Received: 29 March 2021 | Revised: 8 November 2021 | Accepted: 7 January 2022

DOI: 10.1002/vetr.1389

VetRecord

ORIGINAL RESEARCH

Disease prevention efforts on Welsh cattle farms are influenced by farm demographics

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Funding information
University of London Bloomsbury SET, Grant/Award Number: #CCF-17-7779

Abstract

Background: This research seeks to understand how the transition to a new generation of younger, more diverse farmers affects disease prevention efforts on UK farms.

Methods: We apply multivariate regression analysis to analyse survey responses from 112 Welsh cattle farm operators.

Results: Our results indicate that young farm operators (less than 40 years of age) receive less frequent visits from veterinarians. Further, farm operators who identify as female are less likely to screen and vaccinate against a range of diseases. Finally, both young farmers and female farm operators are less likely to achieve disease-free certification for various economically meaningful livestock diseases.

Conclusion: One possible explanation for these outcomes is that female farm operators and young farmers may feel excluded from long-standing social networks in the farm animal health sector.

INTRODUCTION

The future success of disease management in the UK farming industry hinges on the successful transfer of knowledge to a new generation of younger, more diverse farm operators. The current composition of farm operators in the UK is predominately male (≈80%) with a median age of 60 years.[1] However, as new entrants enter farming, these demographics are changing. Compared with past generations, new entrants are more likely to be younger, work part time, possess higher levels of education or qualifications, and are more likely to be women.[1] In livestock farming, a crucial aspect of this knowledge transfer relates to the on-farm management of animal health risks and appropriate use of disease prevention technologies.

Disease freedom or a reduction in the amount of disease on the farm provides gains in areas such as financial stability, antimicrobial resistance, improved animal welfare, better public relations, reduction in greenhouse gas emissions and better mental health among the farming community. This will promote a more sustainable farming industry in areas where rural poverty is an issue, such as Wales.[2] Bovine viral diarrhoea (BVD), Johne's disease, leptospirosis and liver fluke all have economic impacts, and the reduction of these will improve the financial stability of farms. Improving overall farm efficiency will additionally lead to improved land use, with reduced impact on the environment.

Farmers' adoption of technologies and strategies to achieve this disease prevention and infection control depend on numerous factors including economics and perceptions of both the risk of the disease and the efficacy of the management strategy.[3,4] A narrative review of the uptake of disease prevention strategies highlighted the importance of veterinarians' communication skills and their success in educating farmers.[4] However, simply communicating the economic advantages of disease control measures is recognised as insufficient for engaging farmers in such measures, and there is a need for deeper understanding of the reasons why scientific 'best practice' is not translated to action at the farm level.[5] Building trusting relationships with farmers, in which farmer needs and priorities are understood, and recommendations are feasible, is also emphasised.[6] Exploring this issue more deeply, there may be specific farming populations where uptake of disease management strategies is poor, even if more generally, the adoption of strategies by farms served by a particular veterinary practice is good. Farmers' age, education, and gender have been previously noted as influencing their decision making surrounding farm management practices.[7] In a study examining farmers' propensity to change their behaviour relating to environmental practices, younger farmers, those with higher levels of education and female farmers were more likely to demonstrate behaviour change.[7]

A survey of farmers in Wales was conducted in order to determine the characteristics of the farmers who would be most likely to adopt a novel technology. It was hypothesised that younger farmers would be most likely to receive and act on veterinary advice to achieve freedom from disease. This research therefore seeks to understand how the contemporary transition to a more diverse population of farm operators influences disease prevention efforts on UK farms. Multivariate regression analysis was applied to analyse survey responses regarding a range of disease prevention behaviours.

METHODOLOGY

We surveyed 112 farmers in Wales in order to determine the characteristics of the farmers who would be most likely to adopt a novel multipathogen disease screening technology. Information about the demographics of the people making the decisions on farms (the farm operators) and the health status of economically important diseases was collected. Data for this project were collected via a series of in-person surveys of Welsh cattle farmers over the period from November 2019 to March 2020. Ethical approval was given by the SSRERB under URN SR2019-0274 and by the CRERB under URN 2019 1891-2. Information was collected in the context of government-mandated TB tests and at regional trade shows. The non-response rate was less than 1%.

Statistical model

To analyse the demographic correlates of disease prevention practices among Welsh cattle farms, we construct a series of multivariate regression models using the statistical software STATA 16 MP. The disease prevention practices considered here include the frequency of veterinary visits, farm disease screening practices, farm vaccination practices and attainment of disease-free certification.

