Exploring the role of farmers' attitudes in influencing animal health best practice

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Abstract

Animal health is one of the key factors affecting the economic efficiency of the dairy industry and has important implications within an increasingly competitive marketplace. Despite the fact that the economic gains of '*best practice*' with regard to animal health have been well documented, many farmers are still not adopting optimal herd management techniques. This paper utilises Irish nationally representative farm-level data from 2013 to identify drivers and barriers to the adoption of '*best practice*' with regard to mastitis management. Exploratory factor analysis and econometric techniques (logistic regression methods) were employed here to empirically assess the influence of farmers' attitudes towards animal health and mastitis on the adoption of particular mastitis hygiene and herd management practices by farmers. 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 time and cost constraints. Farmer behavior with respect to mastitis management can thus be considered *'reactionary'* as opposed to *'precautionary.'* This research highlights the valuable role of the extension agent in influencing the uptake of animal health *'best practice'* but concludes that engagement around knowledge transfer and *'best practice'* technology adoption is particularly complex.

Keywords: Animal health, technology adoption, attitudes, behaviour.

JEL codes: Q100, Q160, and Q180.

1. Introduction

Improvements in milk quality are important if the Irish dairy industry is to grow sustainably and retain a competitive advantage in the context of EU milk quota abolition. In this regard, superior animal health has an important role to play. 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 presence of intra-mammary infection (Dohoo & 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 (Huijps et al. 2009, 2010). Indeed, the economic losses of animal diseases such as mastitis are often underestimated by farmers due to the mostly hidden effects (van Asseldonk et al. 2010). This paper explores the role of farmers' attitudes towards animal health in influencing their uptake of animal health '*best practice'*. The influence of farm-level structural factors and other pertinent characteristics of the farmer are also considered in affecting their probability of undertaking particular herd management practices to improve herd health. The overall objective of the analysis is to identify the drivers and barriers to the adoption of particular herd-level mastitis management techniques. The data utilised in the analysis is Irish nationally representative farm-level data from 2013. This data is complemented by qualitative data garnered through a number of focus groups with farmers which provides further insights on technology adoption and practice implementation.

2. 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 to

[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 & 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.

farmers, herd health '*best practice'* with regard to mastitis and to describe the disease in monetary terms. Previous research by Dillon et al., (2015) has illustrated the potential productivity and profitability gains associated with the improved control of subclinical mastitis and has in line with previous international research, highlighted the relative importance of farmer behaviour in 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 for a number of reasons. The underestimation of costs by farmers' and the influence of attitudes in explaining mastitis incidence have been cited by amongst others Valeeva et al. (2007) and Huijps et al. (2010b). This paper explores farmers' attitudes to animal health and mastitis as well as examining farmer behaviour with regard to herd health management. In particular, the uptake of particular practices to reduce mastitis incidence are explored. In examining farmer behaviour in this way the drivers and barriers to animal health '*best practice'* are identified helping gain a better understanding of how best to engage with farmers whose behaviour remains sub-optimal in this regard.

3. Methodology

In examining farm-level '*best practice'* with regard to mastitis management Teagasc National Farm Survey (NFS) data is utilised here. 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 €8,000 or more are included in the sample (Hanrahan, et al., 2014). For

[2] Data on over 1,000 farms representing a farm population of over 105,000 farms was collected up to 2012 when sampling changes were made, i.e., in 2012 data was 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 €8,000 are excluded within the NFS, 79,292 were represented in 2012.

the purposes of this paper, the data utilised relates 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 respondents were presented with a series of statements and asked to state how much they agreed or disagreed with these on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*). The statements were based on similar statements drawn from the literature. Exploratory factor analysis was used to reduce the data to a number of latent constructs and logistic regression analysis was then applied to examine the relationship between the latent constructs and a range of herd management '*best practice'* behaviours.

