. Notwithstanding this, there is a wide variation in farmer behaviour more generally with regard to the uptake of the mastitis management practices as reported in Table 2.

The recommended practices can generally be grouped into two categories: milking hygiene and herd management. Hygiene related practices around milking refer to practices such as the wearing of gloves when milking and teat pre- and post- (milking) cleaning and all are useful in terms of mastitis prevention. On the other hand, farmer engagement with practices such as milk recording (monitoring of individual cow and bulk tank milk quality), forestripping (manual checking suspect cows for abnormal milk prior to milking), milking mastitis cows separately and checking new entrant cell count can be thought of as being more diagnostic in nature. Although the majority of respondents appear to engage with relatively simple hygiene practices around milking such as wearing gloves and pre- and post-cleaning there remains a significant cohort whose behaviour could be improved on, i.e., 90 and

Table 2 Farmer uptake of herd management and milking hygiene practices

Farmer behaviour (frequency)	Never (%)	Always (%)	Sometimes (%)	Daily (%)	Weekly (%)	Monthly (%)
Wear gloves	24	54	22			
Milk mastitis cows separately	24	65	11			
Check new entrants SCC	47	44	9			
Check milk vacuum	15			29	27	29
Forestrip cows	36			53	7	4
Pre-clean	14			74	6	6
Post-disinfect	7			90	2	1

74% post-disinfect and pre-clean respectively; however, a lack of consistency is found with regard to wearing gloves with only half wearing them at each milking. This constitutes a simple change in the milking routine which could be adopted easily by farmers. On this, the specific reasoning behind why gloves are actually worn when milking has previously been investigated in England by Garforth et al. (2013) who found that the wearing of gloves may simply constitute habitual behaviour as opposed to a specific attempt to reduce disease risk. Likewise, similar insights were found through the focus groups conducted with farmers as part of this research which found that the wearing of gloves for some was more for their own comfort as opposed to a disease risk reduction strategy, this is reflected in the following statement: "[I wear them] sometimes, it could depend, I could wear them for a week and then I mightn't wear them…" To this end, Garforth et al. (2013) in their study highlight the need for further education and communication to enable farmers to recognise the 'unseen' risk of disease given differences in risk perception between farmers and other stakeholders.

Furthermore, the survey data collected here indicate that only 65% of respondents routinely milk cows identified with mastitis separately with 24% never doing so. This practice is generally recommended as the risk of spreading mastitis via the milking machine cluster is eliminated. Finally, forestripping has been cited as an effective way to detect clinical cases of mastitis however just over half of respondents do so daily with over one-third of respondents never doing so. Given the lack of buy-in by some farmers to such practices proven to be effective in reducing mastitis infection, this paper seeks to explore what factors are related with farmers' uptake of best practice in this regard.

Efficacy of mastitis management practices

An OLS regression model was first utilised to evaluate the efficacy of certain herd management practices in improving mastitis health. This involved an examination of the relationship between farmer uptake of such practices and actual herd-level SCC. The relevant results contained in

Table 3 Efficacy of mastitis management practices—effect on herd-level SCC

Weighted bulk-tank SCC ('000 cells/ml)	Coef.	Std. Err.	P>t
Forestripping*	17.8	10.5	0.09
Pre-cleaning	17.3	12.3	0.16
Post-disinfection**	−36.8	15.9	0.02
Wear gloves	1.0	10.4	0.92
Milk Recording**	−32.1	12.2	0.01
Separate mastitis cows	−16.4	11.0	0.14
Check new entrant SCC	0.2	10.8	0.99
Check milk vacuum**	20.3	11.5	0.08
Extension contact (incl. participatory)***	−37.9	11.6	0.00
Attended CellCheck workshop**	28.2	10.8	0.01
Farmer age	0.1	0.5	0.81
Stocking rate*	15.9	8.8	0.07
Constant	240.2	33.8	0.00