The dependent variables used for the regression analysis are constructed as follows. To measure the frequency of veterinary visits, we asked respondents to report the number of times they received an on-farm visit from a veterinarian over the previous year. We use this information to construct variable V_j, representing the number of visits indicated by farm j. Note that a small number of respondents in our sample indicated that they had an in-house veterinarian. Thus, the question of veterinary visits was inapplicable. Respondents with an in-house veterinarian were excluded from the sample for the purposes of this estimation. For each of the latter three prevention practices (i.e. disease screening, vaccination and disease-free certification), we analyse disease-specific practices for a range of diseases. For disease screening, we consider BVD, respiratory disease, Johne's disease, abortion, dysentery, liver fluke and parasitic gastroenteritis (PGE). For each of these diseases i, we construct indicator S_j^i, which takes value one if the respondent indicated that the farm (j) had screened for the disease over the previous year and equal to zero if the farm had not screened for the disease. For vaccination, we consider BVD, infectious bovine rhinotracheitis (IBR), mastitis, leptospirosis and rotavirus. As with disease screening, we use survey responses to create indicator variable X_j^i, which takes value one if farm j had vaccinated against disease i in the previous year, and equal to 0 if farm j had not vaccinated against the disease. Finally, for disease-free certification, we consider certification for BVD, IBR, Johne's disease, TB and leptospirosis. The variable used to measure disease-free certification (C_j^i) is an indicator that takes value one if farm j indicated that they were certified disease free for disease i and equal to zero otherwise. These specific dependent variables are based on standard disease control strategies employed on Welsh farms.

As explanatory (i.e. right-hand-side) variables, we consider two types of demographic variables to explain disease prevention practices. The first set of demographic variables relates to the production characteristics of the farm. This set of variables include an indicator for whether the farm is engaged in dairy production (denoted Dairy_j), an indicator for whether the farm has pedigree animals (denoted Pedigree_j), a count variable representing the number of animals in the herd (denoted Animals_j), and an indicator variable for whether the farm also keeps non-cattle livestock (denoted Other_j).

The second set of demographic variables relates to the individual characteristics of the farm operator. These variables include an indicator for whether the farm operator is a 'young farmer' defined as a farmer of less than 40 years of age (denoted Young_j), an indicator for whether the farm operator is female (denoted Female_j), and an indicator for whether the farmer has access to the internet (denoted Internet_j).

Our regression models take the following form:

$$\begin{aligned} Y_j = \alpha &+ \beta_{\text{D}}\text{Dairy}_j + \beta_{\text{A}}\text{Animals}_j + \beta_{\text{P}}\text{Pedigree}_j \\ &+ \beta_{\text{O}}\text{Other}_j + \beta_{\text{I}}\text{Internet} + \beta_{\text{Y}}\text{Young}_j \\ &+ \beta_{\text{F}}\text{Female}_j + e_j \qquad (1) \end{aligned}$$

where Y_j is defined—alternatively—to measure the frequency of veterinary visits (V_j), farm disease screening

TABLE 1 Summary statistics

Variable	Description	Mean	SD	Min	Max
Farm demographics					
Dairy	Indicator variable (1 = Yes)	0.27	0.44	0	1
Animals	Number of cattle on-farm	158.13	193.57	5	1500
Pedigree	Indicator variable (1 = Yes)	0.41	0.49	0	1
Other livestock	Indicator variable (1 = Yes)	0.6	0.49	0	1
Internet access	Indicator variable (1 = Yes)	0.86	0.35	0	1
Young farmer	Indicator variable (1 = Yes)	0.17	0.38	0	1
Female	Indicator variable (1 = Female)	0.08	0.27	0	1
Annual veterinary visits	Number of veterinary visits per year	7.07	8.33	0	52
Disease screening					
BVD	Indicator variable (1 = Yes)	0.83	0.38	0	1
Respiratory	Indicator variable (1 = Yes)	0.08	0.27	0	1
Johne's	Indicator variable (1 = Yes)	0.35	0.48	0	1
Abortion	Indicator variable (1 = Yes)	0.11	0.31	0	1
Dysentery	Indicator variable (1 = Yes)	0.02	0.13	0	1
Liver fluke	Indicator variable (1 = Yes)	0.16	0.37	0	1
PGE	Indicator variable (1 = Yes)	0.14	0.35	0	1
Vaccination					
BVD	Indicator variable (1 = Yes)	0.37	0.49	0	1
IBR	Indicator variable (1 = Yes)	0.21	0.41	0	1
Mastitis	Indicator variable (1 = Yes)	0.1	0.3	0	1
Leptospirosis	Indicator variable (1 = Yes)	0.31	0.47	0	1
Rotavirus	Indicator variable (1 = Yes)	0.15	0.36	0	1
Disease-free certification					
BVD	Indicator variable (1 = Yes)	0.21	0.41	0	1
IBR	Indicator variable (1 = Yes)	0.05	0.23	0	1
Johne's	Indicator variable (1 = Yes)	0.09	0.29	0	1
TB	Indicator variable (1 = Yes)	0.05	0.23	0	1
Leptospirosis	Indicator variable (1 = Yes)	0.04	0.19	0	1