Logistic regression models imply a non-linear relationship between the explanatory variable and a dichotomous dependent variable. 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. The general equation for the logistic regression is:

$$\ln(Odds) = \propto + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \qquad (1)$$

The odds are related to the probability (p) by:

$$Odds = \frac{p}{1-p} \qquad (2)$$

The two equations can be combined into an equation for probability.

$$prob(event) = \frac{1}{1+e^{-(\propto + \beta 1 X 1 + \beta 2 X 2 + \cdots + \beta k X k)}} \qquad (3)$$

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. The exponential of the coefficients can be interpreted as follows: for a unit change in the independent variable, the odds of engaging in animal health *'best practice'* are expected to change by a factor of exp (β_n) holding all other variables constant. Within the paper, the influence of particular herd management practices on herd-level bulk-tank SCC is also explored using ordinary least squares regression methods. Finally, a number of focus groups with farmers were carried out, the findings of which enriched the quantitative analysis undertaken. This qualitative approach helped gain a more in-depth understanding around technology adoption and practice implementation and thus the drivers and barriers around *'best practice'* adoption by farmers.

4. Results

4.1 Factor analysis

Survey responses indicate that farmers' attitudes towards animal health are generally positive (see Table 1). The largest proportion of respondents (98%) were in agreement with the statement: *"Improving animal health will increase profit on the farm"* suggesting that the economic gain resultant from improved animal health is overwhelmingly recognised. This is again reflected when farmers' attitudes towards mastitis were considered (see Table 2) with ninety-six percent of respondents agreeing that: *"Reducing somatic cell count will increase profit."* As such, animal health is acknowledged to be important even when there is a cost involved. This is reflected in the fact that ninety-six percent of respondents were in agreement with the following: *"Looking after animal health is important even if it costs money (e.g., bringing a sick animal to the vet)."*

The results here indicate that farmers recognise the importance of seeking advice and learning from others. Although 75% report adequate knowledge around mastitis control 14% do not and almost two-thirds would like to learn more about the disease from their peers and by attending CellCheck workshops (farmer workshops facilitated by a team of trained service providers including veterinary advisors, farm advisors, milking machine technicians and coop milk quality advisors).[3] According to the majority of respondents, the financial loss (and not the suffering of the animal) is the most annoying aspect of the disease. 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.

Table 1: Animal health attitudinal statements

Disagree (1-3) - Agree (5-7)	*Disagree*	*D. Know*	*Agree*	*Mean*	*S. Dev.*
It is important to learn from other farmers about new ways of farming and improving animal health.	1%	12%	87%	5.9	1.1
Improving animal health will increase profit on the farm.	-	1%	98%	6.6	0.8
To survive farmers need to adapt to new ways of farming.	4%	10%	86%	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%	96%	6.3	1.1
It is important to seek advice before making decisions about animal health.	3%	9%	89%	5.9	1.2
New farming methods should first be proven on other farms.	8%	19%	72%	5.3	1.5
Farming is all about making money.	15%	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%	64%	5.1	1.6
It is better to stick with current farming practices even if it means less money is made.	54%	17%	29%	3.4	1.8

Interestingly, the majority of respondents contend that new methods should first be proven on other farms. One could hypothesise that this removes somewhat the risk in undertaking novel methodologies at the farm-level. For the most part, respondents acknowledge the need to adapt and innovate to survive in farming; however, conversely, 29% would prefer to use current practices at the expense of economic gain: *"It is better to stick with current farming practices even if it means less money is made."* Similarly, two-thirds of respondents acknowledge that there is more to farming than making money. To this end some interesting

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

work previously undertaken by Howley (2015) cites the role of non-pecuniary benefits in explaining why some farmers act in a non-profit maximising manner.

Almost three quarters of respondents reported that previous experience of mastitis influenced their management behaviour: *"After having mastitis in the herd I started managing things differently,"* a finding that is reflected in both the quantitative and qualitative analysis undertaken here. In taking into consideration perceived barriers to the uptake of best practice only about one-third cite time and cost as such.