*Statistically significant at 10 percent level

**Indicates statistically significant at 5 percent level

***Indicates statistically significant at 1 percent level

$N=275$, $R^2=0.20$

Table 3 indicate the negative and significant relationship between milk recording and post-milking teat disinfection on bulk-tank SCC (which takes account of weighted monthly deliveries across farms). The influential role of extension contact and discussion group membership in mastitis control is also confirmed by the model however, it should be acknowledged that selection bias may exist, i.e., farmers who are more likely to have lower herd-level SCC are more likely to seek out extension contact.[4] The findings in relation to the regression analysis support our hypothesis that farmer behaviour with regard to mastitis management is in fact reactionary not precautionary. This is evident by what at first glance can be seen as a counterintuitive result in that farmer engagement with some

[4] Extension contact is defined by the Teagasc National Farm Survey as farm contact with the Teagasc advisory service. Teagasc is the Irish Agriculture and Food Development Authority.

practices (i.e., forestripping and checking of the milk vacuum) are positively related with SCC. One likely explanation is that many farmers do not see these practices or at least use these practices as a mechanism for preventing SCC, but rather as a strategy to be employed once an outbreak is evident. The results relating to attendance at a CellCheck meeting would also support this view as discussions at the focus groups implied that those farmers encountering mastitis problems within the herd are more likely to attend such events, with one participant adding: "…you don't go to them unless you need to." Similarly, another acknowledged that he started pre-milking teat cleaning when he encountered a cell count problem but "stopped doing it when the cell count came down…when it was really bad we used it and it seemed to work."

Variables relating to the wearing of gloves and pre-cleaning teats are found not to be significant within the model and it is likely that issues around actual routine and frequency of use by farmers are important here. Indeed, insight from the focus groups around the wearing of gloves as outlined earlier confirms this. In addition, previous research by Rougoor et al. (1999) and McCoy (2013) reports that a significant gap exists between the routine practices and behaviours that farmers report, and the standard to which those practices are carried out. Furthermore, in a systematic review of the literature regarding the efficacy of mastitis management practices Dufour et al. (2011) maintained that additional guidance was needed with regard to certain practices which failed to show consistency.

An interesting aspect with regard to farmer buy-in for certain practices is the potential for a hierarchy of importance, i.e., given time, labour and other constraints, the marginal benefit of particular practices may be taken into consideration. For example, post-milking disinfection may be deemed as being most time efficient and effective and therefore may be preferred to a range of other ancillary practices which are regarded as less important for mastitis prevention, e.g., pre-milking cleaning of teats. The magnitude of the coefficient for the former in the regression model may indeed support this argument. Feedback from the focus groups also indicated that although pre-milking cleaning may be effective it would be time consuming: "Probably the teat dipping would be an idea but it would take a long time." Previous research by Jansen et al. (2010a) and Garforth et al. (2013) has found that farmer assessment of practice efficacy and practicability are indeed important factors influencing practice uptake. In addition, Gunn et al. (2008) underline the need for evidence of effectiveness before implementation, a sentiment which is reflected in the survey results here, i.e., 72% of respondents agree that new farming methods should first be proven on other farms. In this instance, the efficacy of and resultant farmer buy-in with regard to milk recording was confirmed through discourse at the focus groups ("the benefit is bigger than the cost" and "it's the first thing because you're on top of the problem before it even becomes one"). The impact of milk recording on cell count reduction is also confirmed by this model.

Influence of attitudes on best practice uptake

Two separate logistic regression models were developed to explore the relationship between the derived factor variables reflecting farmers' attitudes to animal health and mastitis and optimum herd health management, i.e., uptake of recommended best practice. Two separate dependent variables were examined in each of the models: (1) hygiene and (2) herd management. The hygiene related practices in question relate to the wearing of gloves and teat pre- and post-cleaning and was equal to one if farmers engaged with more than one of these practices and zero otherwise. On the other hand, farmer uptake of more than one of milk recording, forestripping, milking mastitis cows separately and checking new entrant cell count resulted in the herd management variable being assigned a value of 1 or 0 otherwise. Each are defined on the basis of the undertaking of 'more' versus 'fewer' of these practices as only a small number of farmers do not undertake any. Table 4 contains summary statistics on farmer engagement with the relevant herd hygiene and management practices as well as other relevant data relating to the remaining explanatory variables utilised in the regression models. These control variables reflect personal farmer characteristics such as agricultural education and extension contact and differences in farm structural characteristics (e.g., stocking rate). Apart from helping us to identify the effect of our factor variables, the relationship between these variables and farmer practices should also be of interest in their own right.