Note: Data for this project were collected via a series of in-person surveys of Welsh cattle farmers over the period November 2019–March 2020.
Abbreviations: BVD, bovine viral diarrhoea; IBR, infectious bovine rhinotracheitis; PGE, parasitic gastroenteritis.

practices (S_j^i)[a], farm vaccination practices (X_j)[b] and disease-free certification status (C_j^i).[c]

We estimate all models using an ordinary least squares (OLS) procedure. Because the frequency of veterinary visits (V_j) is a count variable, we also report results for that dependent variable using a Poisson estimation. For the models that rely on an indicator as a dependent variable (S^i, X^i and C^i), one could also envision a binary estimation model, such as probit or logit. For each of these prevention measures, we considered both probit and logit; however, for many of the diseases, the model did not converge to a solution. Thus, we rely on the OLS results to make inference. In the instances where the probit and logit models did converge to a solution, results were highly consistent with the OLS findings.

[a] The model is run individually for $i \in$ {BVD, respiratory, Johne's disease, abortion, dysentery, liver fluke, PGE}.
[b] The model is run individually for $i \in$ {BVD, IBR, mastitis, leptospirosis, rotavirus}.
[c] The model is run individually for $i \in$ {BVD, IBR, Johne's disease, TB, leptospirosis}.

RESULTS

Summary statistics

Summary statistics for the data used to estimate Equation (1) are reported in Table 1. Data on the demographics of the agricultural industry in the UK are difficult to ascertain, as these data have not been collected since 2016 for the UK and are not available for Wales at all. However, the farm structure survey of 2016[8] suggests that 84% were male and 40% were over 65. These factors suggest that this sample population is consistent with the wider Welsh farming population.

Referring to the farm demographic variables in Table 1, approximately 27% of respondents (SD 0.44) indicated their was farm engaged in dairy production. The average herd size among respondent farms was

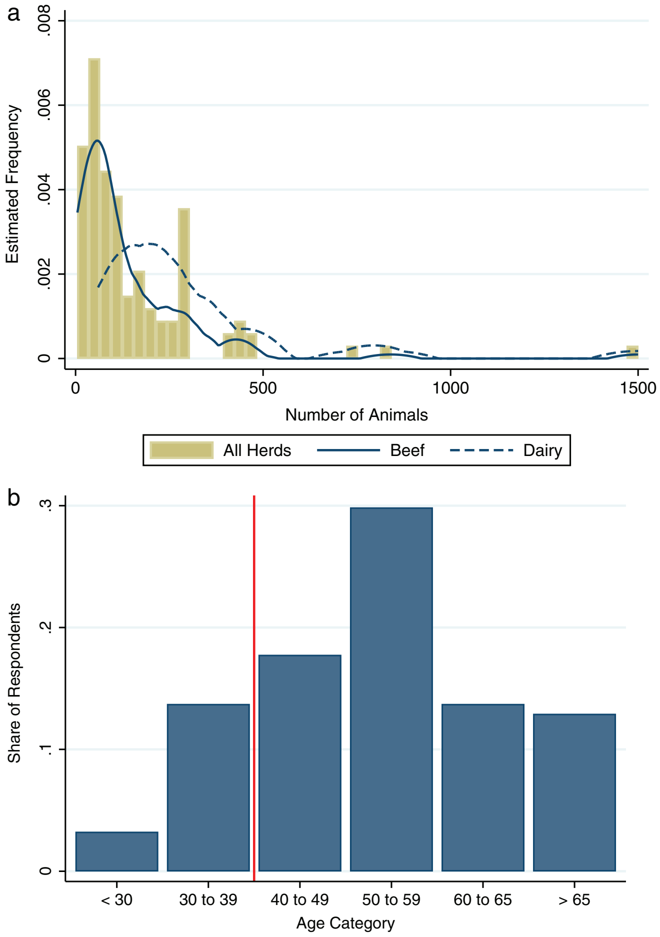

FIGURE 1 Demographic composition of surveyed farms. (a) Distribution of herd size among respondents, disaggregated by beef and dairy farms. (b) Full age range of respondents, where the vertical bar indicates our cut off for the construction of the 'young farmer' indicator

158 animals (SD 193.57). Figure 1a displays the distribution of herd size among beef and dairy farms. As expected, dairy herds tend to be larger than beef herds. The presence of pedigree animals is reported on 41% of respondent farms, and 60% of farms indicate they also keep other (non-cattle) livestock.