Table 2: Mastitis health attitudinal statements

Disagree (1-3) - Agree (5-7)	*Disagree*	*D. Know*	*Agree*	*Mean*	*S. Dev.*
I know enough to control the disease in my herd.	14%	11%	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.	20%	21%	59%	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.	21%	19%	60%	4.7	2.0
Reducing SCC will increase profit.	3%	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%	28%	3.0	2.0
Carrying out all of the measures needed to prevent mastitis costs too much.	52%	12%	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%	16%	42%	3.8	2.2

Exploratory factor analysis was used to reduce the attitudinal statements to a number of latent constructs. This resulted in the omission of some statements. The method employed was principal axis factoring which allows for some measurement error. 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. As a measure of scale reliability, an adequate Cronbach's alpha was reported (.57).[4] The sampling adequacy was assessed by examining the Kaiser-Meyer-Olkin the value of which was found to be 0.66 which is also considered to be acceptable. The three factors combined explained 50 percent of the variation in respondents' response patterns.

Factor loadings are contained in Table 3 these are the weights and correlations between each variable and the factors. The higher the loading the more relevant the statement is in defining the factor's dimensionality. The derived latent constructs reflect farmers' attitudes towards animal health and mastitis management and were labelled *'animal health', 'reluctant'* and *'knowledge'* because of the nature of the relevant statements.

Table 3: 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

Extraction Method: Principal Axis Factoring. Rotation Method: Varimax with Kaiser Normalization.

[4] Cronbach's alpha is a measure of internal consistency of a scale, i.e. how closely related a set of items are as a group. It is expressed as a number between 0 and 1.

Factor scores were subsequently utilised in the regression models to examine the influence of these attitudes on the uptake of best practice with regard to herd health management.

4.2 Uptake of herd management best practice

An assessment of actual (self-reported) farmer behaviour was also undertaken within the survey with questions relating to how often if at all they carried out a range of herd management practices which have previously proven effective in reducing herd-level mastitis. As expected, the vast majority of respondents (98%) monitored SCC within the herd. Almost half of these (45%) did so 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 bulk-tank SCC. Previous research by the authors (Dillon et al., forthcoming) found that both agricultural education and extension are positively related to the uptake of milk recording by farmers therefore it is positive then that this survey indicates that 80% of respondents were in contact with an advisory service with more than half of these (58%) participating in dairy discussion groups. Furthermore, 75% of respondents had undertaken some form of agricultural training and 65% had previously attended a CellCheck meeting.

An indication of the actual routine around milking and the frequency with which certain practices are carried out is insightful with the relevant information contained in Table 4. Although the majority of respondents appear to engage with milking *'best practice'* a significant cohort remains whose behaviour could be improved on. Some of the key hygiene practices of importance in reducing mastitis within the herd relate to simply undertakings such as wearing gloves, pre-cleaning and post-disinfecting teats as part of the milking routine. The results indicate a wide variation in farmer uptake of such practices: 90% and 74% post-disinfect and pre-clean respectively however a lack of consistency is found with regard to wearing gloves with only half always wearing them (with 23% doing so sometimes). This constitutes a simple change in practice which is possible. With regard to checking the milk vacuum there would not appear to be a consistent approach according to the survey with approximately those that do doing so at varying frequencies (daily, weekly, monthly) in equal proportion.

Similarly, with regard to particular herd management practices there is a wide variation in farmer behaviour. *'Best practice'* would indicate that cows identified with mastitis should be milked separately so more time can be devoted to treating such cows and the risk of spreading mastitis via the cluster is eliminated however, only 65% of respondents do so. Finally, foremilk stripping has been cited as an effective way to detect clinical cases of mastitis however just over half do so daily with over one-third of respondents never doing so.

Table 4: Farmer uptake of herd management and milking hygiene practices

Farmer behaviour (frequency)	*Never*	*Always*	*Sometimes*	*Daily*	*Weekly*	*Monthly*
Wear gloves	24%	54%	23%			
Milk mastitis cows separately	24%	65%	10%			
Check new entrants SCC	47%	44%	10%			
Check milk vacuum	16%			29%	27%	29%
Forestrip cows	35%			53%	7%	4%
Pre-clean	14%			74%	5%	5%
Post-disinfect	7%			90%	2%	1%

The actual impact of farmers' uptake of these practices on SCC is also insightful and econometric techniques are employed here to examine their effectiveness. Results from the model are reported upon later.