Regression results from the herd management model indicate a variation across the attitudinal factors in terms of influence on the uptake of best practice by farmers. In presenting results from the regression model, Table 5 contains the odds ratios for both a unit and standard deviation change in the independent variables. Examining the effect of a standard deviation change is particularly useful when variables have heterogeneous scales as is the case here. For ease of interpretation, the percentage change in the odds of engaging in particular herd management practices are given as opposed to the multiplicative or factor change. Post-estimation tests indicate that the model is of good fit and the overall rate of correct classification was 76%.[5]

[5] A set of count data (Poisson) models was also estimated for herd management and hygiene practices respectively. Although little difference was found in terms of key findings and conclusions across

Table 4 NFS dataset relevant summary statistics 2013

Variables	Range	Mean	SD	Min	Max
Hygiene practices					
Always wear gloves	1 = Yes, 0 = No	0.54	0.50	0	1
Clean teats before milking	1 = Yes, 0 = No	0.74	0.44	0	1
Disinfect all teats after milking	1 = Yes, 0 = No	0.90	0.30	0	1
Herd management					
Always milk mastitis cows separately or last	1 = Yes, 0 = No	0.65	0.48	0	1
Check new entrants to the herd for high SCC	1 = Yes, 0 = No	0.44	0.50	0	1
Forestrip cows before milking	1 = Yes, 0 = No	0.53	0.50	0	1
Practice milk recording	1 = Yes, 0 = No	0.45	0.50	0	1
Farmer characteristics					
Age	Age of farm operator	52.9	10.2	24	89
Agricultural education	1 = Yes, 0 = No	0.74	0.44	0	1
Extension contact	1 = Yes, 0 = No	0.80	0.40	0	1
Dairy discussion group participation	1 = Yes, 0 = No	0.49	0.50	0	1
CellCheck participation	1 = Yes, 0 = No	0.31	0.53	1	3
Financial monitoring (Extension provided)	1 = Yes, 0 = No	0.52	0.50	0	1
Stocking rate	Herd Size/UAA	0.96	0.52	0.4	5.4

Table 5 Herd management regression results

Herd management = 1 if respondent engaged with *more than one* of the following practices: Milk recording Forestripping Milk mastitis cows separately Check new entrants for high SCC	Coef.	P > z	%	%StdX	SDofX
Animal health	0.09	0.60	9.90	7.60	0.78
Reluctant**	−0.55	0.02	−42.5	−32.70	0.72
Knowledge***	−0.81	0.00	−55.70	−42.90	0.69
Agricultural training	−0.09	0.80	−8.20	−3.70	0.44
Extension contact (incl. participatory)**	1.00	0.01	170.80	64.70	0.50
Attended CellCheck workshop	0.14	0.67	14.70	6.60	0.47
Farmer age	0.01	0.63	0.70	7.90	10.73
Stocking rate**	−0.72	0.00	−51.50	−38.00	0.66
Financial monitoring (eProfit)	−0.50	0.21	−38.30	−21.50	0.50
Hygiene**	0.73	0.04	106.90	32.00	0.38

% Percentage change in the odds of undertaking herd management "best practice"

%StdX percentage change in the odds of undertaking herd management "best practice" for a standard deviation change in the explanatory variable