Our sample includes 21 young farmers (less than 40 years old). Figure 1b displays the full age range of respondents. The vast majority of respondents indicate they have internet access (86% of respondents). Nine of the surveyed farm operators (8% of sample) were female; two of these female farm operators are also young farmers.

Referring to the disease prevention variables in Table 1, outcomes vary widely across prevention practices and across diseases. The average farm in our sample receives just over seven on-farm visits from a veterinarian per year. Disease screening practices range dramatically across diseases–82% of farms screen for BVD, while only 2% indicated that they screen for dysentery. Similarly, vaccination appears to be most frequent for BVD (37% of respondents) and least frequent for mastitis (10% of respondents). Disease-free certification status ranged from a high of 21% of respondents for BVD to a low of 4% of respondents for leptospirosis.

TABLE 2 Farm demographics and annual veterinary visits

Variables	(1) Annual veterinary visits	(2) Annual veterinary visits
Dairy	7.089*** (2.633)	6.818*** (2.139)
Animals	−0.001 (0.005)	−0.0013 (0.002)
Pedigree	3.038* (1.705)	2.994** (1.477)
Other livestock	−2.265 (1.729)	−2.051 (1.332)
Internet access	1.406 (0.963)	0.941 (1.252)
Young farmer	−3.544** (1.675)	−2.976** (1.066)
Female	0.660 (1.082)	0.796 (1.332)
Observations	98	98
R-squared	0.24	0.23

Note: SE in parentheses robust to heteroskedasticity of an unknown form. Poisson marginal effects reported in column (2).
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Veterinary visit frequency

Table 2 reports the results of demographic correlates of the frequency of annual veterinary visits. Column (1) of the table reports results for the OLS specification. Column (2) reports results from the Poisson specification. Results are consistent across columns (1) and (2), both in terms sign and statistical significance. Dairy farms receive more veterinary visits per year than non-dairy herds (statistically significant at 99% in both specifications). According to both the linear and Poisson specifications, dairy production increases the frequency of veterinary visits by approximately seven visits per year. Similarly, farms with pedigree animals receive more visits than non-pedigree animals (statistically significant at 90% in column 1 and 95% in column 2). The presence of pedigree animals increases the frequency of veterinary visits by one per quarter (consistent across columns 1 and 2). Farms operated by young farmers (less than 40 years of age) receive fewer veterinary visits than those with older farmers. This finding is statistically significant at 95% in both columns. According to column (1), young farmers receive 3.5 fewer visits per year (three fewer visits per year in column 2).

Disease screening

Table 3 reports the demographic correlates of screening for BVD (column 1), respiratory disease (column 2), Johne's disease (column 3), abortions (column 4), dysentery (column 5), liver fluke (column 6) and PGE (column 7). Consistent with the results on the frequency of veterinary visits, dairy production appears to increase the likelihood of disease screening relative to non-dairy herds. The coefficient on the dairy indicator is positive in every column in Table 3, though this

TABLE 3 Farm demographics and disease screening

Variables	(1) BVD	(2) Respiratory	(3) Johne's	(4) Abortion	(5) Dysentery	(6) Liver fluke	(7) PGE
Dairy	0.0478 (0.0833)	0.0975 (0.0777)	0.405*** (0.104)	0.189** (0.0939)	0.0305 (0.0305)	0.0296 (0.0906)	0.0880 (0.0761)
Animals	−6.78e-05 (0.000208)	−0.000162* (9.67e-05)	4.27e-06 (0.000206)	−0.000102 (0.000133)	1.24e-05 (3.01e-05)	9.00e-05 (0.000205)	8.49e-05 (0.000170)
Pedigree	0.137** (0.0660)	0.0270 (0.0584)	0.371*** (0.0886)	0.0935 (0.0664)	0.00466 (0.0197)	0.180** (0.0817)	0.165** (0.0741)
Other livestock	0.219*** (0.0746)	−0.107* (0.0633)	0.111 (0.0812)	0.0739 (0.0633)	0.0312 (0.0214)	0.0954 (0.0696)	0.150** (0.0637)
Internet access	−0.0854 (0.0587)	0.00902 (0.0267)	−0.163 (0.135)	−0.0962 (0.106)	−0.129 (0.122)	−0.0287 (0.143)	−0.0496 (0.118)
Young farmer	−0.0386 (0.0841)	0.0554 (0.0859)	−0.00152 (0.0973)	0.0944 (0.0853)	0.0401 (0.0397)	−0.0315 (0.0818)	0.127 (0.0910)
Female	0.105 (0.0573)	−0.0511** (0.0244)	−0.341*** (0.119)	−0.0295 (0.0699)	0.0560 (0.0598)	−0.0999 (0.0870)	−0.0868 (0.0837)
Constant	0.734*** (0.0938)	0.118* (0.0684)	0.219 (0.156)	0.0648 (0.104)	0.0965 (0.0953)	0.0566 (0.134)	−0.0251 (0.120)
Observations	112	112	112	112	112	112	112
R-squared	0.133	0.091	0.313	0.105	0.116	0.076	0.130