4.3 Regression analysis

Two separate logistic regression models are utilised here to explore the relationship between farmers' attitudes to animal health and mastitis and optimum herd health management. To this end, the association between the latent constructs reflecting farmers' attitudes towards animal health and mastitis (labelled *'animal health', 'reluctant'* and *'knowledge')* and uptake of animal health *'best practice'* is explored. For the purposes of this paper, engagement with some of the recommended herd health management practices outlined above is termed *'best practice'*. A number of relevant control variables relating to both the farm and farmer are also included in the regression models. Indeed, their association with *'best practice'* uptake are also of interest in their own right.

In designing relevant dependent variables around *'best practice'* for inclusion in the regression models it is necessary to group together a number of mastitis management practices. Particular practices around herd management and milking hygiene are grouped into two separate dependent variables to be examined in each of the models: (1) hygiene and (2) herd management. Hygiene related practices around milking refer to practices such as the wearing of gloves and teat pre- and post-cleaning, as all are useful in terms of mastitis prevention. The 'hygiene' dependent variable was equal to 1 if farmers engaged with more than one of these practices and zero otherwise. On the other hand, farmer engagement with practices such as milk recording, forestripping, milking mastitis cows separately and checking new entrant cell count can be thought of as being more diagnostic in nature. Farmer uptake of more than one of these practices resulted in them being categorised to the 'herd management' variable, i.e., the dependent variable was equal to 1 if farmers engaged with one or more of these practices and zero otherwise. Table 5 contains summary statistics on farmer engagement with herd hygiene and management practices as well as other relevant data relating to the remaining explanatory variables utilised in both models.

Table 5: NFS dataset relevant summary statistics 2013

		Mean	*Std. Dev.*	*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
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	1= Yes, 0 = No	0.49	0.50	0	1
CellCheck	1= Yes, 0 = No	1.73	0.53	1	3
Stocking rate	Herd Size/UAA	0.96	0.52	0.42	5.48
Financial monitoring (Extension provided)	1= Yes, 0 = No	0.52	0.50	0	1

These control variables reflect personal farmer characteristics such as agricultural education and extension contact and differences in farm structural characteristics (e.g. stocking rate) and are also of interest in their own right.

Results from the first regression model which attempted to explore the relationship between farmers' attitudes and uptake of particular milking hygiene practices (wearing gloves and pre- and post- cleaning) were found not to be insightful with none of the explanatory variables found to be significant. It is surprising that according to the model, positive attitudes around animal health and mastitis control would not improve the probability of farmers' engaging with effective mastitis management practices. Indeed the finding points to an obvious disconnect between the two and raises further questions around farmers' actual routine and motivation and deviation from same. As a result, 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. To this end their behavior can be considered *'reactionary'* as opposed to *'precautionary.'* The fact that an outbreak of mastitis can induce routine change was also reflected in information garnered through the focus groups undertaken to complement the survey analysis. This qualitative work provided a further in-depth understanding of established routines around milking management and trade-offs farmers make in terms of weighing up the benefits and costs relating to particular practices. Time and cost constraints were also confirmed by the qualitative data as factors in farmers' not undertaking particular management practices.

Regression results from the herd management model were more useful and indicate a variation across the attitudinal factors in terms of influence on actual '*best practice'* uptake. In presenting results from the regression model, Table 6 contains the odds ratios for both a unit and standard deviation change in the independent variables as, 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.

Model results indicate that the factor *'reluctant'* impacted negatively and significantly on the probability of *'best practice'* uptake. This is as expected because respondents' cited time and cost constraints as reasons why they did not carry out all of the preventative measures required for mastitis control. The effect is found to be substantial with a one standard deviation increase corresponding to a 32% decrease in the odds of *'best practice'* uptake around animal health. An increase in stocking rate (a proxy for farming intensity) was also negatively and significantly related to the probability of '*best practice'* uptake. A shortage in labour input may be hypothesized as the reason behind this result.