SDofX the standard deviation of the relevant explanatory variable

*Statistically significant at 10 percent level

**Statistically significant at 5 percent level

***Statistically significant at 1 percent level

Model results indicate that the factor 'reluctant' was negatively associated with the probability of farmer uptake of 'herd management' practices. This is as expected because (survey) statements with regard to lack of time and cost constraints around mastitis control loaded on to this factor. The effect is found to be substantial with a one standard deviation increase corresponding to a 33% decrease in

Footnote 5 (continued)

the model specifications the logit models were preferred on the basis of superior goodness of fit, though the Poisson models provide additional evidence for the robustness of our findings. The results from these Poisson models are available from the authors on request.

the odds of the uptake of recommended herd management practices. Time constraints and labour shortages were also confirmed by the qualitative data as factors in farmers' not undertaking particular management practices. An increase in stocking rate (a proxy for farming intensity) was also negatively and significantly related to the probability of best practice uptake. This result appears somewhat counterintuitive but a shortage of labour input is hypothesized as the reason. The influence of extension contact (including participatory discussion group membership) on the probability of uptake of certain herd management practices is confirmed by the model, the relationship being significant. The effect is found to be substantial with a one standard deviation increase corresponding to a 65% increase in the odds of improved herd health management. This finding is in line with previous research by Edwards-Jones (2006) and Dillon et al. (2015) which have confirmed the role of extension contact in influencing farmer behaviour with regard to SCC control. The impact of formal agricultural training is not found to be significant in this instance however.

The factor 'knowledge' is negatively and significantly associated with the probable uptake of the herd management practices in question. This implied negative relationship is somewhat surprising as respondents reported adequate knowledge of both the financial implications and the actions required to control the disease with statements such as "I know enough about mastitis to control the disease in my herd" and "Reducing SCC will increase farm profit" loading on to this factor. Although a reflection of security in their own knowledge, the model illustrates that these farmers are not in fact adequately engaging with effective herd health management practices. This is in line with previous research by Klerkx and Jansen (2010a) who found that the majority of farmers believe they have adequate knowledge around disease prevention and are confident that they are already doing enough. The possibility of 'routine inertia' may serve as a potential explanation for this, i.e., farmers may not see the need to deviate from their established routine as they do not currently have a mastitis problem within the herd. Issues around disease risk and whether or not the farmer perceives disease as being relevant to him has previously been reflected upon by Garforth et al. (2013) who found that even though farmers feel they have adequate knowledge and awareness around disease control this is not a sufficient condition for implementation. Likewise, previous research by Jansen et al. (2010a) concludes that although farmers' report adequate knowledge of preventive practices and acknowledge the financial losses associated with disease these are only considered relevant to them if a disease problem is perceived within the herd. In addition, the qualitative component of this research indicates that farmers are strongly influenced by practice and implement what is familiar, i.e., they generally persevere with the routine they have developed around mastitis prevention, whether or not it happens to be an optimal strategy, in the absence of any indication of infection or event that will cause them to reassess their routine. To this end, routine inertia as well as constraints around time and labour are put forward as barriers to the uptake of optimum herd management techniques. The finding that cost is not the main barrier to best practice uptake around mastitis management was previously confirmed by Valeeva et al. (2007) and Klerkx and Jansen (2010). Further insights from the focus groups infer that although some inertia exists around herd health management there is a certain amount of 'routine creep', where farmers adjust what they do in response to what is accepted as best practice among their discussion group, for example. To this end, the importance of 'learning by sharing' through such fora has been validated in this analysis. The qualitative data further confirm that in managing their farms, farmers are making decisions about the particular bundles of technologies and practices they use on the basis of various trade-offs in terms of time implications, convenience, effort, impact on overall farm profitability, what has worked in the past, and what is considered the norm in terms of their peers. These decisions are made in a context of uncertainty and downstream supply chain signals and incentives, and the current situation in terms of health status on their farms. The reactionary nature of their managerial behavior is also evident from the focus groups where one participant on foot of some high cell count readings stated: "I started this year to pre-dip and I found it of good benefit…I used to never pre- dip before." Similarly, Stott (2011) and Paterson et al. (2003) have previously found reactionary farmer behaviour in the context of foot-and-mouth disease biosecurity measures.