Note: SE in parentheses robust to heteroskedasticity of an unknown form.
Abbreviations: BVD, bovine viral diarrhoea; PGE, parasitic gastroenteritis.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

result is only statistically significant for screening for Johne's disease and abortion (statistically significant at 99% and 95%, respectively). Similarly, the presence of pedigree animals appears to increase the probability of disease screening. This relationship is statistically significant for BVD (statistically significant at 95%), Johne's disease (statistically significant at 99%), liver fluke (statistically significant at 95%) and PGE (statistically significant at 95%).

The relationships between disease screening and the variables measuring herd size and the presence of other livestock on-farm appear to be complex. The results in column (2) of Table 3 suggest that the size of the herd reduces the probability of screening for respiratory disease. The presence of other livestock increases the probability of BVD (column 1) and PGE (column 7) screening (statistically significant at 99% and 95%, respectively), and reduces screening for respiratory disease (statistically significant at 90%).

Female farm operators appear to a consistently negative correlation with disease screening. The coefficient on gender is negative for respiratory disease (column 2), Johne's disease (column 3), abortion (column 4), liver fluke (column 6) and PGE (column 7). This result is statistically significant for respiratory disease (95% level) and Johne's disease (99% level).

Referring to the magnitude of these relationships, the presence of a female farm operator correlates to a 5% reduction in the probability of disease screening for respiratory disease and a 34% reduction in the probability of screening for Johne's disease.

Vaccination

Table 4 reports the demographic correlates of vaccination for BVD, IBR, mastitis, leptospirosis and rotavirus. Referring to the table, we see that the number of animals on-farm increases the probability that the farm will choose to vaccinate its animals. This result is statistically significant at the 99% level for BVD (column 1), IBR (column 2) and leptospirosis (column 4). The relationship between access to the internet and the vaccination differs depends on the disease. The results in column (1) of Table 4 suggest that internet access reduces the likelihood of vaccinating for BVD by approximately 31% (significant at 90%). In contrast, columns (2) and (5) suggest that internet access increases the probability of IBR and rotavirus vaccination by 11% and 6%, respectively (each significant at 90%).

We find that female farm operators are unambiguously less likely to vaccinate across the range of diseases studied, relative to male operators. Referring to column (1) of Table 4, the presence of a female farm operator reduces the probability of BVD vaccination by approximately 37% (statistically significant at 99%). As shown in column (2), female farm operators are 14% less likely to vaccinate against IBR (statistically significant at 99%). In column (3), female operators are 4% less likely to vaccinate against mastitis, though this

TABLE 4 Farm demographics and vaccination

Variables	(1) BVD	(2) IBR	(3) Mastitis	(4) Leptospirosis	(5) Rotavirus
Dairy	−0.0704 (0.114)	0.0409 (0.0963)	0.0328 (0.0327)	−0.0867 (0.111)	−0.0336 (0.0568)
Animals	0.000961*** (0.000298)	0.000509*** (0.000190)	−4.84e-05 (4.83e-05)	0.00101*** (0.000271)	0.000103 (0.000118)
Pedigree	0.0188 (0.0845)	0.00370 (0.0693)	0.0271 (0.0269)	−0.0301 (0.0807)	−0.00391 (0.0542)
Other livestock	−0.134 (0.0905)	−0.0186 (0.0739)	−0.0183 (0.0185)	−0.0203 (0.0830)	0.0168 (0.0459)
Internet access	−0.314* (0.183)	0.107* (0.0549)	−0.00513 (0.00968)	−0.117 (0.152)	0.0561* (0.0334)
Young farmer	0.185 (0.112)	0.0376 (0.0876)	−0.0189 (0.0193)	0.0452 (0.101)	0.0963 (0.0841)
Female	−0.367*** (0.100)	−0.142*** (0.0493)	−0.00398 (0.00751)	−0.254*** (0.0900)	−0.0764** (0.0318)
Constant	0.549*** (0.203)	−0.0451 (0.0893)	0.0170 (0.0193)	0.263 (0.160)	−0.00870 (0.0459)
Observations	112	112	112	112	112
R-squared	0.229	0.121	0.055	0.184	0.032