Table 6: 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	0.10	0.59	10.30	7.90	0.78
Reluctant**	-0.55	0.02	-42.10	-32.40	0.72
Knowledge***	-0.81	0.00	-55.60	-42.90	0.69
Agricultural training	-0.09	0.79	-8.80	-3.90	0.44
Extension contact (incl. participatory)**	0.99	0.01	168.70	64.10	0.50
Attended CellCheck workshop	0.14	0.67	14.60	6.60	0.47
Farmer age	0.01	0.60	0.80	8.50	10.73
Stocking rate**	-0.73	0.01	-51.70	-38.20	0.66
Financial monitoring (eProfit)	-0.49	0.21	-38.60	-21.60	0.50
Hygiene**	0.73	0.04	107.50	32.20	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.

***indicates statistically significant at 1 percent level,
** indicates statistically significant at 5 percent level,
* statistically significant at 10 percent level.

On a more positive note, the positive impact of extension contact (including participatory discussion group membership) on the probability of '*best practice'* uptake 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 64% increase in the odds of improved herd health management. This finding is in line with previous research by Dillon et al. (forthcoming) which has confirmed the role of extension contact in influencing farmer behaviour with regard to SCC control.

Interestingly, according to the model, the factor *'knowledge'* is negatively and significantly associated with the probable uptake of herd management practices in question. Such respondents reported both adequate knowledge of the financial implications of mastitis and the actions required to control the disease. The implied negative relationship between the factor and *'best practice'* uptake is then somewhat surprising. The possibility once more of routine inertia may serve as a potential explanation for this result, i.e., respondents may not see the need to deviate from their established routine despite not adequately engaging with relevant herd management practices as they do not currently have a mastitis problem within the herd.

The *'hygiene'* variable (wearing gloves, pre and post-cleaning) as outlined in the first regression model is also included here as an explanatory variable in terms of optimum herd management and is found to be positively and significantly related to the probability of '*best practice'* uptake by farmers. The fact that engagement in one particular practice is influential in terms of uptake of another is also found by Huijps et al. (2010) in a similar study undertaken in the Netherlands.

The relationship between the probability of *'best practice'* uptake and the *'animal health'* factor was found not to be significant in the model. Despite this, a positive association is found between the factor which is reflective of the importance of animal health and the link to farm profit as well as the potential for peer learning and optimum herd health management.

A separate OLS regression model is utilised to confirm the effectiveness of farmer uptake of the mastitis management practices listed on herd-level SCC. Results contained in Table 7 indicate the negative and significant impact of milk recording, post-milking disinfection and separation of mastitis infected cows when milking on bulk-tank SCC. The influential role of extension contact and discussion group membership in mastitis control is also confirmed by the model.

Table 7: Efficacy of mastitis management practices – effect on herd-level SCC

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

N = 275, $R^2 = .20$

***indicates statistically significant at 1 percent level,
** indicates statistically significant at 5 percent level,
* statistically significant at 10 percent level.

Although, at initial glance it may seem counter-intuitive that practices such as forestripping and checking the milk vacuum are positively and significantly related to cell count it is hypothesized here that such results indicate a potential mastitis problem on the farm, i.e., uptake of such practices are in fact reactionary. This is potentially the reason also for the positive association between attendance at a CellCheck workshop and SCC as discussions at the focus groups implied that those farmers encountering mastitis problems within the herd are more likely to attend such events.

Variables relating to the wearing of gloves and pre-cleaning teats are found not to be significant 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 this very issue confirms this. Also, previous research by McCoy et al. (2013) reports that a significant gap exists between the routine practices and behaviours that farmers report, and the standard to which those practices are done. An interesting aspect with regard to farmer buy-in for certain practices is the potential for a hierarchy of importance, i.e. given time and other constraints the marginal benefit of particular practices may be considered. For example, post-milking disinfection may be considered as being most time efficient and effective and may be preferred to a range of other ancillary practices. The magnitude of the coefficient for that particular variable in the model may support this argument. The efficacy of and farmer buy-in with regard to milk recording as confirmed through discourse at the focus groups is also confirmed by its impact on cell count reduction according to the model.