The second regression model utilised to examine farmer uptake of particular hygiene practices (wearing of gloves and pre- and post-milking teat cleaning) indicated that the derived attitudes and other pertinent farmer characteristics were of little relevance.[6] Therefore, the 'hygiene' variable was included here as an explanatory variable and was found to be positively and significantly related to the probability of a farmer engaging in diagnostic practices such as milk recording or forestripping. The model indicates that a one standard deviation increase in this variable results in a 32% increase in the odds of undertaking such practices. The fact that engagement in one particular practice is influential in terms of uptake of another is also found by Huijps et al. (2010a, b) in a similar study undertaken in the Netherlands

[6] Results from the model are contained in Appendix 2 Table 8.

and Khanal et al. (2010) who also describe a complementary relationship amongst technologies.

The difficulty inherent in influencing farmer behaviour was previously described by Van Asseldonk et al. (2010) who found that the majority of dairy farmers perceived cow-specific and herd-specific projected losses, due to elevated SCC levels, as not very relevant to them. The complexity of the communication process is further highlighted by Lam et al. (2011) and Hogeveen et al. (2011) who note that demonstrating to farmers the economic benefit of improved management of diseases such as mastitis is not always sufficient as cost-effective measures are not always implemented by the farmer whose objectives can be other than maximisation of profit. Results from the econometric models utilised here confirm that factors other than economic drivers are important in influencing improved mastitis management. Likewise, Gramig et al. (2010) have found that the resultant economic benefit of the uptake of safer dehorning methods was not of practical importance in that adoption decision. This is in line with research by Edwards-Jones (2006) and Valeeva et al. (2007) who found that individual farmer decisions on the implementation of recommended practices are also driven by non-monetary motivating factors internal to farm performance such as self-esteem as well as other external factors such as the wider social milieu and the characteristics of the innovation to be adopted. In terms of changing farmer behaviour, previous research by Nightingale et al. (2007) and Hogeveen et al. (2011) amongst others cite the important behavioural economics phenomena of loss aversion, which indicates that losses loom larger than gains, with farmers more sensitive to penalties rather than bonuses, a finding also reflected in the survey responses reported here. Similarly, Klerkx and Jansen (2010) report that farmers disregard losses relating to mastitis itself but dislike treatment costs, a finding which should thus be borne in mind in the context of future knowledge transfer design.

Conclusion

This paper concludes that farmers' attitudes towards animal health and mastitis are not a key driver in their uptake of related best practice. Despite reporting adequate knowledge of the financial losses associated with disease and recommended preventative practices for mastitis in particular this analysis indicates that farmers consider these as not being relevant to them if a disease problem is not perceived within the herd. This finding is in line with that of Garforth et al. (2013) who conclude that knowledge and awareness around disease control is not a sufficient condition for implementation. In the context of this research, a number of interesting issues arise in identifying barriers to the uptake of best practice, these include the possibility of routine inertia, i.e., farmers do not deviate from the routine developed around mastitis prevention until there is an indication of infection, as well as constraints around the availability of labour and time. The hypothesis that farmer behaviour is reactionary as opposed to precautionary is supported by both the quantitative and qualitative evidence presented.

Agricultural technology adoption has been described as complex by Meijer et al. (2015) who contend that it is influenced by both extrinsic (e.g., characteristics of the farmer and external environment) and intrinsic factors (e.g., farmer knowledge, perceptions, attitudes). This research allows for a deeper understanding of farmer behaviour around herd health management and provides insights for the effective communication of knowledge transfer, essential for improvements in animal health. Animal health improvements generally, and mastitis prevention more specifically, are of relevance not just to farmers and the wider dairy industry but also to society more generally given important implications for animal welfare, food safety and quality (Klerkx and Jansen 2010; Stott 2011). More broadly speaking, this research highlights the potential of social psychology methodology to gain insights into peoples' attitudes, decision-making processes and managerial behaviour and to identify particular influences on behaviour that could be targeted for change. In the context of these research findings relevant cues in modifying farmer behaviour with regard to animal health management are thus identified. As with previous research undertaken in this area the valuable role of the extension agent in influencing farmer uptake of recommended herd health management practices is validated; however, it is concluded that such engagement around knowledge transfer and technology adoption is particularly complex.