Note: SE in parentheses robust to heteroskedasticity of an unknown form.
Abbreviations: BVD, bovine viral diarrhoea; IBR, infectious bovine rhinotracheitis.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 5 Farm demographics and disease-free certification

Variables	(1) BVD	(2) IBR	(3) Johne's	(4) TB	(5) Leptospirosis
Dairy	−0.155 (0.0998)	−0.0315 (0.0398)	−0.0878* (0.0503)	−0.0760** (0.0345)	−0.0577 (0.0368)
Animals	−0.000348* (0.000206)	−0.000103 (8.01e-05)	−0.000116 (0.000103)	−5.56e-06 (5.77e-05)	−4.23e-05 (0.000111)
Pedigree	0.201** (0.0860)	0.163*** (0.0601)	0.279*** (0.0713)	−0.00982 (0.0446)	0.114** (0.0513)
Other livestock	−0.111 (0.0854)	−0.0427 (0.0452)	−0.0399 (0.0574)	−0.00373 (0.0460)	−0.0409 (0.0432)
Internet access	−0.142 (0.218)	−0.189 (0.147)	−0.162 (0.122)	0.104 (0.0706)	−0.189 (0.157)
Young farmer	0.0661 (0.104)	−0.0379 (0.0563)	−0.158*** (0.0507)	0.0488 (0.0687)	−0.0646* (0.0338)
Female	−0.0706 (0.193)	−0.118* (0.0631)	−0.159** (0.0624)	0.0883 (0.129)	−0.0989 (0.0630)
Constant	0.329 (0.230)	0.242 (0.153)	0.254* (0.136)	−0.0320 (0.0798)	0.242 (0.165)
Observations	112	112	112	112	112
R-squared	0.112	0.159	0.276	0.046	0.159

Note: SE in parentheses robust to heteroskedasticity of an unknown form.
Abbreviations: BVD, bovine viral diarrhoea; IBR, infectious bovine rhinotracheitis.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

result is statistically insignificant at conventional levels. Finally, in columns (4) and (5), female operators are 25% less likely to vaccinate against leptospirosis (statistically significant at 99%) and 8% less likely to vaccinate against rotavirus (statistically significant at 95%).

Disease-free certification

Table 5 reports the demographic correlates of disease-free certification for BVD, IBR, Johne's disease, TB and leptospirosis. Dairy herds appear to be less likely to receive disease-free certification than non-dairy herds. The coefficient on the dairy indicator in Table 5 is negative across all specifications. This relationship is statistically significant for Johne's disease (significant at 95%) and TB (significant at 90%). Similarly, the number of animals in the herd also reduces the probability that the herd will receive disease-free certification, though this relationship is only statistically significant (at 90%) for BVD in column (1). Herds with pedigree animals are more likely to achieve disease-free certification. The coefficient on the Pedigree indicator is positive and statistically significant for all diseases except TB.

Referring to the variables of interest in Table 5, we see that young farmers tend to be less likely to achieve disease-free certification than other farm operators. This result is statistically significant for Johne's disease (column 3) at 99% and leptospirosis (column 5) at 90%. The presence of a young farmer reduces the probability of disease-free certification for Johne's disease and leptospirosis by 15.8% and 6.5%, respectively.

Female farm operators are also less likely to achieve disease-free certification than other farm operators. This result is statistically significant for IBR (column 2) at 90% and for Johne's disease (column 3) at 95%. The presence of a female farm operator reduces the probability of disease-free certification for IBR and Johne's disease by 11.8% and 15.9%, respectively.

DISCUSSION

Farm production characteristics and disease prevention

The observed correlations among farm production characteristics and disease prevention behaviours support the overall validity of our results. With respect to the frequency of veterinary visits, it is not surprising that dairy farms elicit a higher frequency of visits than non-dairy herds. Dairy farms would typically use the veterinary surgeon for routine fertility activities and these visits would provide opportunity for wider discussions including disease control. Similarly, we observe a higher frequency of veterinary visits for herds with pedigree animals. Pedigree farms have valuable animals, and the pedigree status requires independent certification of the disease status to retain membership of the appropriate breed society. Working towards and maintaining disease-free status, as well as certification of this status would require the presence of the veterinarian on the farm.