The relative effectiveness of practices such as those included in the model was previously investigated by Yalcin et al. (1999) who found that variation in managerial ability, farming systems and environmental conditions were also important in controlling the disease. The authors concluded that communication regarding the marginal effect of control procedures on revenue loss is essential for economically efficient mastitis control. Further, 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.

5. Discussion

Effective communication with farmers is essential in order to shape behaviour and improve animal health (Jansen et al. 2010, Kristensen et al. 2011). Farmer awareness of the importance of animal health and the subsequent link to profit is confirmed in this paper, and in line with previous research undertaken by the authors and others the valuable role of the extension agent in influencing the uptake of animal health *'best practice'* is validated. Conversely, time and cost constraints as well as routine inertia are put forward as barriers to the uptake of optimum herd management techniques. To this end, according to the models utilised here and the qualitative data garnered, farmer behavior with respect to mastitis management can be considered *'reactionary'* as opposed to *'precautionary.'*

Another important finding, in line with that of Huijps et al. (2010) is the fact that engagement with one particular herd management practice is influential in terms of the uptake of another. Despite this, the potential for a hierarchy of acceptance with regard to particular practices is hypothesised as are possible issues around actual technique and practice implementation, previously found by McCoy (2013).

This research highlights the fact that engagement around knowledge transfer and *'best practice'* technology adoption is particularly complex. Challenges remain therefore for extension service providers and others to educate and encourage more diverse farmers not actively engaging in effective herd health management. 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 e.g. job satisfaction. Similarly, research by Valeeva et al. (2007) and Jansen et al. (2009) 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.

According to Jansen (2010) different farmers need to be approached in different ways through different channels. An important recommendation for effective knowledge transfer arising from this research is that communication with farmers should distinguish between *'best practice'* for both intervention and prevention and differentiate the message for both groups. Understanding the process by which farmers recalibrate their management strategy, and the intervention points around which this is likely to happen, is important in order to provide appropriately timed and configured knowledge transfer support. Given these findings it is suggested that effective knowledge transfer should take account of factors influencing technology and practice implementation as well as adoption rates, including time constraints perceptions of technical performance, ease of use, adequate knowledge of practices and compatibility with the resources and constraints of the farm.

In terms of changing farmer behaviour previous research by Nightingale et al. (2008) 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. Survey results here confirm the relative effectiveness of milk quality penalties over premia.

Research by Barkema et al. (1999), Jansen (2009) and Lind et al. (2012) found that the attitudes (best explained by farmers' perceptions about mastitis control) and management skills of the farmer were important in changing behaviour. Similarly, Brunijis (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. The role of attitudes in influencing uptake of *'best practice'* with respect to animal health is however not as clear cut here. The possibility of routine inertia is put forward as an explanation for the lack of association between attitudes and uptake of optimum herd health strategies. Although, respondents' in general report positive attitudes towards disease control with many citing adequate knowledge to control mastitis they may be unwilling to deviate from their established milking routine. The finding that farmers in general 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 the routine is confirmed by the qualitative component of the research.

Further insights from discussions at 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 component of this research confirmed 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.

This research provides insights for the effective communication of knowledge transfer. Based on this work, it is clear that the perceived usefulness and perceived ease of use of technologies and practices around animal health are important summary ideas for understanding technology and practice implementation for both disease prevention and intervention. The analysis indicates that farm-level routines change over time, in response to trial and error, learning and critical events.

In terms of future work it may be interesting to examine the issues around farmers' attitudes towards animal health and actual *'best practice'* behaviour using alternative methodologies. In particular, social psychology model frameworks such as the Theory of Reasoned Action or the Theory of Planned Behaviour may be useful. A previous study by Jansen et al. (2009) using the latter found that variance in the mastitis situation on Dutch dairy farms was associated with farmers' behavioural determinants such as attitudes, knowledge, norms and perceived behavioural control.

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