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Appendix 1

See Tables 6 and 7.

Table 6 Animal health attitudinal statements

	Disagree (%)	D. Know (%)	Agree (%)	Mean	SD
It is important to learn from other farmers about new ways of farming and improving animal health	1	11	88	5.9	1.1
Improving animal health will increase profit on the farm	–	2	98	6.6	0.8
To survive farmers need to adapt to new ways of farming	4	9	87	5.7	1.3
Looking after animal health is important even if it costs money (e.g., bringing a sick animal to the vet)	1	4	95	6.3	1.1
It is important to seek advice before making decisions about animal health	1	9	90	5.9	1.2
New farming methods should first be proven on other farms	9	19	72	5.3	1.5
Farming is all about making money	24	15	61	4.7	1.9
It is important to isolate purchased stock for a number of weeks before mixing with the rest of the herd	13	22	65	5.1	1.6
It is better to stick with current farming practices even if it means less money is made	47	19	34	3.4	1.8

Table 7 Mastitis health attitudinal statements

Disagree (1–3)–Agree (5–7)	Disagree (%)	D. Know (%)	Agree (%)	Mean	SD
I know enough to control the disease in my herd	13	12	75	5.1	1.7
The most annoying thing about mastitis is the financial loss	14	8	78	5.5	1.8
After having mastitis in the herd I started managing things differently	8	20	72	5.1	1.6
I would like to learn more about mastitis by talking to other farmers	19	21	60	4.6	1.8
The penalty imposed on milk with a high SCC encouraged me to lower SCC in the herd	4	9	87	5.9	1.6
I would be interested in attending a CellCheck meeting to learn more about mastitis	22	19	59	4.7	2.0
Reducing SCC will increase profit	2	2	96	6.2	1.4
The most annoying thing about mastitis is the suffering of the animal	34	28	38	4.0	1.7
I do not have time to carry out all of the measures needed to prevent mastitis	61	10	29	3.0	2.0
Carrying out all of the measures needed to prevent mastitis costs too much	53	11	36	3.6	2.1
The bonus on offer for milk with a lower SCC is not enough for me to make efforts to reduce SCC in the herd	43	15	42	3.8	2.2

Appendix 2

See Table 8.

Table 8 Hygiene management regression results

Hygiene management = 1 if respondent engaged with *more than one* of the following practices: Wear gloves; Teat pre-cleaning; Teat post-cleaning	Coef.	P > z	%	%StdX	SDofX
Animal health	−0.02	0.92	−2.10	−1.70	0.78
Reluctant	−0.04	0.86	−4.30	−3.10	0.72
Knowledge	−0.14	0.55	−13.40	−9.40	0.69
Agricultural training	−0.27	0.50	−23.80	−11.20	0.44
Extension contact (incl. participatory)	−0.43	0.32	−35.30	−19.60	0.50
Attended CellCheck workshop	0.55	0.14	73.60	29.40	0.47
Farmer age	−0.01	0.50	−1.10	−11.40	10.73
Stocking rate	0.03	0.92	2.70	1.70	0.66
Financial monitoring (eProfit)	0.38	0.38	45.90	20.80	0.50
Herd management**	0.73	0.04	107.00	38.30	0.45

% Percentage change in the odds of undertaking herd management "best practice"

%StdX percentage change in the odds of undertaking herd management "best practice" for a standard deviation change in the explanatory variable

SDofX the standard deviation of the relevant explanatory variable

*Statistically significant at 10 percent level

**Statistically significant at 5 percent level

***Statistically significant at 1 percent level

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