On the subject of disease screening, higher Johne's disease screening levels among dairy herds is consistent with the industry's focus on Johne's as a zoonotic disease. We note that this focus on a specific disease is not likely to be causative with respect to the frequency of veterinary visits as screening can be done independently of the veterinarian. However, increased presence of a veterinarian may lead to increased reporting and screening for diseases associated with abortion, particularly if fertility is–as might be assumed–an important focus among dairy herds. Pedigree farms are more likely to be screened for BVD, and this is probably due to a combination of breed society recommendations and location within Wales–a significant program of industry-led BVD screening and eradication is underway. Liver fluke is a disease that is traditionally associated with Welsh farming due to the climatic conditions but requires an enhanced level of intervention to screen as opposed to treatment, and it may require the increased value of pedigree herds to encourage farmers to pursue this.

With respect to the negative correlation between disease screening and herd size, increased herd size may be a proxy for increased movement of cattle onto the farm. Depending on the farm's business model, there is likely to be more than one source of animals arriving on the farm. This reduces the utility of routine screening for respiratory disease in farmers' minds leading to a more fire brigade approach. Whether this is justified is a point for discussion with specific farmers. Disease screening results for farms with multiple livestock species are likely to be predominantly driven by Welsh mixed sheep and cattle farms. There has been a strong emphasis on PGE control in sheep, for example. For mixed beef–sheep farms, this attitude may extend to cattle populations.

With respect to vaccination, the positive correlation between herd size and the likelihood of vaccination is consistent with the fact that the costs associated with disease, as well as the perceived difficulty of eradication, increase with the number of animals. The influence of the internet is variable, and the responses may reflect advertising and/or the dominant message being aimed at farmers. This is best exemplified by the fact that reduction in BVD vaccination as an eradication message has been circulated by social media, television and the internet.

Farm operator characteristics and disease prevention

The observations relating animal health (vaccination, farm visits, disease-free status) to gender and farmer age were surprising, and in some ways contradictory to previous reports, such as an observation that younger farmers were more concerned about biosecurity than their older peers.[9] Although the numbers were low (as most farmers were male and older than 40 years of age), given the demographic changes within farming towards increasing representation of female and younger farmers,[10] the observations merit further discussion. Importantly, we note that our estimates do not fully identify a causal effect between demographic factors and disease prevention efforts. Rather, they are the correlations between these variables. In reality, many other factors may influence herd health, other than demographic and farm-type variables. If any of these are confounded with age or gender, they may influence the results and suggest an effect of age or gender, where in fact the association arises because young/female farmers have animals of a certain breed, or are in a certain location, or are on farms where a given disease has never been a problem.

This is a small study population but is consistent with both data collected by the farm structure survey 2016 and Devlin,[1] as well as observations by the authors. Further understanding of the farming population may well lead to further insights on the impact of the veterinarian–farmer relationship. The literature on gender in European farming demonstrates a persistence of traditional patriarchal models;[11] however small studies provide an insight into the experience of both female and younger farmers, which may help explain this observation and assist farm veterinarians in improving the uptake of veterinary care among non-traditional and less-established farmers.

In order that the farm veterinarian can fulfill their role in biosecurity, disease prevention and health planning, the veterinarian needs to negotiate proactive, consistent access to farms and to encourage a demand for farm health planning, which is not universally well received.[12] Such a relationship tends to be constructed within large farms that are commercially oriented; pig and poultry units are also more consistently defined as fostering this relationship compared to dairy farms, where access tends to more frequently emphasise attending to animals who are unwell.[9,12]

The veterinarian–farmer relationship is often defined in the literature by the extent of social capital;

rather than simply a social relationship. Social capital in this context is a networked connection that provides the farmer access to veterinary resources.[9] It is an intangible concept that is difficult to measure, but depends on trust and collaboration being mutually fostered between the farming and veterinary teams, increasing the access of veterinarians to farms and enhancing the veterinarians' ability to negotiate good animal health practices.[12] Smaller farms and those managed by young farmers are identified as experiencing lower social capital: they tend not to build these relationships with external bodies that would enable access to resources for farm development and improvement.[9,13] They are therefore at risk from receiving fewer veterinary visits and disengaging from disease prevention schemes. Veterinarians report they are more likely to build stronger, more productive farm relationships when they experience long-standing connections with farms, and consistent, regular contact.[9] The longevity of the veterinary–farm relationship may be absent with younger or female farmers compared to farms that have been run by the same farmer (who is more likely to be male) over a prolonged period of time.

The observations in the current dataset might therefore be explained if veterinary relationships with female and younger farmers are not constructed on the same levels of collaboration and trust as exist for older or more established farmers who are more embedded in the local farming community. This may be the case even if the veterinarians perceive that they experience positive interactions during occasional farm visits. Interviews with female farmers in Ireland describe the extensive effort required for them to negotiate entry into the local farming community and gain acceptance; they also alluded to a lack of confidence in their own farming skills, even when brought up on farms, and experiences of resistance among male farming peers, who described them as 'playing farming'.[11] While these women owned successful farms, their experiences demonstrate that the formation of social capital, in this case networks within the local farming community, was particularly challenging. Low levels of participation among young farmers in local farming groups has also been documented in Greece.[13] In that context, poor participation was shown to impend the influence of veterinarians, who are more likely to be influential if they are perceived to be embedded in the farmers' community networks.

CONCLUSION

This research sought to understand how the transition to a new generation of younger, more diverse farmers affects disease prevention efforts on UK farms. Although the new entrants are younger, and in some cases, have higher qualifications than older entrants, the new generation of farmers needs support to deliver the best health outcomes, primarily achieved through the farmer–veterinarian interaction. While it is difficult to precisely assess the success of these interactions, one important measure is the frequency of on-farm veterinary visits. Further, additional useful measures include the uptake of disease prevention technologies and the ability to demonstrate on-farm disease freedom. The results of the study indicate that young farm operators (less than 40 years old) receive less frequent visits from veterinarians. Further, female farm operators were less likely to screen and vaccinate against a range of diseases. Finally, the results suggest that both young farmers and female farm operators are less likely to achieve disease-free certification for various economically meaningful livestock diseases.

While this limitation in transfer of knowledge might seem of limited importance, failure will have an impact of the sustainability of the farming industry. An important contributing factor may be that female and young farmers feel excluded from long-standing social networks in the farm animal health sector, and that this could impact on their engagement with veterinary services.

Further work is needed to explore the significance of this issue, particularly as these results go against the conventional wisdom. Anecdotally, discussion among farming and animal care professionals imply that female farmers would be better animal carers than older males, a notion that is supported partially by the literature of the attitudes of animal care professionals,[14] both among farmers and veterinarians.[15–17] The aforementioned studies also suggest younger animal care professionals are more empathetic than their older counterparts, suggesting that new entrants would be more receptive to gaining veterinary information and using interventions that would improve the health and welfare of the animals under their care. The disconnect between the current findings, anecdotal reports of healthy relationships between veterinarians and their young and female farming clients, and this earlier literature, all suggests that the relationship between farmer demographic and receptivity to disease management strategies is not a simple one. Indeed, in other literature, the gender differences in farming and animal care are not so apparent.[18]

Of course, this research is not without limitations. Perhaps the greatest shortcoming is the small sample size. Because our data collection was interrupted by the COVID-19 pandemic, we obtained information from only 112 cattle farms. Thus, conclusions regarding young and female farmers are made on the basis of 21 and nine farmers, respectively, in a single part of the UK. Although summary statistics indicate that sample is representative of the broader population, further research is needed to ensure external validity. Moreover, alternative explanations for our empirical results also exist, such as the potential for women to be more concerned than their male peers about the financial risk of committing to health prevention activities, particularly if they are concerned about farm income.[19] Further work is needed to explore the observed gender- and age-related differences in farm health practices.

ACKNOWLEDGEMENTS

This work was funded by the University of London Bloomsbury SET #CCF-17-7779. No one other than the authors had any role in the writing of the manuscript or the decision to submit it for publication.

CONFLICT OF INTEREST

The authors report no conflicting interests relevant to this work.

ETHICAL APPROVAL

Ethical approval was given by the SSRERB under URN SR2019-0274 and by the CRERB under URN 2019 1891-2.

AUTHOR CONTRIBUTIONS

Neil Paton, K. Aleks Schaefer and Laura Buggioti were equally involved in the conceptualisation, funding acquisition, methodology and writing. Elizabeth A. Armitage-Chan contributed to the writing, revision and editing. Hannah Cooper and K. Aleks Schaefer contributed to data curation and formal analysis. Laura Buggioti was responsible for project administration.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to cite this article: Paton N, Schaefer KA, Armitage-Chan EA, Cooper H, Buggiotti L. Disease prevention efforts on Welsh cattle farms are influenced by farm demographics. Vet Rec. 2022;e1389. https://doi.org/10.1002/vetr.1389